IntechOpen

IntechOpen Series
Education and Human Development, Volume 2

Active Learning

Research and Practice for STEAM and Social Sciences Education

Edited by Delfín Ortega-Sánchez

Active Learning - Research and Practice for STEAM and Social Sciences Education

Edited by Delfín Ortega-Sánchez

Published in London, United Kingdom

Active Learning - Research and Practice for STEAM and Social Sciences Education
http://dx.doi.org/10.5772/intechopen.100696
Edited by Delfín Ortega-Sánchez

Contributors
Victor Eduardo Martinez-Luaces, José Antonio Fernández-Plaza, Luis Rico, Karina Adbo, Analía Mignaton, Subanji Subanji, Toto Nusantara, Davison Zireva, Gregory Garvey, George Frempong, Raavee Kadam, Armando Lozano-Rodriguez, Fernenda Inez Garcia-Vazquez, José Luis García-Cué, Rita Payan-Carreira, Hugo Rebelo, Luis Sebastião, Song Xue, Daner Sun, Fred Awaah, Cosmas Kombat Lambini, Emmanuel Okyere Ekwam, Christian Williams, Anat Raviv, Samuel Obara, Jake L. Hammons, Shakespear M. Chiphambo, Nosisi N. Feza, Sergio Velázquez-Medina, Pedro Cabrera-Santana

© The Editor(s) and the Author(s) 2022
The rights of the editor(s) and the author(s) have been asserted in accordance with the Copyright, Designs and Patents Act 1988. All rights to the book as a whole are reserved by INTECHOPEN LIMITED. The book as a whole (compilation) cannot be reproduced, distributed or used for commercial or non-commercial purposes without INTECHOPEN LIMITED's written permission. Enquiries concerning the use of the book should be directed to INTECHOPEN LIMITED rights and permissions department (permissions@intechopen.com).
Violations are liable to prosecution under the governing Copyright Law.

Individual chapters of this publication are distributed under the terms of the Creative Commons Attribution 3.0 Unported License which permits commercial use, distribution and reproduction of the individual chapters, provided the original author(s) and source publication are appropriately acknowledged. If so indicated, certain images may not be included under the Creative Commons license. In such cases users will need to obtain permission from the license holder to reproduce the material. More details and guidelines concerning content reuse and adaptation can be found at http://www.intechopen.com/copyright-policy.html.

Notice
Statements and opinions expressed in the chapters are these of the individual contributors and not necessarily those of the editors or publisher. No responsibility is accepted for the accuracy of information contained in the published chapters. The publisher assumes no responsibility for any damage or injury to persons or property arising out of the use of any materials, instructions, methods or ideas contained in the book.

First published in London, United Kingdom, 2022 by IntechOpen
IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales, registration number: 11086078, 5 Princes Gate Court, London, SW7 2QJ, United Kingdom
Printed in Croatia

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Additional hard and PDF copies can be obtained from orders@intechopen.com

Active Learning - Research and Practice for STEAM and Social Sciences Education
Edited by Delfín Ortega-Sánchez
p. cm.

This title is part of the Education and Human Development Book Series, Volume 2
Topic: Education
Series Editor: Katherine K.M. Stavropoulos
Topic Editor: Delfín Ortega-Sánchez

Print ISBN 978-1-80356-356-5
Online ISBN 978-1-80356-357-2
eBook (PDF) ISBN 978-1-80356-358-9
ISSN 2755-9513

We are IntechOpen, the world's leading publisher of Open Access books

Built by scientists, for scientists

6,100+
Open access books available

167,000+
International authors and editors

185M+
Downloads

156
Countries delivered to

Our authors are among the
Top 1%
most cited scientists

12.2%
Contributors from top 500 universities

BOOK CITATION INDEX
CLARIVATE ANALYTICS
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

IntechOpen Book Series

Education and Human Development

Volume 2

Aims and Scope of the Series

Education and Human Development is an interdisciplinary research area that aims to shed light on topics related to both learning and development. This Series is intended for researchers, practitioners, and students who are interested in understanding more about these fields and their applications.

Meet the Series Editor

Katherine Stavropoulos received her BA in Psychology from Trinity College, in Connecticut, USA and her Ph.D. in Experimental Psychology from the University of California, San Diego. She completed her postdoctoral work at the Yale Child Study Center with Dr. James McPartland. Dr. Stavropoulos' doctoral dissertation explored neural correlates of reward anticipation to social versus nonsocial stimuli in children with and without autism spectrum disorders (ASD). She has been a faculty member at the University of California, Riverside in the School of Education since 2016. Her research focuses on translational studies to explore the reward system in ASD, as well as how anxiety contributes to social challenges in ASD. She also investigates how behavioral interventions affect neural activity, behavior, and school performance in children with ASD. She is also involved in the diagnosis of children with ASD and is a licensed clinical psychologist in California. She is the Assistant Director of the SEARCH Center at UCR and is a faculty member in the Graduate Program in Neuroscience.

Meet the Volume Editor

Delfín Ortega-Sánchez holds a Ph.D. in Didactics of History and Social Sciences from the Autonomous University of Barcelona, a Ph.D. in Education from the University of Burgos and a Ph.D. in History from the University of Extremadura. His research interests focus on the processes of construction of cultural, social and gender identities from the educational, anthropological and ethnohistorical fields, and on education for a democratic, inclusive and committed citizenship with social problems and controversial issues. These lines of interest articulate the activity of the Recognized Research Group DHISO, directed by Dr. Ortega-Sánchez (https://www.ubu.es/didactica-de-la-historia-y-de-las-ciencias-sociales-dhiso). His research career has been recognized with his nomination as one of the top ten (Top 10) best social science researchers in the world under 40 years of age in the seventh edition of the Universal Scientific Education and Research Network - USERN Prize 2022. His nomination was proposed by an international jury composed of several Nobel laureates and the top 1% of scientists in their respective fields. He currently holds the position of vice-rector for Social Responsibility, Culture and Sport at the University of Burgos, with competences in activities for the promotion of equality, diversity, social inclusion and non-discrimination, and in attention to diversity and people with disabilities.

Contents

Preface

In line with current approaches to competency-based learning, the purpose of active learning should respond to students' abilities to apply cognitive skills related to the search for and synthesis and critical analysis of information as well as problem-solving and creative thinking [1]. By posing problems related to the student's previous experience and interests, this type of meaningful learning seeks to generate connections with existing problems in the social environment [2].

As a contribution to the body of knowledge specific to the didactic-disciplinary fields of STEAM education and social studies education, this book aims to answer the following educational research and innovation questions:

- What educational practices and teaching experiences have been developed in recent years in relation to active teaching and learning from scientific-technical and social disciplines?

- How do the social agents involved in education (educational centers, families, media, etc.) act to achieve quality education (United Nations Sustainable Development Goal 4)?

- What are the educational and social barriers that limit or hinder the implementation of active learning in the scientific fields indicated?

- What is the level of self-efficacy, in terms of teaching competence, of in-service teachers and pre-service teachers in early childhood education, primary education, secondary education, and higher education in their design of teaching programs for active learning?

- Can we speak of a growing need for critical literacy in online education and in face-to-face education to promote true active learning in the didactic social and STEAM disciplines?

This book was completed with the support and funding of the projects "The nature of I-STEM (NoSTEM) for citizen training" (PID2020-118010RB-I00) [State Research Agency – Ministry of Science and Innovation], and "Future Education and Democratic Hope. Rethinking Social Studies Education in changing times" (PID2019-107383RB-I00) [State Research Agency – Ministry of Science and Innovation].

Dr. Delfín Ortega-Sánchez
Professor,
University of Burgos,
Burgos, Spain

References

[1] Ortega-Sánchez D, Gómez-Trigueros I. Gamification, social problems, and gender in the teaching of social sciences: Representations and discourse of trainee teachers. PLOS ONE. 2019;**14**(6):e0218869

[2] Ortega-Sánchez D, Gómez-Trigueros I. MOOCs and NOOCs in the Training of Future Geography and History Teachers: A Comparative Cross-Sectional Study Based on the TPACK Model. IEEE Access. 2020;**8**:4035-4042

Section 1

Active Learning for STEM and Science Education

Chapter 1

Emergent Chemistry: Using Visualizations to Develop Abstract Thinking and a Sense of Scale within the Preschool Setting

Karina Adbo

Abstract

This chapter is a summary of 5-years of research regarding children's emerging abstract concepts. A longitudinal study focusing on children's conversations during a series of activities with a chemistry focus was designed and implemented. Results show that practical experience with magnifying glasses, microscopes, and the deconstruction of several items did not provide enough backdrop for the children to imagine what an even smaller world would look like. Instead, the children applied their experiences from the macroscopic world to describe what they saw. It was not until aminations, zooming in from the macroscopic to the atomic and molecular levels were used that the children's concept of small began to develop. Results show that the next stage of concept development, besides using descriptions from everyday experiences was the realization these were new experiences, that it was in fact something new they were seeing. Animation technology also helped the children realize that atoms and molecules are everywhere in everything, suggesting that the time elapsed between the transition from the macroscopic level to the submicroscopic level also provided the children with a sense of scale.

Keywords: preschool education, abstract thinking, scale, natural science, chemistry

1. Introduction

Preschool education in all countries has one general goal in common. That goal is to provide children with a broad experience base. This is done since experiences are seen as the foundation of learning, creativity, and imagination. Learning can be seen as a change in previous experiences and Vygotsky proposed that imagination is based on experiences [1]. A proposition suggests that it may be difficult for us to imagine something which we have no experience of. Creativity was as also described by Vygotsky as, new ways to combine experiences. Indeed, learning, imagination, and creativity are some of the intended outcomes of preschool education.

2. Preschool education

Learning can be viewed from different perspectives. A general perspective was provided by Piaget who thought of learning as a change in previous experiences. Piaget [2] then continued to describe learning as being possible within different stages while Vygotsky used another perspective and described learning as more situationally bound. Vygotsky saw learning as not only occurring in all instances but also dependent on what was possible in every situation. He saw learning as occurring in the space between the real and the ideal form. Today researchers use the word the present form instead of the ideal form to emphasize that the social world surrounding a child may not in fact be ideal [3]. The real form is the child's current experiences and the term present form is used to describe what the social environment surrounding the child contributes.

How experiences are formed was also described by Vygotsky with the use of the concept of perezhivanie. The concept of perezhivanie [4] provides a perspective where we all are seen as viewing the world through our own personal prism. A prism that is formed by our previous experiences the prism determines what we notice and how this information is then interpreted. Suggesting that our current experiences affect our learning of new experiences, and our new experiences will affect our current experiences (see **Figure 1**).

Those experiences that are seen as having the greatest impact are those who are emotionally connected. If the theory is placed on a time scale such as a lifetime, then it suggests that emotional experiences will impact what we learn but also that our learning becomes more personalized as time passes. An interest in birds will cause us to focus more on birds something that will make us learn more about birds, something that in turn will make us notice more details regarding birds. If this is the case, then this perspective provides us with three important conclusions regarding preschool education: the first one is that the present form must include a manifold of new experiences, and the second is that it is important to intentionally create positive experiences since they will affect lifelong learning and the third is that activities should be designed for individuals. This research takes inspiration from a cultural-historical approach [5] that involves both cultural and individual aspects.

What is/should/could be included in a broad experience base within preschool education is today argued in the research literature. Most if not all authors agree

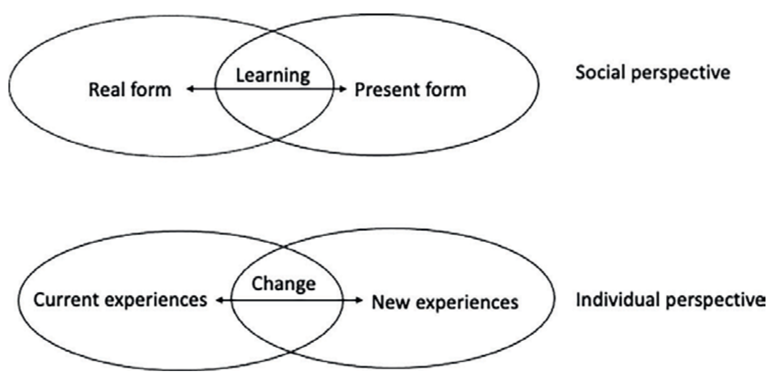


Figure 1.
A general overview of the difference between the social and individual perspectives when the concept of perezhivanie is used.

on the fact that the content of preschool education should meet the children's own interests and needs. For some, this approach means to follow the children's lead and expand on their own interests [6] while others see it as actively introducing children to new experiences by conveying content indirectly through play [7]. In practice, most preschool education is of course a mixture of these two counterparts. As it would be difficult to only follow the children's lead since they all have different experiences so what is following the experiences of one child is staging a new experience for another child.

The content of activities in preschool education is also under scrutiny, there are those authors who argue that preschool education should be free of any academic content [8] while others see preschool as an opportunity to provide children with play-based activities with content that are designed and could well be seen as academic depending on our definition of what is included in academic content. The one thing that most authors agree on is that preschool education should at all costs avoid schoolification. Schooloification is a term used for describing a more direct transfer of academic school knowledge to the preschool level. The key to avoiding schoolification is to analyze children's activities and allowing their questions and current focus, that is, to be the force that drives experience building [9] regardless of whether the content is deliberately introduced by the teacher or not.

2.1 Development as a case of emergence

When researchers describe learning in the preschool context is often described in terms of emergence [10]. When using the term emergence focus is placed on children's own version of content. It is a version that is not evaluated for its correctness but instead because it provides clues that help us provide a more supportive preschool environment. The use of the word emergence also recognizes that what research can describe are only small parts/glints of the process of learning.

2.1.1 Content of preschool education

Today natural science is a part of the experiences that most preschools provide. It is in fact difficult to avoid natural science content in preschool as children have a natural tendency to explore their surroundings [11]. And as natural science is found in all aspects of the immediate world surrounding the child, i.e., in the material-, biological- and cultural aspects it is a content that is difficult to avoid. The goals for this content can be found on both individuals as well as societal levels. On the individual level, the goal is of course to meet individual children's own curiosity and to build positive experiences of science [12]. Positive experiences in science are important for creating self-confidence, that is, positive subject identities so that children feel confident that they are good at science. Indeed, motor active hands-on activities contribute positively to positive attitudes toward science [13] providing a stronger positive subject identity. Another goal is to create cultural motives [14] and thereby making science a natural part of the child's everyday life. On a societal level, the goals include creating interest in the natural environment to develop children's environmental awareness to build for a more sustainable future [15].

From the perspective of learning a natural science content, an early introduction to the concepts and words that natural science is comprised of is seen as beneficial, since many of them take a long time to get familiarized with [16]. Indeed, research on children's science learning on a general level can be separated into categories:

development of abstract thinking [17], development of words, concepts, and their content [18], developing understanding of processes and transfer of knowledge/ideas between contexts (near- and far transfer) [19] as well as the process of science inquiry [20]. Most of these studies include topics that could be categorized into biology and physics. Very few studies have focused on chemistry and how a more chemical content could be transferred into a preschool environment [21–24]. This is even though so many of our chemical methods can be found in the child's immediate surroundings and explored through hands-on experience. One example is separation methods such as filtering something that we do on a daily basis while: separating pasta from water, ions from water, tea leaves from the water, ground coffee from water, preventing pieces of food from entering the pipes in our kitchen or strands of hair from pipes in the bathroom, light from entering a room, butterflies from the air, fish from the water, or preventing sound from entering our ears. Another reason why chemistry should be a part of the preschool environment is because the single most important feature of chemistry is imagination. Chemists have spent centuries trying to imagine what an abstract world, the submicroscopic level could possibly look like and how its different parts combine and dissembles. When taking this perspective, it becomes interesting to explore children's abstract thinking and how they imagine the submicroscopic world, and what sort of circumstances we need to create in a preschool environment to begin this abstract and imaginative journey.

2.2 The development of abstract thinking

Abstract thinking is something that has been defined by many authors. Some examples of these definitions are; the process when children can represent reality by using a representation, for example, an object, that is, symbolic representations, "thoughts that are not immediately connected to the environment" [25]. Or, detaching from the concrete world while still maintaining a connection to it through representations. The first one to define what a representation is may in fact have been Aristotle who stated that the world and the world as we describe it are not the same things. The way we can view the emergence of children's abstract thinking is through their use of objects and symbolic representations in play, where a stick can become a sword or the symbol X on a map can represent a hidden treasure.

The development of abstract thinking, that is, real-world experiences to abstractions thereof has also been described by a few authors. These descriptions vary in specificity from the general to the more specific and from suggesting causes for development to suggesting how this development occurs. When turning toward causes for the development of abstract thinking research suggest that children have a natural tendency to seek patterns in their real-world experiences to generalize the experiences [26]. Suggestions for how this development occurs date as far back as Piaget (1953). Piaget described the development as including three parts: action, symbolic mediation, and then later abstract thought. More specific description has also been suggested. One of these descriptions separates this development into four different parts: i) motor, ii) symbolic representations, iii) functional dependency, and iv) thought. Functional dependency [27] is here used as a category to describe, children practicing making connections between reality and abstract representations as being one of the first steps toward abstract thinking. A stage in development that becomes specifically interesting to further explore as it affects how the representation is used and gives us clues to how natural connections between the representation and the real world are formed, and what they may look like.

2.3 Abstract representations

Here it is not the children's own representations of experiences that are in focus but instead how children being to understand the representations that we use in our daily lives, our cultural tools. When turning to the line of research that focuses on exploring already made representations, they are viewed in the perspective of the dual representation strategy [28]. Were a representation is seen as both a representation of something and at the same time as an object, in itself. The different types of representations that have been described in the early-years literature include representations such as maps, images, and scale models [29], or interactive representations, such as gaming or educational TV programs [30]. Research on young children's use of representations shows that the connection between reality and representation is difficult for young children. Something that has been shown through experiments where children have been presented with scale models of a room, a toy was hidden in the room as well as in the scale model, and the quest given to the child was to find the hidden toy in the real room. For children as young as two years old, the success rate of this quest increased when the idea of a shrinking machine was introduced. The shrinking machine gave the children the impression that the scale model was in fact the real room that had just become smaller [29]. The same result was described in other studies where the scale model was replaced by a video of someone hiding a toy. The rate in success of finding the toy was higher when a window frame was placed around the image of the video giving the children the impression that they were looking into the room itself. It has also been shown that children's use of representations improves if the child does not get to play with the object itself before it is used as a representation. A result suggests that the child's familiarity with the object causes them to place their focus on objects instead of the object as a representation [28]. This result suggests that "removing the duality" makes representations easier for young children to understand.

Research result deriving from young children's use of interactive games and activities adds additional levels of complexity to the use of representations. The more sophisticated interactions become less useful in terms of content if the actual interactive part is difficult to handle as the child's focus is then placed on the object of interaction instead of the intended outcome. Similar results have been seen in for example laboratory work for much older learners where unfamiliarity with equipment changes the intended focus of the laboratory from the intended phenomena to the material itself [31]. When the representation comes in the form of a photo, then young children seem to notice that there is a difference between photographs and real objects [32] but they do not seem to understand this difference something that can be seen when children try to remove items from a photo [33]. When maps are used or scale models as above scale become an additional problem. Young children have difficulties seeing the lines on a map as roads since the lines are much too small to fit a car [34].

Research results also show that it is important for a continuous transformation between the concrete and the abstract, to facilitate functional dependency and abstract thought [35]. It is in fact not until the last decades that technology has made it possible to provide more realistic representations than simple images and molecular models, on a macroscopic scale. Some researchers see visualizations as being powerful since they have the ability to make us think in visual terms instead of in abstract terms, [33] thereby providing us with a kind of immediate reproductions to better support imagination.

So what do we know about children's descriptions of the abstract world? Research also tells us that children use metaphors, analogies, and similes (it looks like... something that they recognize) to describe unknowns [36]. These expressions can in themselves provide us with information to better support our youngest learners [37] as they are highlighting specific aspects, show us interpretations and become means for sharing feelings.

2.3.1 Project design

The results presented here are a summary of a longitudinal project, an intervention, designed to explore the development of children's abstract thinking. The intervention was designed as, an educational experiment where activities were designed and analyzed before the next activity was designed to ensure that it was the children's own interest that was the driving force behind the activities. These precautions were made to ensure the children's own interests were in focus and to avoid schoolification. The development of the concept of small was chosen although several other topics could just as easily have been applied. The reasons for this choice were emergence. Exploring children's emergent science and here, especially children's emergent chemistry means that no evaluation of the scientific correctness of the content was made. Studying emergence then means simply exploring children's own versions of scientific content. Using the development of the concept of small as an entrance also meant that we studied actual emergence since none of the children had previous experiences of levels below the macroscopic lived world, something that was also established in the first set of activities. Means that our findings would be a result of our activities and results would show the first-time experiences of the submicroscopic world. Also transfer between different contexts could also be studied as the interventions initially were the only source of information.

To provide the children with a backdrop for the science activities the activities were framed within a story. The story of the king and his royal family was derived from visits to the preschool and by observing the children's free play. The story began with the king's birthday where he was given a magnifying glass and began to explore the world around him [21].

3. Results

After the first activity, it was clear that none of the children had the experience of small things on a level below the macroscopic level. The smallest thing that they could imagine was on the level of baby bugs. When the interventions moved along it was clear that the story of the king quickly became superfluous. When the researcher entered the preschool, all children attending ran up to her and asked what are we doing today? Suggesting that the items and the researcher were enough to catch the children's attention [21]. This result may not seem significant, but it may also help preschool teachers to make science activities more easily accessible since the results support the idea of the design of play-based activities with an intended content. As the intervention proceeded the magnifying glasses were replaced by microscopes, but the children's descriptions remain at the level of similes. The size difference in children's descriptions moved from baby bugs to pea flour (which was the word they used to describe the content of peas). Mortared sugar was described as ice blocks and the connections made were toward lived experiences, such as brushing teeth and why sugar is harmful to your teeth. All interventions so far did not bring about imagining a world that could not be seen. The choice to introduce zooming-in videos was made to provide as real experiences of the atomic-molecular level as possible. Zooming-in videos of a range of different everyday items were introduced to the children. An experience that was appreciated by all the children. When the molecular level was reached, similes were used once again by the children "look at the meatballs." After a few zooming-in videos that ended in meatballs, the children realized that the meatballs were everywhere, in everything and that it may not be meatballs at all but instead something else. At this point, the researcher labeled them as molecules and atoms [22]. These results support the perspective of the dual representations. The animations were as realistic as possible something that may have assisted in the development of this particular form of abstract thinking as results suggest that removing the duality of the representation makes them more easily understood by children [28]. When using the perspective of functional dependency to look at the actual connection that the children made between the representation and the real world. The connections were based on similes and the change did not begin until the children had been exposed to several animations. A result that also supports the idea of continuous transformations between the lived world and the representation is required [35]. There is no doubt that animations provided these children with new experiences of a world that normally is beyond sensory experiences. New experiences that may be the base for future imagination and creativity. This is a very important result for educational settings as images of atoms and molecules naturally are macrolevel representations and moving animations this may so far be the only way to provide relatively realistic experiences of the submicroscopic level something that may support learners at all educational levels. If the concept of perezhivane and its effect on lifelong learning is valid, then experiences like this may have long-lasting impacts on a personalized learning process.

4. Conclusions

The results show that developing abstract thinking from motor interaction of the macroscopic world with magnifying glasses and microscopes did not induce children's imagination of what came next. Providing visual experiences of the submicroscopic level did show the next stage in concept formation: the realization that it looks like something … but it is not… brought gave rise to a concept by the researcher labeling the experiences. This concept together with "they are every was in everything" suggests that the children to some extent understood the scale of the atoms and molecules, at least to the extent that they are small enough to be inside things. A result that supports Vygotsky's idea that experience is a base for imagination. This is an example of functional dependency in the way the concept has been interpreted in this context. The fact that the children saw several data animations of different items supported their connections between the animation and reality since it was not until several animations had been seen that the separation between their experiences and the animation began to show. Suggesting that connections need to be made on several occasions.

Acknowledgements

This research was funded by the Crafoord Foundation (Refnr: 20200712).

Conflict of interest

There are no conflicts of interest.

Author details

Karina Adbo[1,2]

1 Faculty of Education and Society (LS), Department of Natural Science, Mathematics and Society (NMS), Malmö University, Sweden

2 Faculty of Health, and Life Science (FHL), Department of Biology and Environmental Science (BOM), Linnaeus University, Sweden

*Address all correspondence to: karina.adbo@lnu.se

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Vygotsky LS. Imagination and creativity in childhood. Journal of Russian and East European Psychology. 2004;**42**(1):7-97

[2] Piaget J, Tomlinson J, Tomlinson A. The child's Conception of the World. In: Paul K, editor. Trench. London: Trubner & co., ltd.; 1929

[3] Veresov NN. ZBR and ZPD: Is there a difference? Cultural-Historical Psychology. 2017;**13**(1):23-36. DOI: 10.17759/chp.2017130102

[4] N. Veresov, "Expanding the cultural-historical theory: Fourth generation is coming?." Cultural-Historical Psychology. Jan 2013;3:51-54

[5] Fleer M. Post-Vygotskian lenses on Western early childhood education: Moving the debate forward. European Early Childhood Education Research Journal. 2003;**11**(1):55-67

[6] Gelman SA. Psychological essentialism in children. Trends in Cognitive Sciences. Sep 2004;**8**(9):404-409. DOI: 10.1016/j. tics.2004.07.001

[7] Fleer M. Scaffolding Conceptual Change in Early-Childhood. Vol. 20. Clayton Vic: Australian Science Education Research Assoc; 1990

[8] Lindholm M. Promoting curiosity? Possibilities and pitfalls in science education. Science Education. 2018;**27**(9-10):987-1002. DOI: 10.1007/s11191-018-0015-7

[9] Hedegaard M. The educational experiment. In: Hedegaard MFM, editor. Studying Children: A Cultural-Historical Perspective. New York: Open University Press; 2008. pp. 181-201

[10] Siraj-Blatchford J. Emergent science and technology in the early years. In: Presented at the XXIII World Congress of OMEP. Santiago, Chile; 2001. Available from: https://www.academia.edu/31623661/Emergent_Science_and_Technology_in_the_Early_Years_Ciencia_emergente_y_Tecnologia_en_la_edad_infantil_Science_et_Technologie_dans_lenfance

[11] Haim E. Science Literacy in Primary Schools and Pre-Schools [Electronic Resource]. Dordrecht: Springer; 2006

[12] Mantzicopoulos P, Patrick H, Samarapungavan A. Young children's motivational beliefs about learning science. Early Child Research Quarterly. 2008;**23**(3):378-394. DOI: 10.1016/j. ecresq.2008.04.001

[13] Patrick H, Mantzicopoulos P, Samarapungavan A. Motivation for learning science in kindergarten: Is there a gender gap and does integrated inquiry and literacy instruction make a difference. Journal of Research in Science Teaching. 2009;**46**(2):166-191. DOI: 10.1002/tea.20276

[14] Fleer M. A cultural-historical model of early childhood science education. In: Fleer M, Pramling N, editors. A Cultural-Historical Study of Children Learning Science: Foregrounding Affective Imagination in Play-Based Settings. Dordrecht: Springer; 2015

[15] Caiman C, Lundegård I. Pre-school children's agency in learning for sustainable development. Environmental Education Research. 2014;**20**(4):437-459

[16] Johnston J. Emergent Science: Teaching Science from Birth to 8. New York: Pearson; 2014

[17] Ampartzaki M, Kalogiannakis M. Astronomy in early childhood education: A concept-based approach. Early Child. Educ. J. 2016;**44**(2):169-179. DOI: 10.1007/s10643-015-0706-5

[18] Best RM, Dockrell JE, Braisby NR. Real-world word learning: Exploring children's developing semantic representations of a science term. The British Journal of Developmental Psychology. Jun 2006;**24**:265-282. DOI: 10.1348/026151005X36128

[19] Emmons N, Lees K, Kelemen D. Young children's near and far transfer of the basic theory of natural selection: An analogical storybook intervention. Journal of Research in Science Teaching. 2017;**55**:321-347. DOI: 10.1002/tea.21421

[20] Samarapungavan A, Patrick H, Mantzicopoulos P. What kindergarten students learn in inquiry-based science classrooms. Cognition and Instruction. 2011;**29**(4):416-470. DOI: 10.1080/07370008.2011.608027

[21] Adbo K, Vidal Carulla C. Designing play-based learning chemistry activities in the preschool environment. Chemical Education Research and Practice. 2019;**20**:542-553

[22] Adbo K, Vidal Carulla C. Learning about science in preschool: Play-based activities to support Children's understanding of chemistry concepts. International Journal of Early Childhood. 2020;**52**(1):17-35

[23] Carulla CV, Adbo K. A study of preschool children's motive orientation during science activities. Review of Science, Mathematics, and ICT Eduaction. 2020;**14**:47-67

[24] Vidal Carulla C, Adbo K. Using cultural-historical theory to design and assess a chemistry play-based learning intervention. Kul′t.-Istor. Psikhologii͡a. 2020;**15**(4):35-43. DOI: 10.17759/chp.2019150404

[25] Dumontheil I. Development of abstract thinking during childhood and adolescence: The role of rostrolateral prefrontal cortex. Developmental Cognitive Neuroscience. 2014;**10**:57-76. DOI: 10.1016/j.dcn.2014.07.009

[26] van Oers B, Poland M. Schematising activities as a means for encouraging young children to think abstractly. Mathematics Education Research Journal. 2007;**19**(2):10-22. DOI: 10.1007/BF03217453

[27] Athey C. Extending Thought in Young Children: A Parent-Teacher Partnership. London, UK: Sage Publications; 2007. p. 241. DOI: 10.4135/9781446279618

[28] DeLoache J. Dual representation and young Children's use of scale models. Child Development. Mar 2000;**71**:329-338. DOI: 10.1111/ 1467-8624.00148

[29] Troseth G, DeLoache J. The medium can obscure the message: Young Children's understanding of video. Child Development. 1998;**69**:950-965

[30] Alwitt LF, Anderson DR, Lorch EP, Levin SR. Preschool Children's visual attention to attributes of television. Human Communication Research. 1980;**7**(1):52-67. DOI: 10.1111/j.1468-2958.1980.tb00550.x

[31] Hofstein A, Lunetta VN. The role of the Laboratory in Science Teaching: Neglected aspects of research. Review of Educational Research. 1982;**52**(2):201-217. DOI: 10.2307/1170311

[32] DeLoache JS, Strauss MS, Maynard J. Picture perception in infancy. Infant Behavior & Development. 1979;**2**:77-89. DOI: 10.1016/S0163-6383(79)80010-7

[33] Uttal David H, O'Doherty, Katherine PY. Visualization: Theory and practice in science education. In: John G, Reiner K, Nekhleh M, Mary PB, editors. Comprehending and Learning from "Visualizations": A Developmental Perspective T2 - Models and Modeling in Science Education. New York: Springer; 2008

[34] Liben LS. Thinking through maps. In: Gattis M, editor. Spatial Schemas and Abstract Thought. London, UK: The MIT Press; 2001. pp. 45-77

[35] Otsuka K, Jay T. Understanding and supporting block play: Video observation research on preschoolers' block play to identify features associated with the development of abstract thinking. Early Child Development and Care. Jun 2017;**187**(5-6):990-1003. DOI: 10.1080/03004430.2016. 1234466

[36] Hägglund S, Samuelsson IP. Early childhood education and learning for sustainable development and citizenship. International Journal of Early Childhood. 2009;**41**(2):49. DOI: 10.1007/BF03168878

[37] Low GD. On teaching metaphor. Applied Linguistics. 1988;**9**(2):125-147. DOI: 10.1093/applin/9.2.125

Chapter 2

Integrating Analogy into Scientific Modeling for Students' Active Learning in Chemistry Education

Song Xue and Danner Sun

Abstract

Although active learning places more responsibility and emphasizes the learners themselves, as compared to the traditional learning approach, teaching guidance is still essential in the active learning environment. In most chemistry classes, students are provided with limited opportunities to explore the atomic structures at the sub-microscopic level or participate in learning activities. To address these issues, an effective teaching approach enabling students' active learning called "Analogy integrated Scientific Modeling" (AiSM) has been proposed with the aim of facilitating students' learning of abstract chemistry concepts. This chapter introduces how AiSM approach is integrated into chemistry class and promotes students to understand the atomic structure. The chapter starts with a theoretical background, which consists of analogy in teaching the atomic structure, the scientific modeling, and the AiSM approach. Subsequently, two lesson exemplars illustrate how the analogy and the scientific modeling can get integrated into a chemistry class. Last, the initial results of a pilot study are discussed to demonstrate the effects and benefits of the AiSM approach on promoting students' active learning in chemistry classes.

Keywords: active learning, analogy, educational paradigm, scientific modeling

1. Introduction

One of the primary purposes of science education is to improve students' conceptual understanding of science. Eliminating student misconceptions is always the priority of science educators and researchers. The scientifically inaccurate understanding of conceptions referring to misconceptions has become an obstacle to students' learning process [1, 2]. Moreover, it is widely perceived that the students taught by a typical, teacher-centered approach are unable to integrate their knowledge and thinking critically or creatively, resulting in their lower learning achievement and common misconceptions [3–5]. Consequently, the traditional approach, according to which the teacher acts as an information provider and the students as passive recipients, appears to be antiquated. Recently, the active learning approaches, which enable students to participate in their classes actively, have begun to gain traction to assist students in becoming meaningful learners [3, 6].

Being involved in the active learning process, the students can effectively develop their new understanding and make connections with the previously gained knowledge, which will assist them in gaining further understanding of certain issues [7, 8]. This is accomplished through active learning, which requires higher-order thinking skills and engages students in the learning activities [9]. Therefore, it is meaningful to facilitate students to develop an accurate and comprehensive understanding of the scientific concepts through active learning.

Some chemical concepts, in particular, are regarded as abstract and difficult to comprehend, which may lead to misunderstandings. One of these chemistry concepts is the "atomic structure." Many studies have shown that students found atomic concepts challenging to grasp, especially for the concept of atomic structure, and tend to develop alternative ideas instead [10]. It is mainly because the atom is a type of matter in the sub-microscopic world whose structure cannot be observed directly. Furthermore, students have few opportunities to investigate the atomic structures at the sub-microscopic level, and also the strategies which could assist them in learning the properties of atomic models are few and far between [10, 11]. Thus, building an active learning environment will be valuable for the students to explore these abstract concepts and enhance their scientific understanding by eliminating common misconceptions.

Scientific models and modeling are significantly and pedagogically beneficial in chemistry learning [12–15]. Scientific models are usually used to represent a scientific phenomenon employing different forms, such as analogies [16]. Scientific modeling is crucial in scientific inquiry for generating and evaluating hypotheses and describing natural phenomena. It also plays a crucial role in developing new scientific knowledge [17]. Scientific modeling has been largely neglected in the traditional school curriculum, being reduced to either an explanatory tool for strengthening lectures [18] or simulations, in which students have very little authority for developing their models [4]. Teaching with analogies is an approach, in which teachers help students conduct analogies for understanding the specific content by recognizing the analogy's coherence with the target concept. However, according to some observations, an analogy was sometimes inappropriately designed and implemented, thus failing to generate the intended outcome [19, 20]. Due to these reasons, a new pedagogical and instructional design framework, namely the "Analogy integrated Scientific Modeling" (AiSM), has been promoted as a more comprehensive way of integrating analogies into the scientific modeling process in chemistry classes.

This chapter focuses on introducing and discussing the theoretical background of the AiSM approach. And a pilot study is presented to verify the effects of AiSM on students' conceptual understanding of the atomic structure in chemistry classes. The study will inform the design and development of effective teaching approaches for promoting active learning in science education.

2. Theoretical framework

2.1 Using analogies to teach atomic structure

According to the outlook on the chemistry education adopted by Sarantopoulos and Tsaparlis [21], an analogy could be defined as a system of relations between the parts of two particular domains, namely the analog and the target (i.e., the familiar domain being the analog, and the unfamiliar one being the target). In chemistry education, using analogies may help students understand the new concepts by building upon their familiar experiences or prior knowledge. For example, one commonly used analogy is "the atom being like a tiny solar system." In this case, the spatial and dynamic features of the sun and the surrounding planets are analogous to those of the atomic nucleus and the electrons. To unfold this relationship, an atom is composed of a nucleus and electrons, which travel outside the nucleus rapidly. This is identified as a target concept in the learning process. In the analogy of the solar system, the sun is being compared to the nucleus, while the electrons are being compared to the planets. This analogy helps students understand the relationship between the atomic components and their respective locations.

Most analogies relate to the empirical phenomena, among others, the key functional relations involving causes and their consequences [22]. The analogy presents a new explanation for the occurrence of various phenomena by transferring knowledge about the causal relations, which then enables the further transfer of knowledge when applied to the new situations [22, 23]. According to the principles of constructivism, students could learn new, complex, or even abstract concepts by incorporating the new information into the pre-existing knowledge by use of analogies. This should help students to develop a conceptual understanding and, in turn, reduce their cognitive load. Since one of the challenges of learning about the atomic structure is that the atom is sub-microscopic matter and cannot be observed directly, teachers and educators usually develop analogies to illustrate and visualize the key features of atomic concepts using the reference to the real-world scenarios [23–25]. This teaching method entails drawing on students' prior knowledge and experience to facilitate their understanding. In the secondary education curriculum, the atomic concepts usually include the atomic and quantum theories, the atomic structure, the periodic table, and the chemical bond (in the curriculum of some countries). **Table 1** presents some examples of analogies used in the teaching practices.

However, a closer look at these analogies reveals that they may have their limitations as teaching tools. Each analogy has certain elements that the teacher intends for the students to focus on and use to understand the new concepts. However, some elements of the analogy are inappropriate for the target concepts. For example, everything external to the solar system is driven by its central star, whereas everything external to the atom is driven by the outermost orbitals and their electrons. If the students do not distinguish the difference between the analogy and the target concepts, they may develop new misunderstandings regarding these concepts. Therefore, it is suggested students use only appropriate portions of the analogy during the teaching process [21]. It is also necessary to highlight the relationship between the target and the analogy with a proper scientific explanation [22].

Recently, Gray and Holyoak summarized five principles of an analogical approach based on the research in cognitive psychology and cognitive neuroscience [22]. These five principles include [1] capitalizing on the prior knowledge, [2] highlighting the shared structure, [3] explaining the connections between the semantic information and the mathematical operations, [4] considering the cognitive load, and [5] encouraging the generation of inferences. This approach was proposed to maximize the benefits and minimize the problems encountered in the analogy instruction [26]. Moreover, it provided a framework for better guiding the application of an analogy in the classroom settings, to foster greater conceptual understanding and transfer.

Target concept	Analogies	Relationship between the targeted concept and the analogies
Dalton atomic theory	Round symbol	A combination of symbols used to represent the simple compounds.
Tomson atomic model	Pudding model or Raisin cake model	Electrons are evenly distributed among the atoms.
Rutherford atomic Model	Nuclear model or Solar system model"	An atom consists of a positively charged nucleus situated in the center, where the electrons are moving around in a high-speed motion.
Bohr atomic model	Quantum atom model	The electrons move in a high-speed motion around the nucleus, in a certain orbit.
Atomic structure • *Electrons* • *Neutrons* • *Nuclei* • *Electronic arrangement*	Solar system	The nucleus and the planet are analogous to the sun and the electron, respectively.
Atomic orbital and electronic configuration • *Electronic cloud* • *Energy layer level* • *Energy level* • *Electronic transition* • *Ground state* • *Excited state*	• Bookshelf • Stairs	• The height of the bookshelf is analogous to the energy level. • The change of potential energy in climbing stairs is analogous to the change of electron energy.
Periodic table • *Structure of the periodic table* • *Regularity of elements with the same period and same main group* • *Nuclides and isotopes*	Teacher and students in the classroom	Teachers are analogous to nuclei, attractive to students (analogous to electrons), most attractive to students in the front row, and least attractive to students in the last row.
Chemical bond • *Electronic formula* • *Covalent compound* • *Ionic compound*	Magnets	The interaction between the north and south poles of the magnet is similar to the interaction between the positive and negative charges.

Table 1.
Using the analogies to teach the unit of atomic structure.

2.2 Mental models and GEM scientific Modeling

2.2.1 Mental models

According to Johnson-Laird [27], learners construct internal cognitive representations, or mental models, during their interaction with the environment, artifacts, technology, or communities. A mental model can be defined as a form of organizing knowledge employing representing objects, states of affairs, sequences of events, ways of the world, or the social and psychological actions of daily life [28]. There is growing recognition that mental models are the reasoning tools for both scientists and students in science [29]. The mental models help us make predictions and develop causal explanations between variables [30]. For instance, when students were asked which model was more appropriate for describing the structure of an atom, they chose the Rutherford model and the Bohr model, which could both be considered mental models. This example shows that a mental model is not always a scientific one - it can be analogical, partial, or fragmentary [31], but it can be changed and revised through the learning process.

2.2.2 GEM scientific models

One of the objectives of science education is to make students think about the natural world as a scientist [32]. Therefore, a teaching approach based on the scientific modeling was proposed and developed with the aim of urging the students to build, contest, and ultimately change their knowledge of how the world works, as scientific modeling is one of the main approaches adopted by scientists to investigate and explain the natural world. This approach requires selecting and identifying the relevant aspects of a given, real-world situation and subsequently developing different types of models for different goals to better understand, manipulate, or predict a particular phenomenon [33, 34].

Several scientific modeling-based strategies reported in the literature have involved students in the interactive modeling processes [35–39]. This chapter adopted the GEM (Generate, Evaluate, and Modify) approach [28], designed to develop students' scientific understanding of chemistry through scientific modeling. At the beginning of the GEM modeling process, with due consideration given to the students' pre-existing knowledge, the teacher provides background knowledge or a set of information and asks students to *generate* the relations between variables in the mentioned context. In the *evaluation* process, the teacher provides some additional evidence or new information to the students, who would then evaluate and explain the reasons for the relations, which developed in the *generation* process. Finally, based on the evaluation results, the teacher encourages the students to *modify* the relations between the variables or solve the new cases, if necessary. The GEM approach is applicable to numerous empirical studies [28, 40], in which students' mental models are represented by some external forms, such as drawings, concept maps, computer simulations, or animations. Furthermore, these studies suggest that students' prolonged participation in the GEM cycle could help them achieve the goals of the critical learning process in chemistry.

2.3 AiSM approach for promoting active learning

Some recent work has focused on the role of analogies in building and revising mental models [28, 41, 42]. AiSM is a teaching approach for promoting students' active learning through the integration of analogy into GEM scientific modeling. In AiSM pedagogical approach, the analogies could result in the mental models being manipulated and transformed as a part of the GEM process. The analogy, treated as an external representation of a mental model, can provide explanatory power for making sense of the familiar (analogy) and the unfamiliar (transfer target).

The analogy can be represented in various forms, such as texts, pictures, videos, verbal examples, and computer simulations [28].

In this section, the interaction between the analogies, the mental models, and the modeling is further clarified. **Figure 1** shows the mechanism of AiSMT. In the process of developing mental models, students have to evaluate and integrate the new information into their existing metacognitive framework. When the analogies are used at the beginning of the teaching process, they may help students *generate* an imperfect preliminary model (M1), which is later "evaluated (M2) and modified (M3)". An analogy may also be used at critical points in the subsequent modeling process (GEM) to provide the missing aspects for the target concepts or the scientific phenomena.

Regarding the scientific modeling process, the literature has shown that scientific modeling can be enacted through different processes [42]. These include other modeling processes, such as model construction, model use, model revision, model comparison, and model validation analysis [43], all of which are interactive and do not require the presence of all the other processes in each cycle/iteration [42]. However, the empirical studies reported that novice modelers encountered numerous challenges when taking over a modeling task or other related activities [42, 44]. **Figure 1** presents a relatively simple way of including the three modeling processes: a linear teaching sequence following the GEM or an interactive or cyclical process.

Selecting a pattern for the scientific modeling is determined by the complexity of the modeling task or the target concept. It is important to stress that the modeling, including at least three of these processes, could ensure a meaningful construction of the students' mental models [44]. Thus, active learning may happen when using an internal mental model of a construction process stands in contrast to the direct transmission process. Active learning requires learning by mentally developing or processing information, using construction and criticism rather than listening, and is reflected in an integrated knowledge schema. Teachers could judge whether the students' mental models are scientific through an external representation, such as the analogy, and thus help students construct knowledge by providing them with new information. The theoretical framework proposed in this study is hopefully applicable to the lower educational level or less complex modeling tasks, as well as the novice teachers without modeling experience.

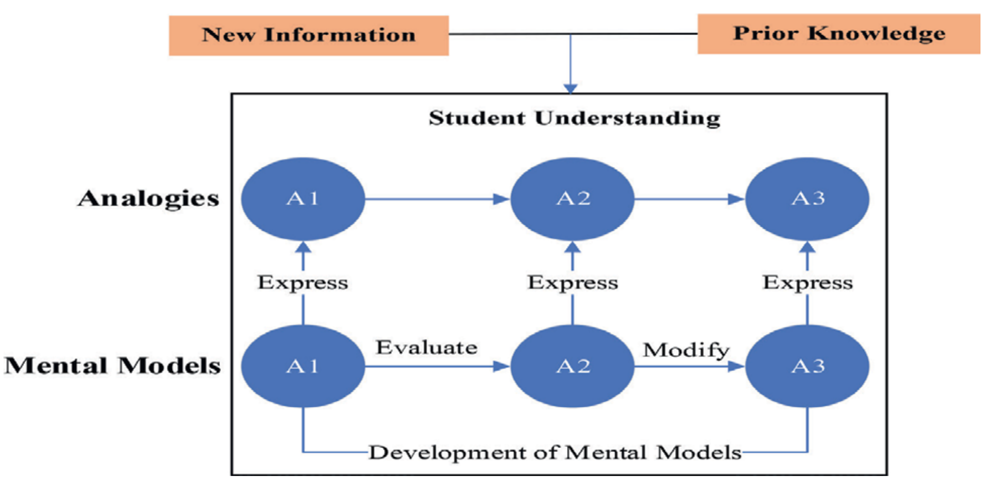


Figure 1.
A theoretical framework for integrating analogy into the GEM scientific modeling.

3. The application of AiSMT and AT into chemistry learning and teaching: Lesson design and Pilot study

3.1 Lesson design

Based on the above literature review, this section presents two lesson exemplars centered around analogy-based teaching (AT) and analogy-integrated scientific modeling teaching (AiSMT), both based on a case of the atomic structure taught in the local Taiwan chemistry curriculum. The learning objectives are (1) the scientific knowledge (learning about the history of atom discovery and understanding the concepts of the atomic structure, the spectrum, the atomic orbital, the electronic configuration, the periodic table, and the chemical bond formation following the lessons) and (2) the scientific abilities (for 10th graders, students should have the ability to "build models based upon the scientific problems or by means of a group discussion and can use, for instance, "analogous or abstract" representations to describe a systematic scientific phenomenon, and then understand the limitations of the model (p. 32)" [45]. Both lesson exemplars had some common features, e.g., both teaching exemplars were based on constructivism, they employed analogical examples (see **Table 1**), and taught the same scientific concepts supported by digital technologies (e.g., PhET).

Figures 2 and **3** demonstrate the process of the AT and AiSMT respectively. The main differences between these two exemplars are (1) AiSMT engaging students in the scientific modeling process (GEM) of atomic structure by using the analogies with promoting multiple interactions between the students and the teacher. Therefore, the development of students' mental models occurred during the process of collaborative construction between the students and the teachers. Regarding the AT, it is more straightforward, as it involved students compiling the information provided by the teacher to select the proper analogies, which they later used to construct the mental models. (2) The other difference is that the AT asked students to consider the relationship between the analogies and one single target concept (atomic structure), whereas the AiSMT encouraged students not just to think about a single target concept, but also to make a connection and a comparison between the other related target concepts (energy level, electron leap). (3) After the actual teaching for the whole unit of the

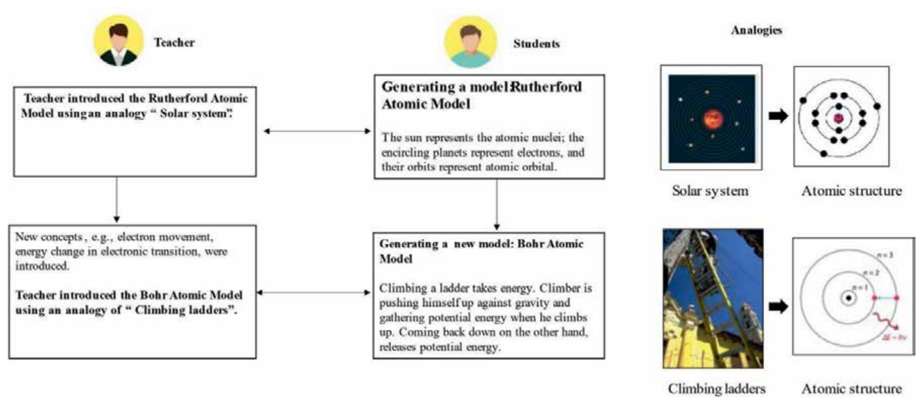


Figure 2.
The flow of the analogy-based teaching (AT).

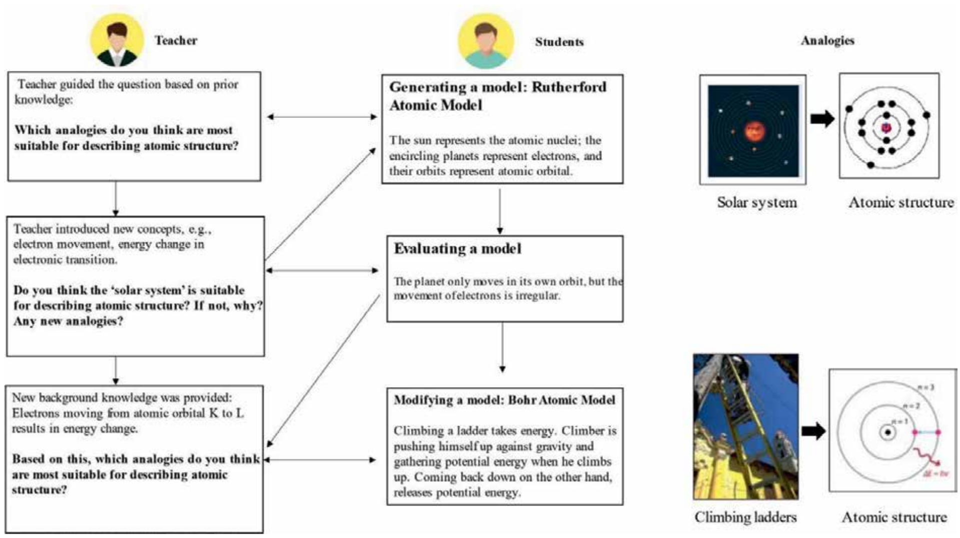


Figure 3.
The flow of the analogy-integrated, scientific modeling teaching (AiSMT).

atomic structure was implemented, it has been found that the AT took less teaching time than the AiSMT (7.5 h vs. 8.25 h).

3.2 Pilot study

A quasi-experimental design was implemented to compare the effects of the two instructional approaches, mainly the AT and the AiSMT, on the high school students regarding their understanding of the atomic structure, as presented in the Taiwanese chemistry curriculum. Two groups of participants, the AT group (n = 69), and the AiSMT group, (n = 68), with an average age of 15.6, were selected and engaged in a three-week teaching intervention. The two teachers, a female teacher (T1) with eight years of teaching experience in chemistry taught the AT group, and a male teacher (T2) with six years of teaching experience in chemistry taught the AiSMT group. Both teachers did not engage in any specific modeling-based teaching training. However, they had prior knowledge and experience of modeling-based teaching acquired during their teaching career.

To examine the effects of two instructional approaches on students' conceptual understanding and compare the learning differences between the two instructional approaches, a pre, post, and delayed post-test design has been conducted. Meanwhile, to collect the data about teachers' respective perspectives on the differently designed teaching approaches as well as their views on the students' learning techniques, the teachers both observed each other's classes during the experiment, and they were invited to participate in the semi-structured interviews after teaching (30 minutes per teacher).

A detailed description of the research design and the results can be found in the work of Xue et al. in 2022 [46]. In this book chapter, the key findings were briefly presented. The quantitative analysis of the pre-and post-test results has shown that, generally, both instructional approaches could significantly facilitate students' content understanding in the field of atomic structure with a large effect size. This finding revealed the value of both instructional approaches in facilitating students' active learning. By comparing the results at the post-test stage, it has been found that there was no significant difference in the content understanding between the two groups. However, the delayed post-test results provided evidence for the significantly lower effectiveness of the integrated modeling in terms of facilitating the content knowledge retention, as compared with the effect of the AT. The MAI group remembered and recalled the atomic concepts thoroughly and did better in the delayed post-test. This finding may result in the increased value of incorporating scientific modeling, which could further assist in the retention of scientific knowledge.

Both teachers agreed that the two instructional approaches were applicable and effective. They also shared their thoughts on each other's approaches. T1, commenting on the AT, concluded that it was important to emphasize the analogy's correspondence with the target concept in teaching, while not neglecting the analogy's limits. She highlighted her positive attitude towards this innovative teaching method when she observed the AiSMT class. She found most students to be engaged in the conversation as well as the activities between the teachers and their peers. This has encouraged them to promote cognitive processing and activated their learning interest as a result. However, she also expressed some concerns. Firstly, she was concerned about the timing of the class, worrying that there would not always be enough teaching time to incorporate the modeling activities. Secondly, due to the fact that the modeling-based teaching entails a lot of questions and interactions, it may be stressful for some students and hard for some low-achievers, who have never engaged with any modeling or scientific inquiry. Thirdly, the application of modeling-based teaching requires a high level of competence, such as carefully developed instructional design, and providing relevant supporting resources, such as computer simulations and background information, which may be a challenging task for some novel teachers. T2, who implemented the modeling-based teaching, said that adapting the GEM approach is beneficial for the students who need to constantly reflect upon, analyze, and revise their mental models. In terms of the teacher's role, he said, the following: "I need to have a deep and comprehensive understanding of the scientific concepts which I taught. In addition, I should keep in mind related concepts students may have some misunderstandings about, in order to eliminate them by means of the modeling process". What was worth noting is his remark on the modeling activities, which apparently did not take up the entire class time but were rather directed at the selection of the suitable teaching elements or concepts. He ended up by summarizing the three criteria for selecting concepts to be used in the modeling-based teaching: target concepts, which have constituent aspects or variables; the possibility of integrating them with the students' life experiences; and the history of the used development and/or evolution being a scientific one.

4. Discussion, conclusions, and implications

This study presented a literature review that discussed the related theory and principle of using analogy and scientific modeling in teaching the atomic structure. A new pedagogical approach, AiSM, has been promoted with the aim of integrating the analogy into the scientific modeling process (GEM) in chemistry education. Two lesson exemplars were designed to show the uses of the AT and the AiSM in active learning. The empirical study has shown that the two teaching approaches proved to be effective in promoting students' content understanding. Both teaching approaches had an equal effect in enhancing students' understanding. These results are aligned with the studies, which reported the positive effects of analogy and scientific modeling and the equally positive effect on students' learning improvement [21, 36, 47]. However, the result, which has not been previously described is the students who engaged in modeling outperformed the non-modeling group [40, 48].

The new finding was found that modeling-based teaching could maintain longer memory and a better understanding of the content being taught among the students. Hofstadter's interpretation of the cognitive processes explains the reason behind the effectiveness of enhancing retention of content understanding by the use of modeling [49]. According to Hofstadter, cognition is mediated by continual processes until a long-term memory node is accessed. Once this is done, cognition gets transferred to a short-memory node where it is unpacked to some degree. This allows for the new structures to be perceived, and the ensuing high-level perceptual act activates the further nodes, which, in turn, are being accessed, transferred, unpacked, etc. (p. 517). Modeling-based instruction is very much in line with the cognitive processes described above. Following the GEM approach implemented in this study, students were leveraged with prior knowledge and experience to develop models of the target concept. They were subsequently evaluated and revised the initial model in accordance with the newly provided information. The modified model was applied to the new contexts and situations, so it could be further improved upon. These constant processes of reflection and improvement could mediate the development of the mental models, which in turn could enhance their fitness and correspondence to the outside world [50].

From the data collected in the interview, the two chemistry teachers who participated in this study recognized the value of analogy and scientific modeling in the development of students' mental models. The dilemmas and challenges of implementing the modeling-based teaching, such as being difficult to control and time-demanding, were found to be consistent with the earlier research [47]. However, the teachers' reflections on the integrated modeling are another worthwhile aspect of this study. The previous research presented the complexity of modeling-based teaching and the strategies for promoting competence using it [28, 51]. This study resulted in the implications of the integrated modeling being learned from the evidence of teachers' empirical application. It could be concluded by listing the four positive aspects of applying modeling-based teaching in the formal school curriculum. These would include selecting the targeted scientific concepts or phenomena along with variables, elements, or factors, combing them with learners' life experiences, and finally choosing concepts with the history of scientific evolution and reasoning.

This study adds to the ongoing conversation on the use of analogy and scientific modeling in chemistry education and contributes empirical evidence in order to justify the use of analogies and modeling as a means of improving the content understanding among students. It is advised that integrating the analogies into the scientific modeling can be achieved in the future classes, provided that the combination of the more science-specific content would be used. Moreover, the appropriate and cautious design for use of the analogy and modeling should be considered by the teachers. Future research could focus on the teachers' professional development of lesson design for analogy-based scientific modeling in science education.

Author details

Song Xue[1*] and Danner Sun[2]

1 School of Education and Social Work, University of Dundee, Dundee, United Kingdom

2 Department of Mathematics and Information Technology, The Education University of Hong Kong, Hong Kong, China

*Address all correspondence to: 2393774@dundee.ac.uk

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Özmen H. Some student misconceptions in chemistry: A literature review of chemical bonding. Journal of Science Education and Technology. 2004;**13**(2):147-159

[2] Üce M, Ceyhan İ. Misconception in chemistry education and practices to eliminate them: Literature analysis. Journal of Education and Training Studies. 2019;**7**(3):202-208

[3] Acar B, Tarhan L. Effects of cooperative learning on students' understanding of metallic bonding. Research in Science Education. 2008;**38**(4):401-420

[4] Sesen BA, Tarhan L. Promoting active learning in high school chemistry: Learning achievement and attitude. Procedia Social and Behavioral Sciences. 2010;**2**(2):2625-2630

[5] Özmen H, Gö DİİĞ, Coll RK. A comparative study of the effects of a concept mapping enhanced laboratory experience on Turkish high school students' understanding of acid-base chemistry. International Journal of Science and Mathematics Education. 2009;**7**(1):1-24

[6] Michael J, Modell HI. Active Learning in Secondary and College Science Classrooms: A Working Model for Helping the Learner to Learn. Routledge; 2003

[7] Heinze-Fry JA, Novak JD. Concept mapping brings long-term movement toward meaningful learning. Science Education. 1990;**74**:461-472

[8] Bodner GM. Constructivism: A theory of knowledge. Journal of Chemical Education. 1986;**63**(10):873

[9] Baharin N, Kamarudin N, Manaf UKA. Integrating STEM education approach in enhancing higher order thinking skills. International Journal of Academic Research in Business and Social Sciences. 2018;**8**(7):810-821

[10] Nakiboglu C. Using word associations for assessing non major science students' knowledge structure before and after general chemistry instruction: The case of atomic structure. Chemical Education Research and Practice. 2008;**9**(4):309-322

[11] Sunyono S, Sudjarwo S. Mental models of atomic structure concepts of 11th grade chemistry students. Asia-Pacific Forum on Science Learning and Teaching. 2018;**19**(1):1-21

[12] Langbeheim E, Levy ST. Feeling the forces within materials: Bringing inter-molecular bonding to the fore using embodied modelling. International Journal of Science Education. 2018;**40**(13):1567-1586

[13] Prins GT, Bulte AMW, Van Driel JH, Pilot A. Students' involvement in authentic modelling practices as contexts in chemistry education. Research in Science Education. 2009;**39**(5):681-700

[14] Chittleborough G, Treagust DF. The modelling ability of non-major chemistry students and their understanding of the sub-microscopic level. Chemical Education Research and Practice. 2007;**8**(3):274-292

[15] Cheng MMW, Gilbert JK. Modelling students' visualisation of chemical reaction. International Journal of Science Education. 2017;**39**(9):1173-1193. DOI: 10.1080/09500693.2017.1319989

[16] Niebert K, Marsch S, Treagust DF. Understanding needs embodiment: A theory-guided reanalysis of the role of metaphors and analogies in understanding science. Science Education. 2012;**96**(5):849-877

[17] Windschitl M, Thompson J, Braaten M. Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. Science Education. 2008;**92**(5):941-967

[18] Piech C, Sahami M, Koller D, Cooper S, Blikstein P. Modeling how students learn to program. In: Proceedings of the 43rd ACM Technical Symposium on Computer Science Education. 2012. pp. 153-160

[19] Cin M. Alternative views of the solar system among Turkish students. International Review of Education. 2007;**53**(1):39-53

[20] May DB, Hammer D, Roy P. Children's analogical reasoning in a third-grade science discussion. Science Education. 2006;**90**(2):316-330

[21] Supasorn S, Promarak V. Implementation of 5E inquiry incorporated with analogy learning approach to enhance conceptual understanding of chemical reaction rate for grade 11 students. Chemical Education Research and Practice. 2015;**16**(1):121-132. DOI: 10.1039/C4RP00190G

[22] Gray ME, Holyoak KJ. Teaching by analogy: From theory to practice. Mind, Brain, and Education. 2021;**15**(3):250-263

[23] Taber KS. Upper secondary students' understanding of the basic physical interactions in analogous atomic and solar systems. Research in Science Education. 2013;**43**(4):1377-1406

[24] Devecioglu-Kaymakci Y. Embedding analogical reasoning into 5E learning model: A study of the solar system. EURASIA Journal of Mathematics, Science and Technology Education. 2016;**12**(4):881-911

[25] Goh NK, Chia LS, Tan D. Applications and analogies: Some analogies for teaching atomic structure at the high school level. Journal of Chemical Education. 1994;**71**(9):733-734

[26] Venville G, Donovan J. How pupils use a model for abstract concepts in genetics. Journal of Biological Education. 2008;**43**(1):6-14

[27] Johnson-Laird PN. Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness. Harvard University Press; 1983

[28] Khan S. Model-based inquiries in chemistry. Science Education. 2007;**91**(6):877-905

[29] Ifenthaler D, Seel NM. Model-based reasoning. Computers & Education. 2013;**64**:131-142

[30] Kotovsky L, Gentner D. Comparison and categorization in the development of relational similarity. Child Development. 1996;**67**(6):2797-2822

[31] Norman DA. Some Observations on Mental Models. Psychology Press; 1983

[32] Chiu M-H, Lin J-W. Modeling competence in science education. Disciplinary and Interdisciplinary Science Education Research. 2019;**1**(1):1-11

[33] Schwarz CV, Reiser BJ, Davis EA, Kenyon L, Achér A, Fortus D, et al. Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for

learners. Journal of Research in Science Teaching. 2009;**46**(6):632-654

[34] Schwarz CV, White BY. Metamodeling knowledge: Developing students' understanding of scientific modeling. Cognition and Instruction. 2005;**23**(2):165-205

[35] Cheng MF, Lin JL, Lin SY, Cheng CH. Scaffolding middle school and high school students' modeling processes. Journal of Baltic Science Education. 2017;**16**(2):207-217

[36] Dukerich L. Applying modeling instruction to high school chemistry to improve students' conceptual understanding. Journal of Chemical Education. 2015;**92**(8):1315-1319

[37] Schwarz C, Reiser BJ, Acher A, Kenyon L, Fortus D. MoDeLS: Challenges in defining a learning progression for scientific modeling. In: Learning Progressions in Science. Brill Sense; 2012. pp. 101-137

[38] Buckley BC, Gobert JD, Kindfield AC, Horwitz P, Tinker RF, Gerlits B, et al. Model-based teaching and learning with BioLogica™: What do they learn? How do they learn? How do we know? Journal of Science Education and Technology. 2004;**13**(1):23-41

[39] Campbell T, Oh PS. Engaging students in modeling as an epistemic practice of science: An introduction to the special issue of the journal of science education and technology. Journal of Science Education and Technology. 2015;**24**(2):125-131

[40] Trey L, Khan S. How science students can learn about unobservable phenomena using computer-based analogies. Computers in Education. 2008;**51**(2):519-529

[41] Lin C-Y, Wu H-K. Effects of different ways of using visualizations on high school students' electrochemistry conceptual understanding and motivation towards chemistry learning. Chemical Education Research and Practice. 2021;**22**:786-801

[42] Louca LT, Zacharia ZC. Examining learning through modeling in K-6 science education. Journal of Science Education and Technology. 2015;**24**(2-3):192-215

[43] Nicolaou CT, Constantinou CP. Assessment of the modeling competence: A systematic review and synthesis of empirical research. Educational Research Review. 2014;**13**:52-73

[44] Louca LT, Zacharia ZC. Modeling-based learning in science education: Cognitive, metacognitive, social, material and epistemological contributions. Education Review. 2012;**64**(4):471-492

[45] Ministry of Education in Taiwan. Curriculum Standards for Grades 1-12. Taipei: Ministry of Education; 2018

[46] Xue S, Sun D, Zhu L, Hui-Wen Huang KT. Comparing the effects of modelling and analogy on high school students' content understanding and transferability: The case of atomic structure. Journal of Baltic Science Education. 2022;**21**(2):325-341

[47] Chiu MH, Lin JW. Promoting fourth graders' conceptual change of their understanding of electric current via multiple analogies. Journal of Research in Science Teaching. 2005;**42**(4):429-464

[48] Campbell T, Zhang D, Neilson D. Model based inquiry in the high school physics classroom: An exploratory study of implementation and outcomes. Journal of Science Education and Technology. 2011;**20**(3):258-269

[49] Hofstadter DR. Analogy as the Core of Cognition. Analog Mind Perspect from Cognition Science. Douglas Hofstadter; 2001. pp. 499-538

[50] Rapp DN. Mental models: Theoretical issues for visualizations in science education. In: Visualization in science education. Springer; 2005. pp. 43-60

[51] Khan S. What's missing in model-based teaching. Journal of Science Education and Technology. 2011;**22**(6):535-560

Chapter 3

About the Notion of Inverse Problem in STEM Education

Victor Martinez-Luaces, José Antonio Fernández-Plaza and Luis Rico

Abstract

Inverse problems play an important role in STEM disciplines; although this concept is not well-defined in STEM education. For instance, Mason considers inversion as 'undoing', whereas Keller observes that if two problems are inverses of one another, then one of them has been studied extensively, while the other is newer and the former is called 'direct', while the latter is called 'inverse'. Groetsch observes that if y is the effect of a given cause x when a mathematical model K is posited ($Kx = y$), then, two inverse problems arise: causation (given K and y, determine x) and model identification or specification (given x and y, determine K). This last view is an adaptation of the IPO-model, taught in Computer Science. During the last 5 years, we designed and put in practice and experience based-on inverse problems and their utilization in teachers training courses. This area is strongly connected with active learning, since as Kaur observed, an effective mathematics instruction begins when the instructors take the role of designers with the aim of facilitate active learning activities. In this chapter, we reflect on these experiences to construct a wider theoretical framework for inverse problems in STEM education.

Keywords: inverse problems, STEM education, mathematical models, didactic analysis, problem posing, task enrichment, active learning

1. Introduction

There exists a wide range of learning activities, commonly included under the term active learning (AL). Among them, it should be mentioned the computer-assisted learning, project work, role play exercises, small group discussion, individualized work schemes and collaborative problem-solving.

As Lugosi and Uribe [1] observe, there is no definition of AL, used and accepted by everyone, although it is regarded in general as 'classroom practices that engage students in activities that promote higher-order thinking' [2], which includes the analysis, synthesis and evaluation of the information presented rather than receiving it passively [3].

One of the most used definitions is the one proposed by Freeman et al. [4]: 'Active learning engages students in the process of learning through activities and discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group-work.'

A similar vision is given by Good & Brophy [5], who argued that 'active learning involves providing pupils with an opportunity in which they raise their own questions and use teachers and other resources to pursue self-defined goal'.

In the same way, Kyriacou [6] states that AL 'can be described as the use of learning activities where pupils are given a marked degree of ownership and control over the learning activities used, where the learning experience is open-ended rather than tightly predetermined, and where the pupil is able to actively participate and shape the learning experience'.

Independently of the definition of the concept, in the last decades an increased importance of the role of AL pedagogies was observed, which includes several reported benefits in teaching STEM disciplines [4, 7]. For instance, Freeman et al. [4] conducted a meta-analysis of 225 studies which reports the positive impact of AL pedagogies on student learning in all the STEM disciplines.

On the other hand, as Wieman [8] stated, mathematics has a different behavior, since it is a very traditional discipline in terms of its teaching and, consequently, it shows more resistance than other STEM areas in adopting teaching methods based on research results.

This is a very important issue, since as Kaur [9] mentioned, an effective mathematics instruction begins when the instructors take the role of designers, and they facilitate the AL activities. Then, in order to change teaching practices, it is necessary to start by working with prospective teachers in their formation courses.

For this reason, during the last 5 years, we designed and put in practice an experience based on inverse problems in teachers training courses.

It is important to mention that despite the essential role of inverse problems in many different disciplines, they were almost forgotten [10] and unfortunately, in the traditional Mathematics Education the situation was the same as mentioned in different works [11–13].

One of the consequences of this fact is that an elaborated theoretical framework for this theme was no developed. In an attempt, by Groetsch [11, 12], the IPO model—which is commonly taught in in Computer Science courses and textbooks [14]—was adapted for this purpose. In this article we propose to construct a wider theoretical framework for inverse problems and their utilization in Mathematics Education and so, the adaptations of the IPO model can be considered just as a starting point for this purpose.

This paper reflects on some examples previously described [14–16] and analyses data obtained in a doctoral thesis fieldwork [17], which concern several dimensions of the Didactic Analysis. Nevertheless, in this first attempt for building a theoretical framework for inverse problems and their role in Mathematics Education, we focus only on the cultural/conceptual dimension of Didactic Analysis [18]. It is important to remark that the chapter objectives, methodology and results interpretation are based on this theoretical framework.

Our main purpose is to consider this chapter as a starting point for future deeper developments about inverse problems in Mathematics Education.

2. Inverse problems in mathematics education

In a recent paper by Mason [19], the following excerpts can be read: 'the pervasive mathematical theme of inverse also known as doing and undoing … ',

'… can be used to get an answer (a doing), it is useful to consider the undoing … ' and 'The pedagogic point here is to emphasize the power of formulating and considering "undoing" or inverse problems'. These excerpts show that—at least for some researchers such as Mason—inverse problems are more or less a synonym of 'undoing'.

As Kunze and collaborators mentioned, 'this distinction is not well-defined' [20] but later, in the same paper they state that 'however, in general, a direct problem involves the identification of effects from causes' in full agreement with Mason's viewpoint.

Long time ago, Keller [21] proposed a different point of view when he says that 'We call two problems inverses of one another if the formulation of each involves all or part of the solution of the other'. After that, he argues that due to historical reasons, ' … one of the two problems has been studied extensively … while the other is newer … ' and then, he states that 'In such cases, the former is called direct problem, while the latter is called the inverse problem'. So, in this original point of view, a problem is classified as direct or inverse depending on its own history, more than the inputs and outputs of the proposal.

Outside Mathematics Education, it is possible to find a wider conceptualization, for instance, Groetsch [22] says that 'The type of direct problems we have in mind is that of determining the effect y of a given cause x when a definite mathematical model K is posited: $Kx = y$' and then, he adds ' … two inverse problems may be immediately posed. These are the inverse problems of causation (given K and y, determine x) and model identification (given x and y, determine K)'. Then, it is possible to outline the resolution of a conventionally so-called direct problem, as it is showed in **Figure 1**.

In a previous paper [14], it was observed that there is a strong connection with the IPO model (input-process-output), usually taught in computing and information technology courses. The IPO cycle can be represented as in **Figure 2**.

Now, as Groetsch mentioned, in the causation problems the model and the effect are well known, and the question is about the cause, so this situation can be schematized as can be observed in **Figure 3**.

In model identification problems, both cause and effect are known, and the main question consists in determining the model that gives the expected result. This situation is schematized in **Figure 4**.

It is important to remark that in other works [11, 12], the model identification inverse problems were called 'specification problems'.

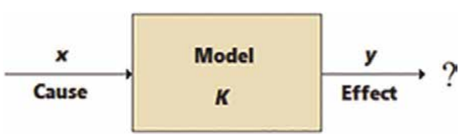


Figure 1.
Scheme for an initial direct problem, following Groetsch ideas.

Figure 2.
IPO model.

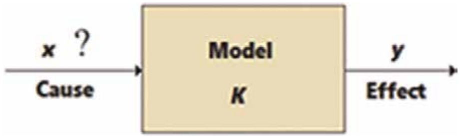


Figure 3.
Scheme for causation inverse problems.

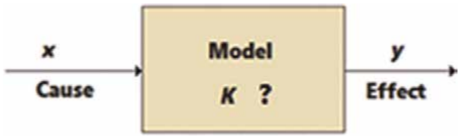


Figure 4.
Scheme for model identification inverse problems.

In a previous paper [13], three different types of inverse problems were described: causation, specification and double-inverse problems. The first two categories correspond to those described by Groetsch, whereas the last one corresponds to those proposals that can be considered at the same time, causation and specification inverse problems. As it was mentioned, the last kind of problems were called 'double inverse problems' by Martinez-Luaces [13].

An interesting example appears in a problems list which was released by PISA a few years ago [23]. One of them is the so-called 'Apartment Purchase' problem which proposes to measure the room sizes of an apartment, as a first approach to calculate the total floor area. Then, the statement adds the following: 'However, there is a more efficient method to estimate the total floor area where you only need to measure four lengths. Mark on the plan above the four lengths that are needed to estimate the total floor area of the apartment'. Since the problem statement asks to measure four lengths in order to obtain the same result of the first approach, it should be considered as a causation inverse problem. On the other hand, in order to choose the correct four lengths, the student must know what to do with those lengths, and so, implicitly it should be considered also as an inverse specification problem.

In the previously mentioned doctoral thesis research [17], it was observed that in several proposals, the student needs to solve a direct problem as a first step, and in a second step, use the obtained result as an input for solving an inverse problem. An interesting example is described in the next paragraphs.

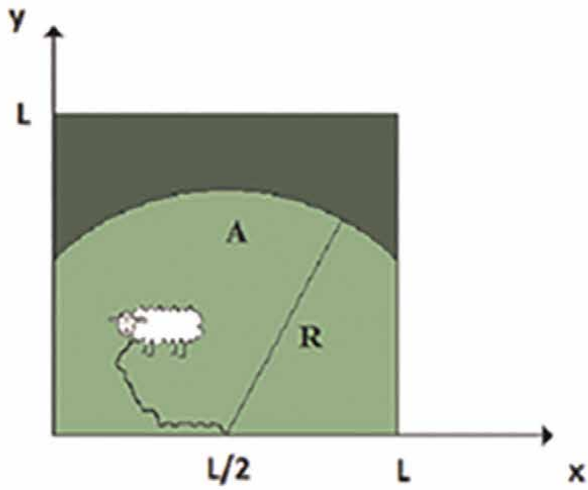
In the fieldwork of this doctoral thesis, the participants—prospective teachers of Mathematics at Secondary School—were asked to reformulate the problem proposed in **Figure 5**.

A prospective teacher proposed an inverse problem (see **Figure 6**), where the field geometry and the stake position are the same of the original statement.

In this proposal, the rope length $R = \frac{L}{3}$ is given, and the statement mentions that the sheep eats all the grass in the accessible area. The problem has several questions, the first one being about R', the rope length that allows the sheep grazing the same amount of grass. After that, other questions ask for the rope lengths corresponding to the third and for the fourth day, once again, in order to eat the same amount of grass of the first day. Finally, the author asks on which day the sheep will not have the same amount of grass to eat?

Problem: accessible area for a sheep in a square field

Let us consider a sheep that grazes in a square field, being L the side length. The sheep is tied with a rope of length R, at the point $(L/2\ ,\ 0)$ as can be observed in the following figure:



In this figure, A represents the area accessible for the sheep, $r = R/L$ is the ratio of the rope length to field side length and $f = A\ /\ L^2$ represents the fraction of the total area accessible for the animal

A possible direct problem consists in asking the students to obtain the fraction of area accesible for the sheep, f, that corresponds to a given value of the ratio r, for instance: Which is the fraction of the total area which is accessible to the sheep if the rope is three-fourths the length of the side of the field?

Figure 5.
Direct problem: Accessible area for a sheep grazing in a field.

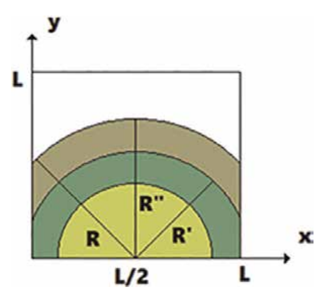


Figure 6.
Sequential inverse problem.

It is easy to observe that this proposal is as a 'mixed inverse problem' with a structure direct-inverse, since firstly it is necessary to solve a direct problem (for the first day) and then, the order of the variables involved is inverted for the following days.

Also, it is not difficult to pose an inverse problem with the opposite structure, i.e. inverse-direct, for instance: For the rope length such that the sheep can eat 50% of the grass, which is the perimeter of the accessible area?

Then, we can describe two subgroups of mixed inverse problems: direct-inverse and inverse-direct.

So, considering the type of inversion, we can describe four groups: causation problems, specification problems, double (both causation and specification) and mixed (direct-inverse or inverse-direct).

It is important to comment that posing inverse statements from an original statement is an important way of enriching mathematical problems. In fact, it is not the only possibility, since modeling can also be considered for task enrichment and of course, both can be combined in the so-called inverse modeling problems, firstly described in a book chapter [24] and a journal paper [25].

Despite the importance of these strategies, inverse problems were almost ignored. For instance, Bunge [10] remarks that 'inverse problems are so difficult and have been so discriminated that the first international congress on the subject was held as late as year 2002' and 'the treaties on the subject can be counted on the fingers of one hand'. In a certain way, this can be considered an unexpected result, since—according to Groetsch [11, 12]—the first mathematical inverse problem was posed almost five centuries ago (a ballistics inverse problem studied by Tartaglia in 1537, which consisted of determining the elevation angle θ for reaching a given shot range R).

The same situation happens in mathematics education, where inverse problems have been ignored, at least in traditional courses [11, 13].

Because of these facts, it is not surprising to observe the absence of a theoretical framework adequate to study the inversion of a statement as a task enrichment strategy in mathematics education. In order to construct this theoretical framework, firstly we need to analyze three related topics: problem posing, task enrichment and Didactic Analysis, the last one being the tool we have chosen for developing this frame.

3. Theoretical framework

As we already mentioned, there are three topics that deserve to be considered to analyze the inversion as a strategy of task enrichment in mathematics education, with'problem posing' being the first one.

3.1 Problem posing

Problem posing is a traditional research area, where important authors such as Brown and Walter [26, 27], English [28, 29], Kilpatrick [30], Silver and Cai [31] produced several milestone papers. When those authors use the term 'problem posing', they include new problems formulations but also reformulations of given statements. These problem posing activities are developed in different ways, with more or less structured formats [28, 29, 31–33].

An interesting case takes place when students need to pose a different problem as part of the solving process of the given one [34]. This situation already appeared in the works of Polya [35], who proposes this possibility as a possible strategy which consists of establishing variants, such as discarding one or more of the original statement conditions.

It is important to remark that problem reformulation is not always a strategy for problem-solving. In fact, in some works problem invention starts from an experience or a situation previously given [32, 33].

It is also possible to combine the last previous approaches, for instance, the students are asked to solve a certain problem, where one of the conditions was changed, and for this reason, it should be considered as a new problem [32].

Brown and Walter [26, 27] proposed a different approach for obtaining new problems, in a strategy that they called 'What if not?'. Their approach consists of changing the problem conditions or restrictions to create a new statement. This strategy may lead to interesting causation/specification inverse problems.

In the work of Stoyanova [36], problem-posing activities are classified into three groups: free, semi-structured and structured. In free problem posing activities, there are no restrictions. In the case of the semi-structured activities, problem posing is based on a previous experience and/or some quantitative information. Finally, in structured problem posing, the original statement problem is reformulated (or some conditions are changed) in order to obtain a new one. In our research a direct problem was given to the participants, and they were asked to propose an inverse reformulation. As a consequence, our fieldwork constitutes an example of structured situation, if the previous classification is followed [36].

3.2 Task enrichment

In our research, problem posing is carried out for tasks enrichment as the final goal. It is important to remark that Lester and Cai [37] stated ' ... teachers can develop worthwhile mathematical tasks by simply modifying problems from the textbooks'.

Other authors, such as Santos and Barmby [38], observed that 'the question of what is meant by enrichment has been an ongoing question for researchers'. Moreover, Barbe [39] says 'an aura of vagueness and confusion seems to surround the term' and 40 years after that, Feng [40] concluded that 'no overall consensus has yet been reached on the definition and nature of enrichment'.

Taking into account the previous comments, what is a rich task that consists more of a description than a precise/exact term definition. An example of this approach is given by Grootenboer's works [41], since he makes a description of 'the key aspects of rich mathematical tasks', like the following:

- Academic and intellectual quality.
- Extended engagement.
- Group work.
- Attention to the diversity, achieved through multiple solution pathways and entry points.
- Connectedness.
- Multi-representational'

After discussions with several teachers, Clarke and Clarke [42] suggested their own list of characteristics for 'rich assessment tasks'. Some of the selected characteristics are the following:

- 'Address several outcomes in only one task.
- Allow all the students to make a start.
- Different approaches and methods can be successfully utilized.
- Encourage students to reveal their own understanding of what they have learned.
- Allow students to make connections between the concepts they have learned.
- Authentically represents the forms in which mathematical knowledge and skills will be used in the future.
- Allow students to transfer knowledge from a well-known context to a new, less familiar one'

As it was mentioned, this list is about 'rich assessment tasks', although it can also be used for 'rich tasks' characterization. Obviously, those characterizations are not a definition of rich tasks, but they reasonably describe what can be expected in task enrichment activities.

As it was mentioned, in our research we consider inversion as another tool for task enrichment, so there is a strong connection between Section 2 and sub-Section 3.2 of this work.

Finally, as Bonwell and Eison [2] remarked 'Though the term "active learning" has never been precisely defined in educational literature, some general characteristics are commonly associated with the use of strategies promoting active learning in the classroom' and particularly, they mentioned the following ones:

- 'Students are involved in more than listening.
- Less emphasis is placed on transmitting information and more on developing students' skills.
- Students are involved in higher-order thinking (analysis, synthesis, evaluation).
- Students are engaged in activities (e.g., reading, discussing, writing).
- Greater emphasis is placed on students' exploration of their own attitudes and values'.

It is easy to observe a strong connection with the characteristics of rich tasks described by Santos and Barmby [38] and Clarke and Clarke [42], and most of these characteristics are present in our fieldwork, described below, in Section 4.

3.3 Didactic analysis

This sub-section is devoted to briefly describe the characteristics of the Didactic Analysis. The didactic Analysis considers 'the structure, levels, dimensions, categories, and components to perform and organize the didactic school mathematics content analysis and how it makes possible the design, implementation and evaluation of teaching and learning activities, corresponding to any specific mathematics subject' [18, 43, 44].

'This description gives rise to a cyclical structure, where the information obtained in each analysis will be essential for a new implementation of the didactic analysis' [45].

The system of components, categories and contents for the didactic analysis of the mathematics school curriculum is briefly summarized in **Figure 7**. **Figure 7** is a remake of Table 2 of a previous paper written by one of the co-authors of the chapter [18].

In our research, didactic analysis was the main tool for the design of the fieldwork and also for the prospective teachers'productions analysis. However, due to length constraints, in this chapter, we analyze only the conceptual content analysis of the proposals, so our focus is placed on the meanings analysis (i.e. the second column of **Figure 7**).

DIDACTICAL ANALYSIS CATEGORIES			
Dimensions			
Cognitive Content Analysis	**Conceptual Content Analysis**	**Instruction Content Analysis**	**Evaluative Content Analysis**
Study object			
Intentionality and learning conditions of school mathematics	Meanings of school mathematics contents	Planning and implementation of mathematics teaching	Evaluation and decision making from learning achievements
Organizers or categories used to perform the content analysis of the curricular dimensions			
1. Learning expectations	1. Conceptual structure	1. Tasks and sequences	1. Modalities and design
2. Limitations	2. Representation systems	2. Classroom work organization	2. Intervention and decision making
3. Opportunities to learn	3. Senses and modes of use	3. Materials and resources	3. Quality indicators
Components of the organizers to analyze didactically school mathematics			
1. Objectives, competencies	1. Formal and Cognitive functionality, emotional, moral, and ethical attitudes	1. Task variables and their functions	1. Functions, regulations, and moments
2. Errors, difficulties, blockages	2. Symbolic, graphic, numerical representations	2. Complexity, creativity, and organization	2. Criteria, instruments, and performance
3. Conditions, demands, challenges	3. Terms, contexts, phenomena, modes of use	3. Characteristics, types, and uses	3. Strategic and comparative studies
Synthesis of main contents			
Task learning structure and coherence	Priority of meanings for teaching and learning	Teaching organization through units	Quality of the achieved learning
Mathematics didactic content obtained as synthesis of elements encompassed by didactical analysis			

Figure 7.
Components, categories and contents for the didactic analysis.

It is important to comment that the meaning concept in this work based on the so-called semantic triangle, which corresponds to an interpretation of Frege's works [46–48]. Following this frame, the mathematical content analysis can be organized into three categories: the contents' structure, the representation systems and the senses or modes of use.

The conceptual structure takes into account the relations of the concepts and the procedures which are involved in the studied content, paying attention to the mathematical structure that includes them.

Representation systems are related to the different forms of 'representing a mathematical content, which can be expressed through signs, graphics, symbols, rules, relationships, conventions, along with their translations into other concepts and conversions according to different procedures'.

Finally, the sense considers the modes of use of the content, which includes phenomena, situations and contexts that give meaning to the mathematical content.

4. Research objectives and methodology of a related study

The general objective of this work consists of characterizing and identifying prospective teachers' strategies to propose inverse problems and reflect on those experiences, in order to clarify and construct a wider theoretical framework for inverse problems in STEM education.

The specific objectives related to the general objective are:

- Characterization of the statements corresponding to the inverse problems reformulations proposed by the participants.

- Characterization of the complexity in terms of the resolution process, corresponding to the inverse problems proposed by the prospective teachers.

- Organize the prospective teachers' proposals and describe and explain the different groups obtained.

For this purpose, the fieldwork of this research was carried out with two groups of prospective teachers at the University of Granada, Spain, during the academic year 2018–2019. The first group of prospective teachers (Group A) had 32 students and the second one (Group B) consisted of 33 students.

It is important to mention that both groups' professors (Moreno in Group A) and Ruiz-Hidalgo in Group B) collaborated with this research, which was developed in two sessions. In the first one, a brief explanation about inverse problems was given to the participants, and also a few examples were discussed. As a homework of this first session, an inverse reformulation of a given problem was requested. That problem was about a swimming pool filled with water, and the reformulation should be considered as a task enrichment of the original statement to be utilized in Secondary School courses.

In the second session, the prospective teachers' reformulations corresponding to the swimming pool problem were analyzed with the whole group. After the swimming pool reformulations discussion, a new problem (the sheep problem, **Figure 5**) was provided for reformulation to the participants as a new homework. There were several differences with the first homework, since the participants were asked to solve the given (direct) problem and then propose an inverse reformulation and solve their own proposal.

It is important to remark that only a few reformulations were discarded because they corresponded to ill-posed problems, or the reformulation cannot be considered an inverse one.

It should be mentioned that several participants proposed two or even three inverse reformulations. Then, there is not a single proposal for each participant, and not all the proposals were considered for this study. As a consequence, the reformulations were coded by responses rather than coding by author.

For the classification of the prospective teachers' reformulations corresponding to the sheep problem, several criteria were taken into account. One of the most important elements analyzed was the kind of inversion, but also possible changes in the geometry, the use or not of external variables, among others criteria, were considered.

As mentioned, firstly, inverse problems were classified in terms of the type of inversion (i.e. causation, specification, etc.). Nevertheless, there are several variants that deserve to be considered, for instance, a general inversion of the given function can be proposed, or an inversion just for a particular value and even an interval inversion, among other possibilities. A similar situation happens with specification inverse problems, where the prospective teacher proposal may ask about parameters interpretation, graphical representations or even a more creative solution without using integrals. Lastly, double and mixed inverse problems were also found among the proposals.

A similar analysis can be made for the item 'changes in geometry', since they can include changes in the shape of the field and/or the stake position as well as other obstacles, such as fences, not included in the original problem.

Considering all these variables, a first classification was made, in order to summarize the information about the reformulations (and their authors) in a table which is partially shown in **Figure 8**.

For this first classification (see **Figure 8**), a list of the variables considered are as follows:

- Type of inversion, as discussed in Section 2.
- Inputs of the proposal (particular or general values, an integral, etc.).
- Outputs of the problem (values, croquis, a process, etc.).
- Changes in geometry (field, stake, fences, etc.).
- Other elements (additional variables and/or change of context).
- Solution (geometrical, numerical, etc.).
- Difficulty (trivial, low, medium and high).

Finally, considering this classification, it was possible to observe three groups of problems, which will be deeply analyzed in the following section.

5. Results

In the previous analysis, we used the following nomenclature: firstly, the capital letters 'PT' indicates that the participant is a prospective teacher. Secondly, the letters are followed by a two-digit number (which corresponds to the student number), and

Group B Sheep Problem	Direct/ Inverse	Type of Inversion	Geometry and Dimensions	Other elements (fences, costs, etc.)	Difficulty	Solution	Input	Output	Comments
PT1	Inverse	Several pointwise inversions	Same Geometry No numbers	No	Greater	Incorrect and incomplete solution	f	r	Incomplete solutions for both direct and inverse problems
PT2	Inverse	Sketch of the region	Same Geometry No numbers	Change of context: cobblestone town area	Conceptual problem	From the integral the curve and the boundary terms are obtained	f (R, L)	Sketch	Gives f (R, L) as an integral
PT3	Inverse	Sketch of the region	Same Geometry No numbers	No	Conceptual problem	From the integral the curve and the boundary terms are obtained	f (R, L)	Sketch	Similar to PT2, but keep the original context
PT4	Inverse	Sketch of the region	Same Geometry No numbers	No	Conceptual problem	Gives the integral and the change of variable. Reverts the substitution and obtains the region	A as integral with its change of variable	Sketch	Gives A as an integral after the change of variable
PT5	Inverse	Tends to ask for the sketch of the region	Same Geometry No numbers	Change of context: irrigation and fertilize part of the field	Conceptual problem	Gives f as a quotient of the integral and L^2 and from that obtains the region	Gives f as a quotient of the integral and L^2	Sketch	Sketch is not requested explicitly, but it arises from the solution

Figure 8.
Example of a first classification of the proposals.

finally, in some cases there is a small letter, which refers to the number of reformulation considered, if it is applicable. As an example, the code PT23c corresponds to a proposal authored by 23rd prospective teacher, and it can be observed that this participant proposed at least three reformulations (here, the one considered is the third).

As it was mentioned, the analysis of the proposals allowed us to identify three groups of problems.

- A first group of proposals related to procedural knowledge (skills).
- A second group that involves graphic representations.
- A third group of proposals related to conceptual and deep knowledge (reasoning and strategies).

5.1 The first group of problems

The first group of problems is formed by prospective teachers' proposals based on the procedural content knowledge. An interesting example is given by the production PT31a, which considers a square field $[0, L] \times [0, L]$, where the sheep is tied at $(L/2, 0)$. The situation is sketched in **Figure 9**.

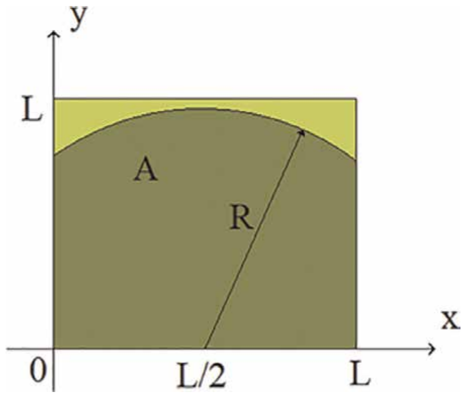


Figure 9.
Sketch corresponding to the proposal coded as PT31a.

The author mentions that $r = \frac{R}{L}$ represents the ratio of the rope length to field side length, and he/she gives the following data: $L = 20m$. and $f = \frac{A}{L^2} = 0.877$ with A being the area accessible for the sheep. The required output of this proposal is the radius R.

In his/her solution, the prospective teacher divides the area A into three parts (a circle sector and two right triangles) as in **Figure 10**.

Since the circumference is given by $(x - L/2)^2 + y^2 = R^2$ for $x = 0$ it is easy to obtain $h = \sqrt{R^2 - (L/2)^2} = \sqrt{R^2 - \frac{1}{4}L^2}$, then each triangle has an area equal to $A(T) = \frac{1}{2}\frac{L}{2}\sqrt{R^2 - \frac{1}{4}L^2} = \frac{1}{4}L^2\sqrt{r^2 - \frac{1}{4}}$. Moreover, the angle θ in those triangles can be obtained as $\theta = \cos^{-1}\left(\frac{L/2}{R}\right)$, and then the angle of the circle sector can be written as: $\alpha = \pi - 2\cos^{-1}\left(\frac{L/2}{R}\right)$. So, the circle sector area is $A(CS) = \frac{\alpha}{2\pi}\pi R^2 = \left[\frac{\pi}{2} - \cos^{-1}\left(\frac{L}{2R}\right)\right]R^2$, which can be written as $A(CS) = \left[\frac{\pi}{2} - \cos^{-1}\left(\frac{1}{2r}\right)\right]R^2$, and then a non-linear equation is obtained: $f(r) = \frac{1}{2}\sqrt{r^2 - \frac{1}{4}} + \left[\frac{\pi}{2} - \cos^{-1}\left(\frac{1}{2r}\right)\right]r^2 = 0.877$.

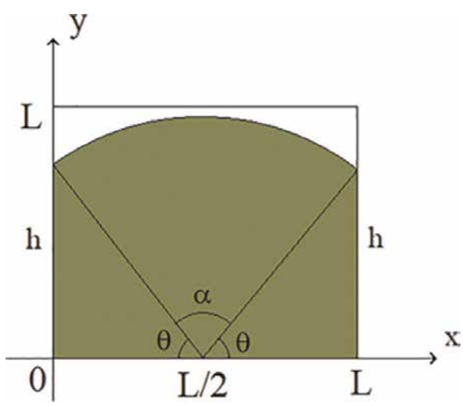


Figure 10.
Sketch corresponding to the solution of the proposal coded as PT31a.

The prospective teacher solves this non-linear equation in r by using Bisection Method, resulting in $r = 0.925$ and finally $R = 18.5$ m.

As it can be observed, the prospective teacher solved his/her proposal without using integrals. As a final remark, it should be mentioned that the problem solution mainly requires procedural knowledge.

5.2 The second group of proposals

This second group is very homogeneous and contains only proposals based on the use of different representation systems. The production PT03 gives an interesting example. This proposal utilizes the same geometry of the given direct problem and adds a different input. The participant proposes that e$f = \frac{1}{L^2}\int_0^L \sqrt{R^2 - (x - L/2)^2}\, dx$, gives the fraction of area where the sheep may graze, where $R,\ L > 0$. A sketch of the situation descripted in the previous statement is the required output of this reformulation.

In his/her solution, the author observes that $y = \sqrt{R^2 - (x - L/2)^2}$, is the equation of a semi-circumference centred in the point $\left(\frac{L}{2}, 0\right)$ with a radius R and L^2 is the area of a square with a field side length L.

From these observations, the requested region can be obtained, and the corresponding sketch is the same as in **Figure 9**.

5.3 The third group of inverse problems

The conceptual content knowledge is fundamental for solving the third group of proposals. For instance, the production coded as PT23c is a representant of this third group. In his/her proposal, the geometry of the field remains the same and the participant asks for the stake position and radius R to maximize the accessible area for the sheep with an extra condition: the animal should not reach the boundary of the field.

Obviously, the stake should be in the centre of the field, i.e. at the point $\left(\frac{L}{2}, \frac{L}{2}\right)$ and the radius proposed by the author is $R = L/2$, as illustrated in **Figure 11**.

It should be mentioned that the proposed solution—sketched in **Figure 11**—is a supreme, not a maximum. The other important remark is that the solution basically requires conceptual knowledge and no geometrical, analytical and/or numerical procedures are necessary to solve it.

6. Discussion

In this first attempt to construct a theoretical framework for inversion as a task enrichment strategy, we focused only in the cultural/conceptual dimension of the didactic analysis. Although we have concentrated on this single dimension, we have observed that there several different ways to classify inverse problems according to the type of inversion, input/output, type and difficulty of the solution and external variables/context changes, among others.

As it was mentioned, considering the type of inversion—which is related to the inputs and outputs of the proposal—we can consider four types of inverse problems:

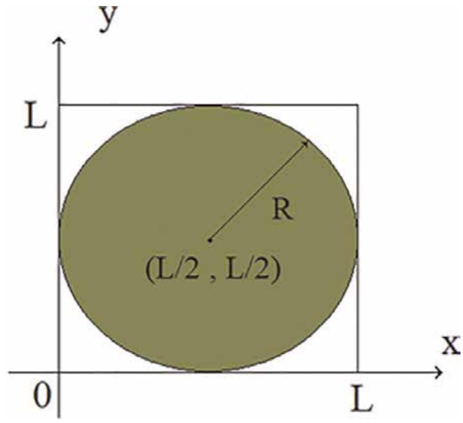


Figure 11.
Sketch corresponding to the solution of the proposal coded as PT23c.

- Causation inverse problems.
- Specification inverse problems.
- Double or dual inverse problems.
- Mixed (divided into two subgroups: direct-inverse and inverse-direct).

Nevertheless, this is not the only possible classification. In fact, this classification does not explain the results obtained in Section 5, where three groups of proposals were observed. Then, in order to explain the previous result, another classification based on the semantic triangle should be considered. Then, we can also classify inverse problems into three groups:

- Conceptual inverse problems.
- Procedural inverse problems.
- Representational inverse problems.

These classifications fit well with the three groups observed in Section 5 and at same time, have a stronger connection with the framework utilized (the didactic analysis).

Another option is to classify inverse problems in pure or combined with another task enrichment strategy, such as modeling. This fact was already observed in previous papers [24, 25] where inverse modeling problems were studied as a different group from other inverse problems.

It should be remarked that in the fieldwork, it was observed that several participants decided to add other variables to the original problem and/or make changes in the context. The external variables can be physical, chemical, biological and economical. One proposal asked for the amount of herbicide and other asked for the amount of fertilizer for the grass, which are chemical external variables. Other participant asked for the velocity of a sheep, which is a physical variable, other one asked for the cost of a fence per unit of length (economical variable) and finally, there was a proposal which requested about the kilograms of grass the sheep can eat per day (i.e. a biological parameter).

About the context changes, for instance, one of the participants (PT22b) considers a goalkeeper that throws the ball in a handball field and which can cover a certain area (instead of a field where a sheep is grazing). Another one (PT27) proposed considering a bush fire without wind. This fire evolves covering concentric circles and the proposal asks for the point where the fire started, knowing that $R = L$ and f is 95.60%. It must be remarked that PT22b and PT27 are just a couple of examples where the context is different from the original proposal.

So, the inclusion or not of external variables and/or the context changes can be used as criteria for a different classification into four groups:

- Inverse problems with the same variables and context.
- Inverse problems where external variables were added.
- Inverse problems in a different context.
- Inverse problems with external variables and a different context.

Another option considers the inputs and outputs of the proposal. These inputs and/or outputs can be particular values (like in PT33, where the area accessible for the sheep is $A = 433.36\, m^2$) or general ones (like in PT27, where $R = L$), a croquis (like PT03, where a sketch of the region where the sheep may graze is requested) or even a process (like PT34, who asks for a criterion that allows distinguishing among different geometries in terms of the grazing area).

Lastly, it should be mentioned that the problem may be classified by analyzing its possible solutions. Then, the proposals can be classified in terms of the difficulty (trivial problems, low, medium and high difficulty) and the mathematics branches involved (analytical, trigonometrical, algebraic and numerical solutions, among others). These possibilities constitute more 'classical' options for classifying the prospective teachers' productions.

As a final comment, it is important to observe that these different criteria do not contradict previous works of other authors such as Groetsch [22] or Mason [19], or our own previous works [14–16]. On the contrary, we believe that they complement those previous works, giving a broader vision of inversion as a strategy for task enrichment.

Author details

Victor Martinez-Luaces*, José Antonio Fernández-Plaza and Luis Rico
University of Granada, Granada, Spain

*Address all correspondence to: victorml@correo.ugr.es

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Lugosi E, Uribe G. Active learning strategies with positive effects on students' achievements in undergraduate mathematics education. International Journal of Mathematical Education in Science and Technology. 2022;**53**(2):403-424. DOI: 10.1080/0020739X.2020.1773555

[2] Bonwell CC, Eison JA. Active Learning: Creating Excitement in the Classroom. ASHE-ERIC Higher Education Report. Vol. No. 1. Washington, DC: The George Washington University, School of Education and Human Development; 1991

[3] King A. From sage on the stage to guide on the side. College Teaching. 1993;**41**(1):30-35

[4] Freeman S, Eddy S, McDonough M, Smith M, Okoroafor N, Jordt H, et al. Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences of the United States of America. 2014;**111**(23):8410-8415

[5] Good TL, Brophy J. Teaching the lesson. In: Slavin RE, editor. School and Classroom Organization. New York: Routledge; 2013. pp. 25-68. DOI: 10.4324/9780203056950

[6] Kyriacou C. Active learning in secondary school mathematics. British Educational Research Journal. 1992;**18**(3):309-318

[7] Fairweather J. Work allocation and rewards in shaping academic work. In: Enders J, Weert E, editors. The Changing Face of Academic Life. London: Palgrave Macmillan; 2009. pp. 171-192

[8] Wieman C. Improving How Universities Teach Science. Cambridge, MA: Harvard University Press; 2017

[9] Kaur B. Towards excellence in mathematics education – Singapore's experience. Procedia-Social and Behavioral Sciences. 2010;**8**:28-34. DOI: 10.1016/j.sbspro.2010.12.004

[10] Bunge M. Filosofía y Ciencia. Problemas directos e inversos [Internet]. 2006. Available from: http://grupobunge.wordpress.com/2006/07/20/119 [Accessed: 2021-05]

[11] Groetsch CW. Inverse Problems: Activities for Undergraduates. Washington, D.C: Mathematical Association of America; 1999. p. 234

[12] Groetsch CW. Teaching-inverse problems: The other two-thirds of the story. Quaestiones Mathematicae. 2001;**24**(1 Supplement):89-94

[13] Martinez-Luaces V. Problemas inversos: los casi olvidados de la Matemática Educativa. Acta Latinoamericana de Matemática Educativa. 2011;**24**:439-447

[14] Martinez-Luaces V, Fernández-Plaza JA, Rico L, Ruiz-Hidalgo JF. Inverse reformulations of a modelling problem proposed by prospective teachers in Spain. International Journal of Mathematical Education in Science and Technology. 2021;**52**(4):491-505. DOI: 10.1080/0020739X.2019.1683773

[15] Martinez-Luaces V, Rico L, Ruiz-Hidalgo JF, Fernández-Plaza JA. Inverse modeling problems and task enrichment in teacher training courses. In: Nata RV, editor. Progress in Education. New York: Nova Science Publishers; 2018. pp. 185-214

[16] Martinez-Luaces V, Fernández-Plaza JA, Rico L. Inverse modeling problems in task enrichment for STEM courses. In: Fomunyam KG, editor. Theorizing STEM Education in the 21st Century. London: IntechOpen; 2020. pp. 29-44. DOI: 10.5772/intechopen.89109

[17] Martinez-Luaces V. Posing Inverse Modeling Problems for Task Enrichment in a Secondary Mathematics Teachers Training Program. University of Granada: Granada; 2021

[18] Rico L, Ruiz-Hidalgo JF. In: Shimizu Y, Vithal R, editors. Ideas to Work for the Curriculum Change in School Mathematics. Tsukuba, Japan: ICMI Study; 2018;**24**:301-308

[19] Mason J. How the theme of 'doing and undoing' applied to the action of exchange reveals overlooked Core ideas in school mathematics. Mathematics. 2021;**9**(13):1530. DOI: 10.3390/math9131530

[20] Kunze H, La Torre D, Ruiz GM. Optimization methods in inverse problems and applications to science and engineering. Optimization and Engineering. 2021;**22**:2151-2158. DOI: 10.1007/s11081-021-09688-y

[21] Keller JB. Inverse problems. The American Mathematical Monthly. 1976; **83**(2):107-118. DOI: 10.1080/00029890.1976.11994053

[22] Groetsch CW. Inverse Problems in the Mathematical Sciences. Berlin: Springer Science & Business Media; 1993. p. 154. DOI: 10.1007/978-3-322-99202-4

[23] OECD. PISA 2012 released mathematics items. 2013. Available from: https://www.oecd.org/pisa/pisaproducts/pisa2012-2006-rel-items-maths-ENG.pdf [Accessed: 2021-02]

[24] Martinez-Luaces V. Inverse-modelling problems in chemical engineering courses. In: D'Arcy-Warmington A, Martinez Luaces V, Oates G, Varsavsky C, editors. Proceedings of Delta 07. El Calafate, Argentina: ISC-Delta; 2007

[25] Martinez-Luaces V. Modelling and inverse-modelling: Experiences with O.D.E. linear systems in engineering courses. International Journal of Mathematical Education in Science and Technology. 2009;**40**(2):259-268. DOI: 10.1080/00207390802276291

[26] Brown SI, Walter MI. The Art of Problem Posing. 3rd ed. Mahwah, NJ, USA: Lawrence Erlbaum Associates; 2005. p. 888

[27] Brown SI, Walter MI. Problem Posing. Reflections and Applications. New York: Psychology Press; 2014. p. 360

[28] English L. The development of fifth-grade children's problem-posing abilities. Educational Studies in Mathematics. 1997;**34**:183-217. DOI: 10.1023/A:1002963618035

[29] English L. Children's problem posing within formal and informal contexts. Journal for Research in Mathematics Education. 1998;**29**:83-106. DOI: 10.2307/749719

[30] Kilpatrick J. Problem formulating: Where do good problems come from? In: Shoenfeld A, editor. Cognitive Science and Mathematics Education. New Jersey: Lawrence Erlbaum Associates; 1987. pp. 123-148

[31] Silver E, Cai J. An analysis of arithmetic problem posing by middle school students. Journal for Research in Mathematics Education. 1996;**27**(5):521-539. DOI: 10.2307/749846

[32] Silver EA. On mathematical problem posing. For the Learning of Mathematics. 1994;**14**(1):19-28

[33] Silver E. Fostering creativity through instruction rich in mathematical problem solving and problem posing. ZDM-Zentrallblatt fur Didaktik der Mathematik. 1997;**29**(3):75-80. DOI: 10.1007/s11858-997-0003-x

[34] Silver E, Mamona-Downs J, Leung S, Kenney P. Posing mathematical problem: An exploratory study. Journal for Research in Mathematics Education. 1996;**27**(3):293-309. DOI: 10.2307/749366

[35] Polya G. How to Solve it? A New Aspect of Mathematical Method. 2nd ed. Princeton, NJ: Princeton Science Library; 1957. p. 252

[36] Stoyanova E. Problem posing in mathematics classrooms. In: Mcintosh A, Ellerton N, editors. Research in Mathematics Education: A Contemporary Perspective. Perth, W.A: MASTEC, Mathematics, Science and Technology Education Centre, Edith Cowan University; 1998. pp. 164-185

[37] Lester F, Cai J. Can mathematical problem solving be taught? Preliminary answers from 30 years of research. In: Felmer P, Pehkonen E, Kilpatrick J, editors. Posing and Solving Mathematical Problems. Cham, Switzerland: Springer International Publishing; 2016. pp. 117-135

[38] Santos S, Barmby P. Enrichment and engagement in mathematics. In: Joubert M, Andrews P, editors. Proceedings of the British Congress for Mathematics Education. 2010. pp. 199-206

[39] Barbe WB. What is enrichment? In: Magary JF, Eichorn JR, editors. The Exceptional Child: A Book of Readings. New York: Holt, Rinehart and Winston Inc; 1960. pp. 199-206

[40] Feng WY. Conceptions of enrichment. In: Cambridge Education Research Annual Conference (CamERA). England: University of Cambridge; 2005

[41] Grootenboer P. Rich mathematical tasks in the Maths in the Kimberley (MITK) project. Crossing Divides. 2009; **1**:696-699

[42] Clarke D, Clarke B. Using rich assessment tasks in mathematics to engage students and inform teaching. Background paper for seminar for upper secondary teachers, Stockholm, September [Internet]. 2002

[43] Rico L, Lupiañez JL, Molina M, editors. Análisis Didáctico en Educación Matemática: metodología de investigación, formación de profesores e innovación curricular. Granada: Comares; 2013

[44] Rico L, Moreno A, editors. Elementos de didáctica de la matemática para el profesor de Secundaria. Madrid: Pirámide; 2016

[45] Rico L, Fernández-Cano A. Análisis didáctico y la metodología de investigación. In: Rico L, Lupiañez JL, Molina M, Molina M, editors. Análisis didáctico en educación matemática. Metodología de investigación, formación de profesores e innovación curricular. Comares: Granada; 2013. pp. 1-22

[46] Castro-Rodríguez E, Pitta-Pantazi D, Rico L, Gómez P. Prospective teachers' understanding of the multiplicative part-whole relationship of fraction. Educational Studies in Mathematics. 2016;**92**:129-146. DOI: 10.1007/s10649-015-9673-4

[47] Fernández-Plaza JA, Rico L, Ruiz-Hidalgo JF. Concept of finite limit of a function at a point: Meanings and specific terms. International Journal of Mathematical Education in Science and Technology. 2013;**44**(5):699-710. DOI: 10.1080/0020739X.2013.805887

[48] Martín-Fernández E, Ruiz-Hidalgo JF, Rico L. Significado escolar de las razones trigonométricas elementales. Enseñanza de las ciencias: revista de investigación y experiencias didácticas. 2016;**34**(3):51-71. DOI: 10.5565/rev/ensciencias.1871

Chapter 4

Mathematical Creative Model: Theory Framework and Application in Mathematics Learning Activities

Subanji Subanji and Toto Nusantara

Abstract

One of the most crucial abilities in the face of global issues is creativity. Because of this, research on creativity is always intriguing, especially in the context of mathematics education. Two investigations pertaining to original mathematical models are presented in this paper. The first study had 72 primary school instructors who took part in enhancing mathematical learning. Participants given open challenges with cube net material. Out of 137 high school students that consistently responded, 124 were included in the second study. Two descriptive statistical issues affect secondary school students. After a thorough interview to understand the subject's thought process, the results of the problem-solving process were used to support the subject's stance using an original mathematical model. Impersonation, adaptation, and building make up the creative model's structure. The findings demonstrate the consistency of mathematical creativity model properties. The subject only imitates a successful routine method due to the level of imitation. According to the characteristics of the level of modification, the subject is able to alter the methods discovered in order to meet the difficulties at hand. The hallmarks of the creation level are that they develop novel, rational, and methodical approaches to problem-solving. Based on the findings of this study, a new method of learning mathematics was devised. The open-ended activities that have been packed into the form of a mathematical tree are utilized, together with the strategic approach to problem-posing.

Keywords: mathematical creative model, mathematics learning activities

1. Introduction

In order to prepare future generations for the challenges of a globalized society, creativity is crucial. Pioneers and entrants to change and progress can only be creative people. The foundation of artistic, technological, and scientific advancement is creativity. The advancement of information technology as a creative human endeavor that can make solving problems easier. Numerous academics have looked into the value of creativity, notably in the teaching of mathematics. This is consistent with the essence of mathematics education, which entails learning by fostering critical thinking and reasoning in order to become an effective problem-solver. Consequently, it is applied in mathematics to develop higher-order thinking skills (HOTS). One of HOTS's most important components is creativity. The greatest degree of cognition, in accordance with the revised Bloom's taxonomy, is creativity. The ability to be creative makes one an excellent problem solver and innovator.

Studying creativity is always fascinating, particularly when it comes to the realm of math instruction. The importance of creative research in mathematics education and the expansion of the scope of study were emphasized by Joklitschke et al. [1]. This supports a study by Schindler & Lilienthal [2] that emphasizes the importance of student creativity processes in mathematics education research. The development of creative mathematics is followed through open challenges to show how creative research progresses from creative outputs to creative processes. Multiple Solution Tasks (MSTs) were employed by Schindler & Lilienthal [2] in order to foster and assess students' mathematical creativity, particularly the creative process.

In addition to the usage of open assignments, problem solving can be used to stimulate creativity. Problem-based research (PPI) is a method used by Leikin & Elgrably [3] to examine how creative solutions to mathematical issues are produced. According to their research, a stronger creative process does not always result in a stronger creative product and a higher degree of strategic originality. But it relates to the end product of creativity. Here, the two distinct aspects of cognitive processing connected to creative problem-solving are the creative outcome and the creative process. Three aspects of creativity—fluidity, flexibility, and creativity—are the foundation of their research. Their findings indicate that problem generation and problem solving cannot be separated when someone completes PPI creativity challenges.

Schoevers et al. [4] investigated into the connection between mathematical problem-solving in elementary schools and creative thinking. There are four closed routine issues, six closed non-routine problems, and four open non-routine problems using geometry tests (multiple solution problems). The findings indicate that creativity plays a significant role in predicting how well children will succeed on various geometry problems. However, it was more closely connected with how well students performed on open tasks that were not routine, which shows that kids with more creativity were more successful at solving geometry problems.

Numerous research, spanning from the classification of creative thinking components to the level of creativity, have been conducted as a result of the significance of creativity. The classification of creativity in this study is not based on the cognitive process by which it is formed, though. The mathematical creative model is a development of Subanji et al. [5] and is based on the mental process of creative formation. The context of issues involving mathematical thinking is examined in their research. Having unique qualities like reason and logic, mathematics is a fundamental science. The rationale behind using the framework of mathematical reasoning is that it calls for higher-order thinking, which is necessary for creative thinking. On the basis of the properties of the mathematical content, a study of argumentation in the field of mathematics was conducted. It is known as covariational reasoning in the context of building graphs, algebraic reasoning in the context of solving comparative problems, proportional reasoning in the context of solving analogy problems, analogical reasoning in the context of solving controversial problems, and controversial reasoning in the context of solving controversies. In this study, a problematic mathematical problem—one that defies the preexisting framework of thought—is the focus of the mathematical problem that is being used. The controversial question was picked because it was good at causing cognitive conflicts, or dis equilibration in Piaget's terminology, which pushes for higher order thinking, particularly creative thinking. The development of mathematical creative models is based on the cognitive process of the formation of creative thought in solving mathematical problems. This creative model is important for research because it can be used to develop mathematical thinking in the correct way based on cognitive processes. The learning of mathematics is the learning of reason and logic, especially the formation of HOTS, which includes: analysis, assessment, and creation (creative). According to Bloom's taxonomy, creativity is the highest level of thinking. Whoever can reach the level of creative thought will become a good problem-solver, initiator and innovator. The importance of creativity has led to various studies, from the classification of elements of creative thinking to creative thinking levels. Researchers have assessed the originality, fluidity, and adaptability of pupils' problem-solving to assess their creativity [6, 7]; Additionally, Kattou et al. [6] discovered a link between creativity and mathematical aptitude. Four stages—preparation, incubation, illumination, and verification—were identified by Sriraman [8] after studying the creative processes of five mathematicians.

Learning mathematics requires a lot of creative thinking. Numerous academics looked at the elements of fluidity, flexibility, and invention in addressing open questions to determine how creatively kids thought [6, 7]. The number of alternative solutions to a given problem is considered in the assessment of fluency. The capacity to modify several concepts to generate various means of completion is related to flexibility. Originality is the generation of fresh approaches to challenges. Additionally, the structure of the connection between mathematical prowess and creativity was examined by Kattou et al. [6]. According to their research, pupils fall into one of three categories based on their mathematical prowess: those with low, medium, or high mathematical prowess. Sriraman [8] conducted a study of five mathematicians to ascertain the characteristics of the creative process, and the results showed that the creative process of mathematicians followed the four stages of the Gestalt model, namely the preparation-incubation-illumination-verification. However, the mathematical creativity of the three categories also varied, so it was found that students with the highest scores on the math test were also the most creative. In this situation, learning mathematics, especially statistics, can involve the creative process.

The basic and secondary mathematics curricula include statistical content on data analysis and probability, according to the National Council of Teachers of Mathematics [9]. This demonstrates the significance of statistics in mathematics. The mathematics curriculum in Indonesia similarly includes statistical components from primary to higher education. This is because statistics have a wide range of applications in the fields of law, medicine, agriculture, and economics. The sciences of data collection, analysis, presentation, interpretation, and decision-making are known as statistics [10]. There are two types of statistics: descriptive statistics and inference [11]. Measurements of concentrations and dispersion fall within the purview of descriptive statistics, whereas hypothesis tests that can extrapolate from samples and make generalizations about population features go under inference statistics. In this study, descriptive statistics were utilized to present data visually. The kind of qualitative or quantitative data also affects the type of diagram [12]. For instance, histograms, line graphs, stem and leaf charts, and pie charts are frequently used to depict the distribution of qualitative data (on a nominal or ordinal scale) (interval or ratio scale). In this situation, understanding information requires the capacity to read graphs and diagrams.

Sharma [13] examines and discusses how pupils comprehend the information in graphical forms such as tables and bar graphs. According to his research, a lot of pupils employ instinctive and experience-based tactics. Further research by Aoyama [14] into the hierarchy of students' interpretations of graphs revealed several challenges younger students face when considering open-ended questions due to their lack of prior learning. According to Mann & Lacke [10], descriptive statistics include techniques for gathering data, showing it, and summarizing it using tables, graphs, and summary measures of concentration. Since there are so many graphs used to depict data in written and electronic media, it is important to comprehend how the graph might be used to interpret numbers. In order to solve the measure of concentration problem, students used the descriptive statistics they had learned in this course to portray data as line graphs and bar charts. This study's problem is an open one that has to be solved with original thought.

To address common difficulties, creative thinking is necessary. Mathematical exercises can foster the development of creative thinking [8, 13, 15–19]. Logic-based concepts, structures, and interactions are a foundational part of mathematics, according to this theory. Using logical and methodical justifications, the truth of mathematics is established. Numerous mathematical tasks are performed through logical and methodical thought processes, including as formulating and testing hypotheses, seeking parallels, drawing connections, creating representations, creating generalizations, proving theorems, and ultimately solving problems. High-level thinking calls for pupils to exercise both critical and creative thought when completing these mathematical assignments.

Creative thinking occurs in mathematical activities, called mathematical creative thinking, and is often associated with problem solving. [9, 15, 20, 21]. The National Council of Teachers of Mathematics [9] proposes to give students difficult problems that can promote their mathematical creativity. This can be done because problem solving enables students to improve their creativity skills through various solutions. Baran et al. [15] discovered that mathematical creativity can be seen in problem-solving abilities, especially in open mathematical situations. Chamberlin & Moon [20] discovered creativity in the thinking processes of mathematicians related to the solution of non-routine problems.

Mathematical creative thinking, which happens when performing mathematical tasks, is frequently linked to problem-solving [9, 15, 20, 21]. Giving pupils challenging tasks that can foster their mathematical creativity is a suggestion made by The National Council of Teachers of Mathematics [9]. This is possible because problem solving gives kids the chance to develop their creativity through a variety of solutions. Mathematical creativity can be evident in one's ability to solve problems, particularly in scenarios involving open-ended mathematics, according to research Baran et al. [15]. Chamberlin & Moon [20] found that the way mathematicians solve non-routine problems involves creativity. Therefore, one part of mathematical creativity is problem solving. Additionally, Beghetto & Karwowski [22] contend that teachers might accomplish this balance by turning some normal tasks into nonroutine difficulties. Routine practice must be matched with innovative and creative approaches. Can be achieved by teachers by changing some routine tasks into nonroutine problems.

Researchers have investigated the use of mathematics to foster creativity [15, 19, 23, 24]. To predict students' creativity in solving mathematical problems, Lin & Cho

[24] created a model of creative problem-solving abilities. According to gender, Baran et al. [15] discovered a correlation between creativity and mathematical aptitude. Voica & Singer [19] looked at the creativity of math-gifted children and discovered that those who had a strong grasp of the subject had good inventiveness. Using Model-Eliciting-Activities, Coxbill et al. [23] developed and tracked students' mathematical inventiveness (MEASs). Sheffield [25, 26] has conducted research on the value of fostering and enhancing pupils' creativity as they study mathematics. Understanding mathematics can aid in the development of students' creativity [27]. Some of these studies highlight how crucial it is to research students' mathematical creativity.

The other aspect of the study of creative thinking is examined in this article, specifically the creative model, which is founded on the cognitive process of creative formation.

2. Creative model framework

General creativity includes creative mathematical thinking. It is possible to think of creativity as a process of thought that involves original concepts and ideas [28, 29]. Numerous methods, such as studies of creative outputs and creative processes, can be used to examine creative mathematical thinking [3]. The cognitive process that results in creative thinking is referred to as the creative process. A type of creativity whose focus is mathematics is known as mathematical creativity. Therefore, the development of mathematical creative frameworks is founded on general creative frameworks that consider the properties of mathematical structures. In general, creativity occurs in daily life and can be divided into three categories: creation, modification, and imitation.

When someone wishes to create a product that replicates an already existing product, they start at the lowest level, which is later referred to as a creative model of imitation. The process of invention in this instance is restricted to product imitation. Even if they just copy, imitators nevertheless engage in the creative process since they consider ways to make their creations more affordable than the originals. Simple cognitive processes are used in the creative model of imitation. This imitation creativity model in mathematics is influenced by the learning process, which only prioritizes procedures. Students can solve a problem if the procedures are known.

The Creative Model of "modification" refers to the second level, which is a change. This level is reached when a product is transformed into a new one by looking at its "functions, advantages, and forms." The highest level is creation, which is referred to as the "creation" model. This occurs when someone creates a new product without first considering the associated items that already exist.

A mathematical creative model is one that can be created from a general creative model in the context of mathematics. The general creative, mathematical creative models categorize creativity into three levels (three): imitation (imitation), modification (change), and creation. **Table 1** below provides the conceptual framework for the construction of general creativity-based mathematical creativity models.

The core of the imitation level creative model is the principle of making products with the same design and functionality but at a cheaper cost. You must cut or substitute other less expensive materials in order to lower the cost of the product. A creative imitation model produces a varied grade of goods as its outcome. The definitions of "original product," "super replica product" (quality 1), "medium replica" (quality 2), and "low replica" (quality 3). Models for creative modification are based on the idea of modifying items to make them more cozy, lovely, alluring, and practical. The process of modifying a product's function, benefit, or form results in a new product with additional functions, one that is more useful, and one with a more appealing shape. This process is the basis for the creative modification model. Finding new ideas, thinking, and solutions to issues is the foundation of creative creation models.

In the context of mathematics, imitation levels, i.e., imitate only the facts or techniques obtained when completing problems/tasks. The methods he was able to find in this situation varies from the most basic to the most sophisticated. The technique of generating new challenges or tasks by adjusting the data, graphics, and procedures obtained is known as modification level mathematical creative modeling. The process of constructing or resolving issues by gathering data, making graphs, or coming up with novel problem-solving techniques constitutes the creation level of the mathematical creative model.

3. Method

The research develops a model of creativity based on the idea that creativity is seen as a cognitive process of creative formation. The first research was carried out on teachers of elementary schools attending cube net materials training, and on students of secondary schools undergoing descriptive statistics training. The paper describes only part of the two studies of the creative model. The first study was a creative model for 72 primary school teachers who participated in mathematics learning courses jointly held by Universitas Negeri Malang and the PT. Pertamina. This teacher-powering cooperation lasted 6 years, but the data sources used in the study were only last year. The training is conducted every year at three strengthening stages and in two classroom exercises. The first and second strengthening phases took 10 days (80 hours) to complete. The third phase of strengthening was 5 days (40 hours) long. Learning practice is conducted in intervals between strengthening stages. There are materials to solve mathematical problems at each stage of the reinforcement. Among the problems-solving materials, the most interesting are cube net materials. This material is always chosen by the participants as the most interesting material, because it is related to real life, different from what is usually presented to students, the problem is open, makes sense, and is very challenging. Then, the process of solving the problem of cube net material and conducting an in-depth interview was used as a data tool to investigate creative models.

Creative models	General creativity	Mathematical creativity
Imitation	• Imitate a product with a simpler process or lower cost • Imitate a production process to produce another product that is better	• Just imitate similar forms of settlement to solve the problems at hand
Modification	• Changing the function/benefit/form of a product so that it becomes a new product	• Changing the problem/data/solution procedure to obtain a more efficient solution
Creation	• Create new works that are more interesting, more practical, and have more functions	• Develop new settlement procedures according to the demands of the problem

Table 1.
Mathematical creative model.

The second study was the creative model of 137 secondary students to solve problems in descriptive statistical material. Students received two open problems relating to descriptive statistical materials, the tea sale problem and the math test results problem. To assess the consistency of the level of student creative models, two problems were presented. Of the 137 students, 124 were re-examined (59 boys and 65 girls). From the process of solving statistical descriptive problems, followed by tracing the process of cognition through in-depth interviews, and used to justify the position of the subject based on the creative model.

4. Results

The results of the research are presented on the basis of two studies, namely the mathematical creative model for solving the problem of cube nets and creative mathematical model to solve descriptive statistical problems.

4.1 Creative model of cube net problem solving activities

This study included 72 primary school teachers participating in mathematics education training. One of the materials presented is a mathematical problem solved with a cube net. The topic was given the following problem about applying cube networks.

Cake box company

Pak Romli is the head of the company "MAKMUR" which produces cake boxes. Pak Romli always thinks how to get big profits. Several attempts have been made: first, to make various models of boxes that may be liked by buyers and secondly to make savings, namely to produce as many boxes as possible from the same material. Sir. Regarding the first attempt, Pak Romli has conducted a survey of 200 cake sellers, the result is that 70% of the respondents liked the cube-shaped cake box on the grounds that it could contain more. To save money, Pak Romli conducted an experiment by making a box and opening it with each side still intertwined (not separated from each other), which are often called cube nets, as shown in **Figure 1***.*

*To make an efficient cube design, Pak Romli prepared a "cube material" (***Figure 2***) in the form of a sheet of paper that has been completed with unit squares. Then Pak Romli*

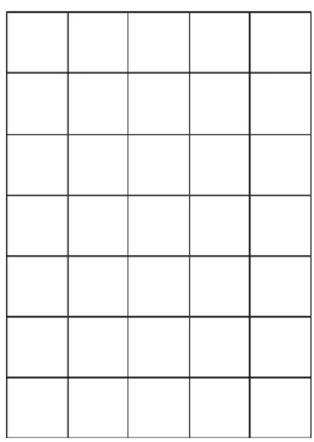


Figure 1.
Net cube.

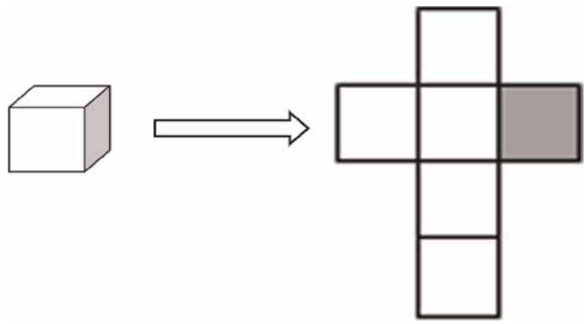


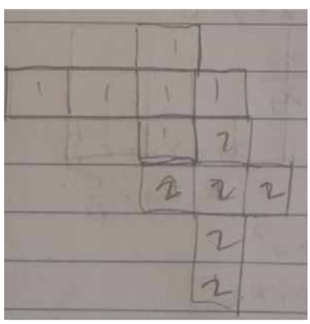
Figure 2.
Cube material.

thought about how to use a piece of paper to make as many cubes as possible (and as little paper wasted as possible). You are asked to help Pak Romli efficiently design cube nets from **Figure 2** *material (the cubes produced are the most and the paper is wasted the least)! Determine the maximum number of cubes that can be made!*

Research subjects participating in mathematics learning training had the characteristics of 11 early-career teachers (1–3) and 61 high-career teachers (4–6). Of the 72 subjects, 9 (13.50%) were imitation levels, 34 (47.2%) were modifications levels, and 29 (40.28%) were creativity levels. Each level's description is given as follows.

4.2 Imitation level

At the level of imitation, the object only imitates Pak Romli's cube nets and immediately places the cube nets on the cube material sheet.

Problem solving activity	Subject answer	Imitation form
• Counting the number of unit squares on the cube material horizontally as much as five and vertically as much as 7, while the existing nets are four long and three wide. This means that they can be arranged horizontally and vertically. • The number of cube nets obtained is 2		Imitate the cube nets given in the problem and immediately arrange them on a 7x5 cube material

One can see from the subject's response on the level of imitation that the subject only copies the information provided in the question and keeps the relevant cube materials structured. The subject does not take into account various cube net configurations; rather, what is noteworthy is the subject's cognition, which copies the provided material and simply modifies its position to produce consequences. To further understand the subject's position at imitation level, the researcher conducted an interview.

Q: What is your comment on this matter?

S: The problem is contextual and very challenging.

Q: Have you ever had a question like this?

S: Never.

Q: What do you think when you face a problem like this?

S: Since there are already nets of the cube, then I make the same nets with different positions so that the solution is immediately obtained.

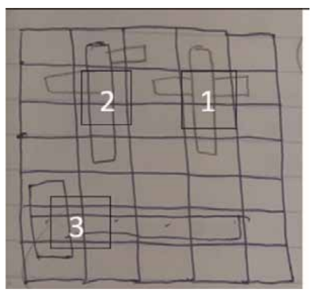
Q: In your opinion, are there other forms of nets?

S: There should be, but I do not remember because all this time I have been teaching the lower class (grade 2), so I do not know the cube nets by heart.

From the interviews, the subject seems to "imitate" the net only in different horizontal and vertical positions. This may occur because the subject is taught in a lower class and the net material of the cube is given in 5' class.

4.3 Modification level

At the level of modification, the topic changes the shape of the problem's cube net by changing the position of one unit square. In addition to (1), you can change one step of the left square to (2). Modification from (1) to (3) is done by shifting the topmost square to the bottommost position. Next is the position adjustment.

Problem solving activity	Subject answer	Modification form
• change the shape of the net (1) by shifting one unit square at the wing position to (2) and shifting one unit square from the top to the bottom so that it becomes (3) • the number of cube nets obtained is 3.		Modify the cube nets given in the problem, so that they can be arranged on a 7x5 cube material

To further explore the creative model of the subject in modification level, a task-based interview was conducted.

Q: What is your comment on this matter?

S: This problem makes sense but is not easy to solve.

Q: Have you ever had a question like this?

S: Never. Usually the problem of cube nets is limited to their type.

Q: What do you think when you face a problem like this?

S: I am curious. At first I thought it was simple, but after thinking about it, it's not easy, even though I've got this answer, I am still curious.

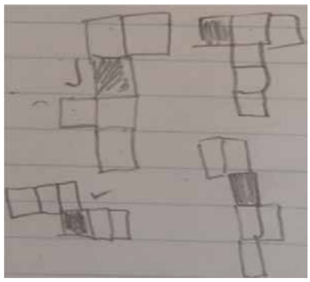
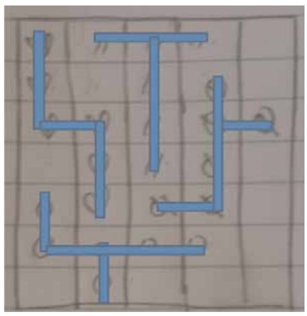
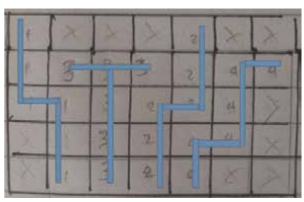
Q: How do you get the nets of cubes (2) and (3)?

S: I changed it at the same time wondering whether the result of the conversion is still a net of a cube. And after I imagined the results of the conversion were cube nets. Next, I arrange like that position and get three closed cubes.

From the interview, it appears that in solving the problem, the subject begins by "changing" the cube nets that are already known in the problem into several different cube nets and then arranging them in the cube material provided.

4.4 Creation level

At the level of creation, integrative thought focuses on the shape of the 7x5 cube. The subject is “How to cover a cube material as many cube nets as possible and ignore the nets in the problem. The topic was explored and was successfully created by making a “new” cube net that allowed for more cube material configuration.

Problem solving activity	Subject answer	Creation form
• Explore and create some “new” cube nets, as well as define the bottom side by shading.		Create new cube nets that are different from the ones that have been exemplified.
• arrange the “new” cube nets on a 7x5 cube material with several different alternatives; • rethink the rest of the unit cube to make an open cube; • grouping the arrangement alternatives whose remainder can still be used for open cubes and those that cannot be used for open cubes; • conclude that the most efficient arrangement is the number of closed cubes that can be made as many as four and one open cube.	 **so** 	Make several alternative arrangements of different cube nets, choose the most cubes, construct the rest to make the cube open.

To further investigate the characteristics of creativity models at the creation level, task-based interviews were conducted. The interview focused on the process of constructing answers for the subject.

Q: What is your comment on this matter?

S: I never thought of a problem like this, because when teaching cube nets, we only showed several alternatives for cube nets.

Q: Have you ever had a question like this?

S: Never. This problem inspired me to connect math material with life.

Q: What do you think when you face a problem like this?

S: I realized that to teach mathematics it is necessary to think about the use of mathematics in life. Therefore, so far, I teach cube nets only procedures, so I feel guilty.

Q: How would you construct an answer like this?

S: At first, I thought this problem was simple, but it turned out to be complex. I started with a 7x5 cube material, while one cube only needed six unit squares. I suspect that five nets of the cube can be made.

Q: Why do not you use the cube nets that have been given?

S: I suspect that the exemplified web cannot produce many cubes. It was a hindrance, so I ignored it. And I created new cube nets alternatives.

Q: What are your next steps?

S: I arrange cube nets into cube materials with various alternatives. It turns out that the maximum number of cubes that can be made is four. Then I was still thinking again, the rest, it turns out that there are some that cannot be made into cubes anymore, but there are also some that can be made into open cubes. I think that the open cube is still of some use, too. Finally, I conclude that the most efficient arrangement is four closed cubes and one open cube, there are still six unit squares left but randomized, no more cubes can be made. I am also thinking further, what if the size of the cube material is different (not 7x5), but I have not tried.

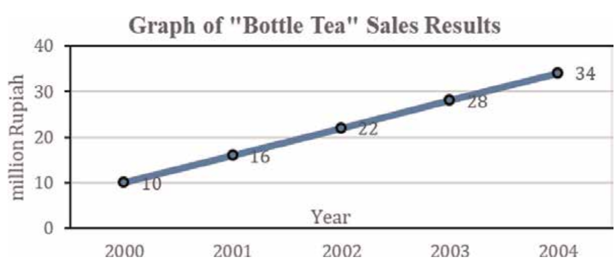
The results of the interviews show that the creation level topics continue to think about the creation of the most effective cube. In fact, the topic does not stop with the solution he is given, but thinks he wants to change the size of the cube material so that it's a little wasted.

5. Mathematical creative models on descriptive statistical problem-solving activities

This section provides students with the level of creative model to solve statistical descriptive problems [5]. The study was conducted with 137 secondary students and provided two open problems with descriptive statistical materials, namely problem 1 (tea sales) and problem 2 (mathematical test scores). To see the consistency of the level of creative models of students, two problems have been given. Of the 137 students, 124 (59 boys and 65 girls) were consistently re-recognized.

Problem 1. Tea Sales

A shop sells two soft drinks "tea bottle" and "tea box" from 2000 to 2009. The graph below shows the sales of the drink "Teh Botol" for 5 years. Make a line graph of the sales results of "Teh Botol" and "Teh Kotak" in one graph so that in 2009 the sales of the two soft drinks were the same.



Problem 2. Math Exam Score

A Mathematics teacher teaches in two classes, namely classes A and B. **Table 1** *below is the result of the Mathematics score for class A. The number of students in class B is 35 people. Make a bar chart of the Grade B Mathematics grades (Scores 0–100) if the mean, median, and class B mode scores are greater than the class A mode.*

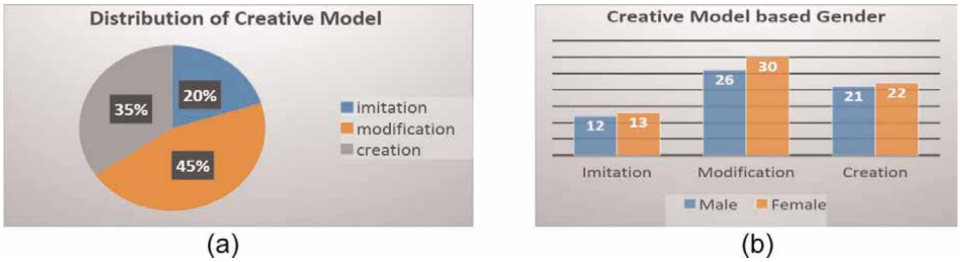


Figure 3.
(a) Distribution of creative models; (b) creative model by gender.

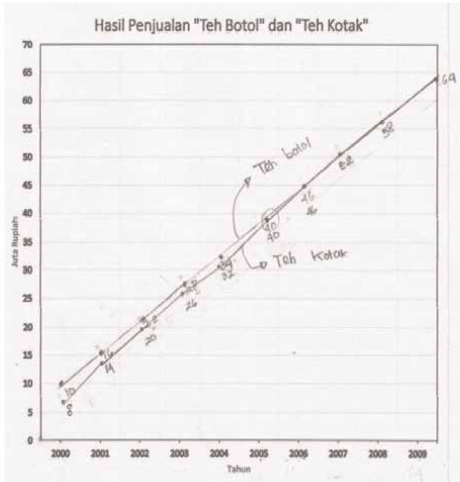
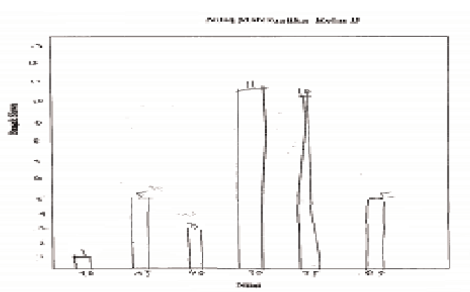
One Hundred and Twenty four people responded consistently to questions based on creative model levels. 25 subjects (20.16%) are classified as imitation levels, and their problem solving processes are characterized by imitating data display, graphics, or strategy. Fifty six subjects (45.16%) are characterized by modifying data and graphics display processes to solve problems.; and 43 creative subjects (34.68%) are characterized by problems solved by the construction of new data and graphics. **Figure 3**(**a**) shows the distribution of the creative model for solving the open problem.

Figure 3(**b**) shows that the distribution of the creative model of male subjects: level of imitation 12 (9.7%), level of modification 26 (21%), and level of creation 21 (16.9%). Creative models of female subjects: level of imitation 13 (10.5%), level of modification 30 (24.2%), and level of creation 22 (17.7%). In carrying out open-ended problem solving activities, both male and female students are mostly on the modified-level creative model. The following presents a creative model of the subject in solving open-ended problems for each level.

5.1 Imitation level

The creative model of imitation level is characterized by imitation of the context of problem solving strategies. In the first problem, the creation model at the imitation level is reflected in the process of imitating graphic shapes and numbers to make them similar to existing graphics and numbers. In the second problem, the creativity model at the level of imitation is reflected in the process of imitation only of the available data. This shows that the creative models of the level of imitation of the subjects in problems 1 and 2 are consistent. The student's activities in the mathematical creative model of imitation level are presented in the following.

No	Problem solving activity	Subject answer	Imitation form
1.	• Make the increase in sales of tea bottle in 2005–2009, the same as the increase in sales in 2000–2004. • Make the sales of tea box from 2005 to 2009 the same as the sales of tea bottle so		Imitating graphic shapes and number patterns so that they are the same and also to be similar to the appearance of the existing data.

No	Problem solving activity	Subject answer	Imitation form
	the graphs coincide. Meanwhile, the sales of tea box from 2000 to 2004 experienced an upward trend every year, similar to the pattern of increasing sales of tea bottle.	 Translate: *Sales results of tea bottle and tea box*	
2.	• students determine grade B math scores by imitating exactly the same as grade A math scores; • create a bar chart based on the results of imitating class A value data.	 Translate: *Mathematics score of Class B*	Mimic the grades of class A that are already available. The subject does not change the existing values and is used to show that the mean, median, and mode are greater than class B.

In problem 1, the subject only imitated the shape of the graph and the trend of the sales of bottled tea so that the two soft drinks had similarities both in the form of graphs and the increase in sales results which experienced the same increase every year. The results of interviews with researchers (P) and students (S) are as follows:

Q: What is your process for completing problem 1?

S: I saw the difference in the increase in tea bottles by six, then I followed it until 2009, it went up by six until I got 64. Then for the tea box graph, the value must be the same in 2009, so I started to make it from the back first from 2009. From my score of 64 less 4 continues every year until 2000, sales results 28

Q: Why did you choose the difference 4, not any other number?

S: because you are free to choose ma'am

Q: Why not make six to make it the same as tea bottle

S: Therefore, that the graphs do not overlap, mam

In problem 1, the subject who is at the imitation level in determining the sales of tea bottles in 2005–2009 by "imitating" is exactly the same as the increase in sales in 2000–2004, which is Rp. 6 million every year. The subject used the Rp. 6 million to continue the pattern of increasing sales of tea bottle in 2005–2009 so that the sales of tea bottles in 2009 were Rp. 64 Million. Furthermore, the subject made a graph of the sales results of tea boxes starting in 2009 and imitated the pattern of increasing sales of tea bottle which the increase was the same every year. This subject makes an increase in the sales of tea boxes by Rp. 4 million every year. From the sales in 2009 of Rp. 64 million, the subject made a downward trend by counting backward from Rp. 4 million every year so that the sales of tea box in 2000 amounted to Rp. 28 million. In this case, the subject makes a pattern for the sale of tea bottles in the form of an arithmetic sequence with a difference of Rp. 6 million. By using the concept of the arithmetic sequence, the subject imitated it to determine the sales of tea boxes with a difference of Rp. 4 million. The imitation level creative model that the subject did in problem 1 is reflected in the process of imitating graphic shapes and imitating number patterns.

In problem 2, the creative model of the imitation level is reflected in the subject's activity in determining the score of mathematics in class B which "imitates" the values of mathematics in class A. Although in Problem 2 it is stated that the subject is free to determine the range of mathematics values for class B (values 0–100), but the subject chose to imitate all grade A math scores. To create a bar chart, the subject made the horizontal axis the same as the math score of class A. In other words, the subject used all the scores of the class A, i.e., grades 40, 45, 60, 70, and 85 to make a bar chart of grade class B math scores. Next, the subject made the frequency on the vertical axis so that the mean, median, and mode of class B were greater than class A. The subject's position at the imitation level was strengthened by the following interview results.

Q: Why did you choose the value on the horizontal axis like that? (pointing to the bar chart).

S: I made the value the same as the score of the class A, mam.

Q: What is your reason for making the values the same and not choosing another value?

S: I will just make it the same, ma'am.

Q: In the question from being free to choose of class B math score from 0 to 100, did you not read.

question?

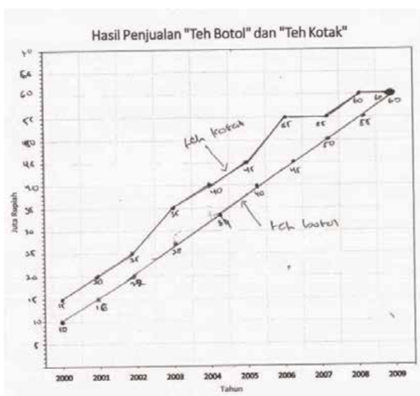
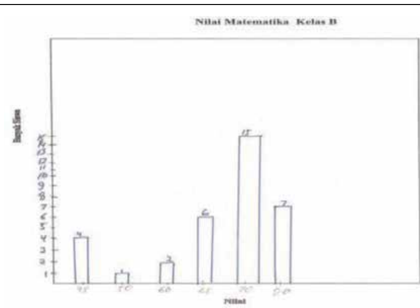
S: Read ma'am,

The question reveals that although he read the question, he can freely choose from 0 to 100 the Class B score. Furthermore, the subject has made the class B score equal to the class A score. Subjects can determine class A average values of 65, median values of 60, and mode values. Therefore, if the subject determines 70 as the highest frequency of 11 students, the pattern and average of class B are larger than class A. The subject determines that 26 students got a score of more than 70 and as many as nine students got a score of less than 70, so the subject believed that the average value of class B was greater than class A.

The descriptive statistical activities for problems 1 and 2 depend only on the information shown in the task. This is in line with the opinion of Mecca & Mumford [30] which states that imitation occurs if there is an object to be imitated or imitated so that imitation depends on how people work with examples. For example, in problem 1, students create a positive trend in the sales of tea box because there is an example of a graph in the form of a positive trend in the sales results of tea bottle which is displayed in problem 1. Likewise, in Problem 2, students scored mathematics in class B because students observed that class A contained mathematics scores. The math scores in class A can also be used for students in class B. In this case, students can get information about something that they experience directly and from what is around them. Buttelmann et al. [31] state that children are more likely to imitate reliable models than unreliable ones. While Okada & Ishibashi [32] state that imitation is the core of the learning process, someone imitates the attitudes of others not only superficially but also at the level of deep cognitive processes.

5.2 Modification level

The Creative Model of the Modification Level occurs when the subject changes and combines components, data, and strategies to complete the task. In problem 1, subject changes some or all of the existing graphics and numerical models to construct the graph. This is consistent with problem 2 completion, which is used to modify the scores of the A class students and construct the completion of the B class data. Examples of mathematical creative models at the level of modification are given below.

No	Problem solving activity	Subject answer	Modification form
1.	• create an upward trend line on the line graph of tea bottle sales results in 2005–2009 which the size of the increase remains the same as in 2000–2004; • make a line graph of the sales results of tea box from 2000 to 2009 which has a different trend every year.	 Translate: *Sales results of tea bottle and tea box*	It starts with imitating a number pattern similar to the existing pattern and continues by modifying the uptrend line on the chart
2.	• Modify the class A data, so that it is in accordance with the characteristics of class B and continue with describing the bar chart.	 Translate: *Mathematics score of Class B*	Take class A value data and modify the data so that it becomes class B data, and continue to draw the bar chart

In the creative model of the modified level, subject changes the pattern of increasing the sale of tea bottles so that they are different from tea bottles and that the graphics are different from tea bottles. The results of research interviews with students confirm the position of modification level as follow.

Q: How did you complete problem 1?

S: In making the tea box from 2005 to 2009 ma'am, I followed the multiples of six ma'am like.

year 2000–2004,

Q: Why not make another multiple?

S: I think from 2000 to 2004 the increase was regular, so I also made the increase regularly for 2005-.

2009

Q: Why not make up and down like a tea box chart?

S: I just continued the previous one, mam.

Q: Why do the lines on the tea box chart go up and down?

S: Because I made it different from tea bottle mam.

In the first issue, the subject made a series on tea bottles sales from 2005 to 2009, continuing the previous year's series. Between 2000 and 2004, tea bottles were sold by Rp. 6 million every year, so the students added Rp. 6 million to the sales of the last year. In this case, the subject made modifications by changing the trend of the sales of tea bottles so that the sales of tea box experienced an up and down trend. The student made the sales of tea box that are different from the tea bottle, so that the shape of the trend line on the graphs of the two soft drinks is also different.

In problem 2, the subject uses some of the score of class A; namely scores 45, 60 and 70 and modifies them to 50, 65, and 90. These values are used on the horizontal axis on the bar chart of grade B math scores. While on the vertical axis, the subject determines the number of students so that the mean, median, and mode of class B are greater than class A. The subject uses a score of 85 in class A and modifies the other values to 90, 95, and 100. These values are used by the student to make a bar chart for class B. The position of the subject at this modified level is supported by the following interview results:

Q: Why did you make a bar chart like this (while pointing to the student's answers).

S: Because judging from the problem, mam, from the questions obtained in class A there are 30 students, from various grades from 40 to 85, right, the order is to make a bar chart for class B whose value is up to us, sir, from 0 to 100. The average value, the median and mode of class B must be greater than class A. The first score is recorded for class A, in class A the average is 65 books, the mode is 60 and the median is also 60. So, how do I find the value for class B, I choose First the numbers are high so that the mean, median and mode of class B are greater than class A.

Q: Why were the scores 85, 90.95 and 100 chosen for class B score, why not other grades?

S: I choose the largest value in class A, which is 85, then I choose a number greater than 85 so that the average, median and mode exceed class A.

Q: Are you sure?

S: Sure, because the value is bigger than the grade A class bu.

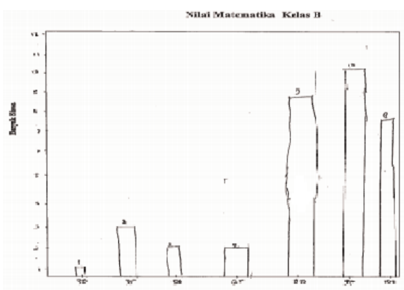
The interview showed that the subject merged the highest score of class A 85 and other values of more than 85 and modified the data. Students do so without mathematical calculation, so that the average, average, and mode score of class B is higher than class A.

The creative modification level model is an electronic data modification by merging and synthesizing several objects and concepts to generate new objects and concepts. This is in line with Batanero et al. [33] which states that through synthesis, such as combining the concept of a measure of concentration with the concept of a measure of dispersion, a new concept emerges, namely the distribution of data as a fundamental concept.

DOI: http://dx.doi.org/10.5772/intechopen.106187

5.3 Creation level

The level of creation of creative models is an activity performed by a person in the development of new information. The level of creativity in solving descriptive statistical problems is marked by the subject developing the existing line graph into a new line graph to solve the problem of presenting data in graphical form. The subject creates a new bar chart based on the table to solve the centering size problem. Subject activities on problem 1 and problem 2 on the creative level of creative model are presented in below.

No	Problem solving activity	Subject answer	Creation form
1.	• draw a line on the graph of bottled tea sales from 2005 to 2009 exactly the same as the trend line for 2000–2004; • make a line graph of the sales of boxed tea from 2000 to 2009 up and down every year.	 Translate: *Sales results of tea bottle and tea box*	Constructing a new pattern through changing the shape of the graph
2.	• draw a line on the graph of bottled tea sales from 2005 to 2009 up and down; • make a line graph of the sales of boxed tea from 2000 to 2009 up and down every year.	 Translate: *Sales results of tea bottles and tea box*	Created two different new patterns
3	• Make a bar chart of math grades for class B where all students' grades in that class are different from those of class A	 Translate: *Mathematics score of Class B*	Create new math scores

To further study the status of the subject in the creation phase, the researcher conducted the following interviews.

Q: How is your process to complete problem 1?

S: I made a graph of tea box and tea bottles from 2005 to 2009, some of which went up and some went down, mam, because I think that every sale does not always increase or decrease, there are times when sales also increase and decrease, that's why I made a graph, some are up and some are down.

Q: What are the initial steps taken?

S: First, I made the sales of tea bottle from 2005 to 2009 go up and down, mam. Then I made the sales of tea box starting in 2000, the value was 17, then in 2001 it decreased to 10, and in 2002 it increased again to 26, in 2003 it increased again to 23, in 2004 it became 43. decreased to 25, in 2006 it rose again slowly to 29, in 2007 it rose to 35, in 2008 it rose to 40, and finally in 2009 the sales of tea box and tea bottle were equal to 50. So in the middle of the year the sales had decreased drastic.

Q: Is there a number pattern that you make in determining it?

S: No mam, I'll take anything.

Q: What is the reason for taking any?

S: No, mam, just create your own.

In completing problem 1, the subject of the creative level of model creative is not affected by the shape of the pattern or the shape of the trend in the graph in the problem, the subject makes or creates his own pattern and shape of the trend on the graph. It is believed that sales results should not continue to rise, and sometimes they must also rise and decrease. In this case, the subject is able to connect the problem in the problem with real life, the subject is not fixated on what is shown in the problem, but students think realistically and logically to complete tasks associated with everyday life. The pattern of numbers made by the subject is irregular, meaning that the amount of increase in sales results does not form a line that has a regular pattern so that it results in a different graphic form from the graph shown in the assignment.

In problem 2, the creation-level, subject creates a class B mathematical score bar chart by designing its own class A mathematics score. In problem 2, students can use values in the range 0–100, the range of values used by the subject to create new score of class B. The activity carried out by the subject in the creative level creative model is designing new scores so that the math scores of students in class B are different from those of students in class A. The student chooses scores of B student's score by 30, 35, 50, 65, 90, 95 and 100 where all these values are different from the scores of students in class A. These values are used by students to make a bar chart, where the horizontal axis contains student scores and the vertical axis contains the number of students who got these scores. The subject determined that more students scored 90, 95 and 100, i.e. there were 27 students and eight students scored lower than 90. The results of the following interviews reflect the creative process of a creative subject.

Q: How is the process of answering problem 2? (while pointing to the student's answer paper).

S: The first step is to determine the mean, median and mode of class A. The average of class A is 65, the median and mode are 60. To make it bigger than class A, I make high marks in class B, there are 90, 95 and 100, I made the stems high, class B has a mode of 95 because there are 10 people, while in class A there are low scores and high scores, but the score is not up to 100. Because in the question class B has to be bigger in average, median, and mode, so I make a few few who score low and many who score high.

Q: Did you use formulas to solve for mean, median, and class B mode?

S: No, mam.

Q: How can you be sure that the mean, median and class B mode are greater?

S: I made a lot of students get high marks from class A mam.

Q: Why did you choose the score in class B like this? (pointing to the horizontal axis of the bar chart).

S: Because in a class usually there are those who get low scores, there are also moderate, and some are high and very high, I made it so that the grades of classes A and B are different.

Q: Any other reasons?

S: No, mam, so that the values are different.

The subject first determines the mean, medium and model of Class A before selecting the mathematical score of Class B so that the average, medium and model of Class B are greater than Class A. The average, average and class A mode values are 65, 60, and 60. Subjects can ensure that the mean, median and mode of score of class B are greater than class A without performing mathematical calculations by placing more students with scores higher than 65. Activities of these topics are classified as creative. This is in accordance with Sheffield [34] opinion that student solutions are considered creative if the student can produce something unique and new to what is in their environment.

6. Creative models in mathematics learning assisted by mathematics tree media

The mathematical problem that can promote students' mathematical creative thinking is usually open-ended, allowing students to create new ideas and ideas freely. Students should participate in activities that allow them to explore the problems, ideas, and ideas necessary to solve the problems [17, 18]. Problems that stimulate creativity are usually addressed in several ways [8] or open-ended problems. In addition, creative thinking can be built by problem posing. In the development of the level of creative models, the learning of mathematics must use open-ended or problem posing [35].

The importance of open ended in learning mathematics activities has been studied by several researchers [36, 37]. Hitt & Dufour [37] examined students' mathematical activities when they completed an open-ended task related to speed and found that students used different representations in the process of modeling the situation when they were solving open-ended problems. Chan & Clarke [36] provide an open-ended problem in collaborative group work activities. Mathematics learning activities using open ended are able to develop problem solving skills and negotiation skills in collaborative learning groups. This shows that open-ended assignments can challenge students to think higher and ultimately be able to improve problem-solving skills.

Many experts believe that creativity can be developed by open-ended activities and problem posing. The problem is how to package open ended and problem posing in learning mathematics. This paper offers mathematics learning with open ended activities and problem posing which is packaged in the form of a mathematical tree. Mathematics learning is assisted by mathematical tree media, hereinafter referred to as the Mathematical Tree Learning Model. The mathematical tree learning model is intended as a learning model that facilitates students to: (1) pose a problem whose answers are known or (2) answer questions from open-ended problems.

Learning with the mathematical tree media is a form of learning with the following syntax: (1) the teacher models/explains the material, (2) the teacher presents problems and students solve them in groups, (3a) the teacher gives answers on the twigs & students construct the appropriate questions on the leaves. Or (3b) the teacher gives open ended questions on the twig & students determine all possible answers on the leaf, (4) the teacher asks students to exchange and correct other students' answers, (5) the teacher asks students to rate other students' answers, and (6) the teacher provide reinforcement to the problems or answers made by students. In this case the teacher has prepared media in the form of a mathematical tree, which consists of stems, twigs, and leaves. The stem contains the subject matter, the twig contains open-ended problems or answers, the leaves contain answers to open-ended problems or problems whose answers are already known. Students make leaves (compose problems or determine answers) as much as possible. The more leaves produced, the more fertile the tree is. On the other hand, if the leaves are made incorrectly, they will become INSTRUCTIONS. Therefore, in determining the assessment, the leaf (the correct answer/problem) is scored 3 (three). When the parasite (answer/problem made) is wrong, then the value is –1 (negative 1).

For example, in teaching students about the application of definite integrals, the questions usually given by the teacher are determining the area of a region bounded by some curves or determining the volume of a curve that is rotated around an axis. While learning with the mathematical tree media is done by determining the tree, namely, the integral and the branch is the area or volume whose value has been given. Next, students are asked to make leaves (find as many problems as possible) whose answers are on the branch. The integral tree can be made as shown in **Figure 4** below.

In the integral tree, students are asked to construct a leaf (i.e., a problem whose answer is already known) - the definite integral will result in 12. The definite integral form whose result is 12 is very large, therefore students can arrange as many definite integrals as possible, the important thing is that the result is 12. In this case, it is not enough for students to just remember the procedures exemplified by the teacher, but students must be creative in determining as many alternatives as possible. Therefore, learning with this mathematical tree media can develop students' creative models.

Another example, learning straight line equations. The tree is the equation of a straight line. The stick is to determine as many equations as possible the line that passes through the point (1.2) and determine as many equations as possible the line parallel to $y = 2x–3$. The line equation tree is presented in **Figure 5** below.

The thinking process of students who are built in learning with the media tree of mathematics can be described as follows.

In determining the equation of a straight line that passes through (-2.1), the students' thinking process is built by determining any line equation. For example $y = 2x$, then students will be able to think that if $x = -2$, then y must be worth one. Whereas when $x = -2$, the value of y is $2\ (-2) = -4$. To get a value of 1, you must add five. Therefore, so that $y = 2x$ through (-2.1), it must be changed to $y = 2x + 5$.

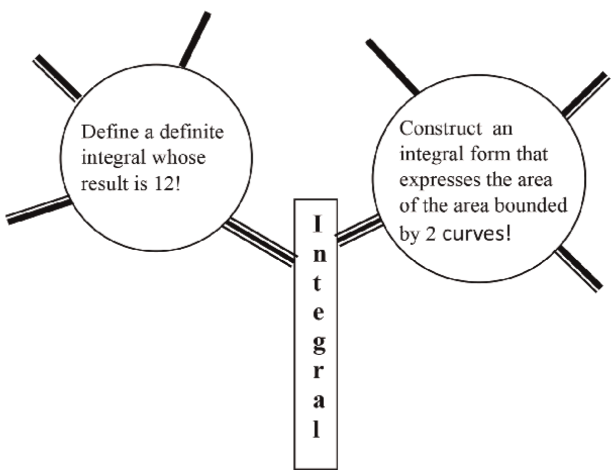


Figure 4.
Integral tree.

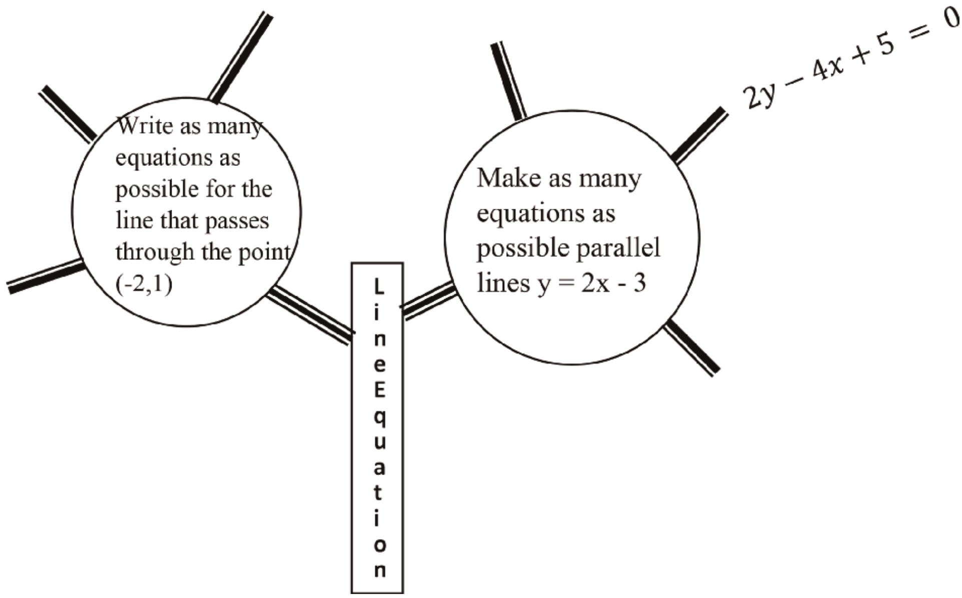


Figure 5.
Line equation tree.

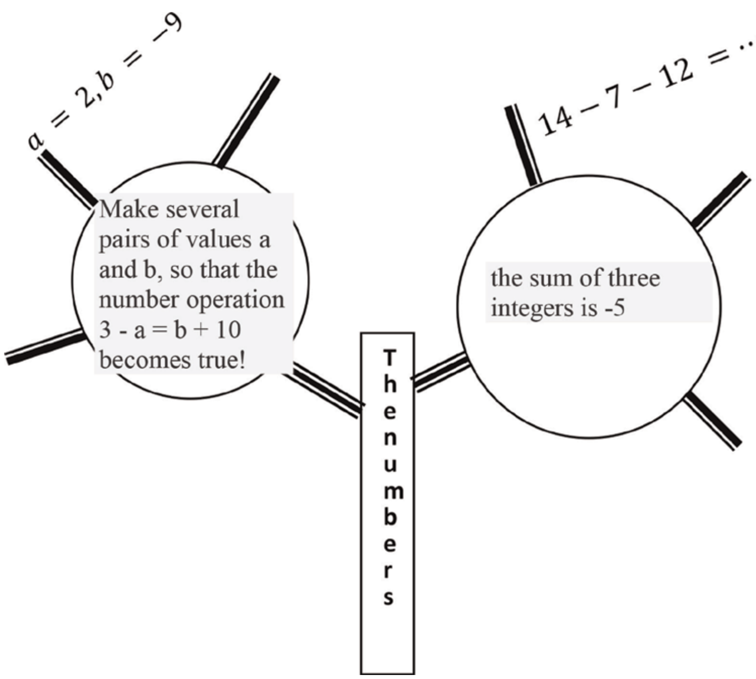


Figure 6.
The number operation tree.

This thought process will be able to empower students' reasoning. If the students' reasoning is well developed, then when students are asked to solve other problems, for example the equation of a line through (-2.1) with a gradient of –3, students will easily determine by thinking, if the gradient is–3, it means the equation of the line is $y = -3x$. If $x = -2$, then y must have a value of one. Whereas when we substitute $x = -2$, we get $y = -3\ (-2) = 6$. Therefore, in order to fulfill 1, the equation of the line is $y = -3x-5$. Therefore the equation of the line through (-2.1) with a gradient of-3 is $y = -3x-5$.

Mathematical trees can also be developed in elementary schools in various materials: integer operations, fraction operations, perimeter and area. Here's an example of a math tree in elementary school about the number operation tree (**Figure 6**).

When students are asked to make pairs of numbers that meet $3 - a = b + 10$, students will think, one of which is if $a = 2$, then the left side is equal to 1, and so on the right side the value is 1, then $b = -9$. If $a = 3$, then the left-hand side is zero and so that the right-hand side is zero, b must be -10. In this case, students are doing creative thinking activities, where students make many answers and finally students can find a pattern if an increases by 1, then b decreases by one. Mathematical tree learning will build HOTS and creative thinking.

7. Conclusion

Mathematical creative models are based on cognitive processes of creative thinking in mathematical activities and are divided into three levels: imitation, modification, and creation. Levels of imitation are characterized by cognitive processes in which people can only imitate provided strategies/processes problem solving methods. The level of modification is characterized by a cognitive process in which one hopes to change strategy/procedure, and the problem-solving process is more effective or simple. The creation level is characterized by the cognitive process, i.e. the ability to construct new strategies/procedures for solving problems.

Mathematics learning emphasizes only procedures and only forms creative models at imitation levels. Students who can only remember procedures can apply them only to problems similar to solved problems. Students face problems if they face new problems or modified problems. Therefore, mathematics must be learned to stimulate creative thinking, such as using the mathematical tree media.

Mathematical tree learning was developed based on problem posing and open ended. The stimulus is given in the form of open ended, requiring students to determine several alternative correct answers. Problem posing in a mathematical tree has a special characteristic, namely the stimulus given is in the form of an answer and students are asked to construct a problem with the answers already provided.

Author details

Subanji Subanji* and Toto Nusantara
Department of Mathematics, Universitas Negeri Malang, Indonesia

*Address all correspondence to: subanji.fmipa@um.ac.id

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Joklitschke J, Rott B, Schindler M. Notions of creativity in mathematics education research: A systematic literature review. International Journal of Science and Mathematics Education. 2022;**20**:1161-1181. DOI: 10.1007/s10763-021-10192-z

[2] Schindler M, Lilienthal AJ. Students' creative process in mathematics: Insights from eye-tracking-stimulated recall interview on students' work on multiple solution tasks. International Journal of Science and Mathematics Education. 2020;**18**(8):1565-1586. DOI: 10.1007/s10763-019-10033-0

[3] Leikin R, Elgrably H. Strategy creativity and outcome creativity when solving open tasks: Focusing on problem posing through investigations. ZDM – Mathematics Education. 2022;**54**(1):35-49. DOI: 10.1007/s11858-021-01319-1

[4] Schoevers EM, Kroesbergen EH, Moerbeek M, Leseman PPM. The relation between creativity and students' performance on different types of geometrical problems in elementary education. ZDM–Mathematics Education. 2022;**54**(1):133-147. DOI: 10.1007/s11858-021-01315-5

[5] Subanji S, Nusantara T, Rahmatina D. The statistical creative framework in descriptive statistics activities. International Journal of Instruction. 2021;**14**(2):591-608. DOI: 10.29333/iji.2021.14233a

[6] Kattou M, Kontoyianni K, Pitta-Pantazi D, Christou C. Connecting mathematical creativity to mathematical ability. ZDM. 2013;**45**(2):167-181. DOI: 10.1007/s11858-012-0467-1

[7] Tabach M, Friedlander A. School mathematics and creativity at the elementary and middle-grade levels: How are they related? ZDM. 2013;**45**(2):227-238. DOI: 10.1007/s11858-012-0471-5

[8] Sriraman B. The characteristics of mathematical creativity. ZDM. 2009;**41**(1–2):13-27. DOI: 10.1007/s11858-008-0114-z

[9] National Council of Teachers of Mathematics (Ed.). Principles and Standards for School Mathematics. New York: NCTM; 2000

[10] Mann PS, Lacke CJ. Introductory Statistics. Seventh ed. The United States of America: Wiley; 2010

[11] Creswell JW. Educational research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research. 4th ed. Bostonk: Pearson; 2012

[12] Cooper LL, Shore FS. The effects of data and graph type on concepts and visualizations of variability. Journal of Statistics Education. 2010;**18**(2):2. DOI: 10.1080/10691898.2010.11889487

[13] Sharma SV. High school students interpreting tables and graphs: Implications for research. International Journal of Science and Mathematics Education. 2006;**4**(2):241-268. DOI: 10.1007/s10763-005-9005-8

[14] Aoyama K. Investigating a hierarchy of students' interpretations of graphs. International Electronic Journal of Mathematics Education. 2007;**2**(3):298-318. DOI: 10.29333/iejme/214

[15] Baran G, Erdogan S, Çakmak A. A study on the relationship between six-year-old children's creativity and mathematical ability. International

Education Studies. 2011;**4**(1):105. DOI: 10.5539/ies.v4n1p105

[16] Brunkalla K. how to increase mathematical creativity- An experiment. The Mathematics Enthusiast. 2009; **6**(1–2):257-266. DOI: 10.54870/1551-3440.1148

[17] Nadjafikhah M, Yaftian N, Bakhshalizadeh S. Mathematical creativity: Some definitions and characteristics. Procedia - Social and Behavioral Sciences. 2012;**31**:285-291. DOI: 10.1016/j.sbspro.2011.12.056

[18] Švecová V, Rumanová L, Pavlovičová G. Support of pupil's creative thinking in mathematical education. Procedia - Social and Behavioral Sciences. 2014;**116**:1715-1719. DOI: 10.1016/j.sbspro.2014.01.461

[19] Voica C, Singer FM. Creative contexts as ways to strengthen mathematics learning. Procedia - Social and Behavioral Sciences. 2012;**33**: 538-542. DOI: 10.1016/j.sbspro.2012.01.179

[20] Chamberlin SA, Moon SM. Model-eliciting activities as a tool to develop and identify creatively gifted mathematicians. Journal of Secondary Gifted Education. 2005;**17**(1):37-47. DOI: 10.4219/jsge-2005-393

[21] Sriraman B, Haavold P, Lee K. Mathematical creativity and giftedness: A commentary on and review of theory, new operational views, and ways forward. ZDM. 2013;**45**(2):215-225. DOI: 10.1007/s11858-013-0494-6

[22] Beghetto RA, Karwowski M. Educational consequences of creativity: A creative learning perspective. Creativity. Theories – Research - Applications. 2018;**5**(2):146-154. DOI: 10.1515/ctra-2018-0011

[23] Coxbill E, Chamberlin SA, Weatherford J. Using model-eliciting activities as a tool to identify and develop mathematically creative students. Journal for the Education of the Gifted. 2013;**36**(2):176-197. DOI: 10.1177/0162353213480433

[24] Lin C-Y, Cho S. Predicting creative problem-solving in math from a dynamic system model of creative problem solving ability. Creativity Research Journal. 2011;**23**(3):255-261. DOI: 10.1080/10400419.2011.595986

[25] Sheffield LJ. Developing mathematical creativity-questions may be the answer. In: Creativity in Mathematics and the Education of Gifted Students. Rotterdam: Sense Publishers; 2009. pp. 87-100

[26] Sheffield LJ. Creativity and school mathematics: Some modest observations. ZDM. 2013;**45**(2):325-332. DOI: 10.1007/s11858-013-0484-8

[27] Leikin R, Pitta-Pantazi D. Creativity and mathematics education: The state of the art. ZDM. 2013;**45**(2):159-166. DOI: 10.1007/s11858-012-0459-1

[28] Leikin R. Evaluating mathematical creativity: The interplay between multiplicity and insight. Psychological Test and Assessment Modeling. 2013; **55**(4):385-400

[29] Yaftian N. The outlook of the mathematicians' creative processes. Procedia - Social and Behavioral Sciences. 2015;**191**:2519-2525. DOI: 10.1016/j.sbspro.2015.04.617

[30] Mecca JT, Mumford MD. Imitation and creativity: Beneficial effects of propulsion strategies and specificity. The Journal of Creative Behavior. 2014; **48**(3):209-236. DOI: 10.1002/jocb.49

[31] Buttelmann D, Carpenter M, Daum MM. The reliability of a model influences 14-month-olds' imitation. Journal of Experimental Child Psychology. 2010;**106**(4):208-220. DOI: 10.1016/j.jecp.2010.03.002

[32] Okada T, Ishibashi K. Imitation, inspiration, and creation: Cognitive process of creative drawing by copying others' artworks. Cognitive Science. 2017;**41**(7):1804-1837. DOI: 10.1111/cogs.12442

[33] Batanero C, Burrill G, Reading C, editors. Teaching Statistics in School Mathematics-Challenges for Teaching and Teacher Education. Vol. 14. Netherlands: Springer; 2011. DOI: 10.1007/978-94-007-1131-0

[34] Sheffield LJ. Commentary paper: A reflection on mathematical creativity and giftedness. In: Mathematical Creativity and Mathematical Giftedness: Enhancing Creative Capacities in Mathematically Promising Students. Springer International Publishing; 2018. pp. 405-425

[35] Silver EA, Cai J. An analysis of arithmetic problem posing by middle school students. Journal for Research in Mathematics Education. 1996;**27**(5):521. DOI: 10.2307/749846

[36] Chan MCE, Clarke D. Structured affordances in the use of open-ended tasks to facilitate collaborative problem solving. ZDM. 2017;**49**(6):951-963. DOI: 10.1007/s11858-017-0876-2

[37] Hitt F, Dufour S. Introduction to calculus through an open-ended task in the context of speed: Representations and actions by students in action. ZDM–Mathematics Education. 2021;**53**(3):635-647. DOI: 10.1007/s11858-021-01258-x

Chapter 5

The Language That Grade R Students Use to Achieve the Envisaged Mathematics Outcomes, a South African Perspective

Shakespear M. Chiphambo and Nosisi N. Feza

Abstract

In South Africa, the debate on the Language of Teaching and Learning of mathematics in Grade R has been underway. Amid the robust debate on the teaching of mathematics in home language, the students have no voice. This paper explored the language that Grade R students use to navigate mathematics space to achieve the policy's envisaged outcomes. The theoretical premise for the study is based on Vygotsky's theory of social constructivism. The qualitative approach guided by the case study design of Grade R 8 students were employed in the study. It is anticipated that this paper provides valuable insights into the understanding of the Grade R students' acquisition of mathematical language and contributes to the increased awareness in the field of Grade R mathematics teaching to achieve active learning. The findings revealed that (i) students failed to establish that the number of objects does change with the changed arrangement of the same number of objects and (ii) students were able to understand questions asked in their home language, yet their responses were in English.

Keywords: active learning, grade R, home language, second language, students

1. Introduction

In South Africa, schooling system ranges from Grade R to 12. Grade R is the reception year. This is part of the Department of Basic Education's National Curriculum. It is aimed to give children a firm foundation in preparation for grade one (it is preprimary phase). Grade R is not mandatory; however, the child who skips it is more disadvantaged than the one who goes through it.

Language plays a major role in the teaching and active learning of mathematics to any grade. Many students find it difficult to excel due to the language of instruction, which acts as a barrier to their learning. Several studies [1, 2] acknowledge that English proficiency heralds mathematics proficiency, particularly when English is the medium of instruction. As English second language (ESL) students struggle to understand mathematics concepts that are being taught the English first language

IntechOpen

(EFL) speakers feel more comfortable because they understand the medium of instruction. Research confirms that ESL performs low in mathematics compared to their counterparts EFL speakers [3]. Numerous research studies in language acquisition and mathematical learning have developed along mostly discrete trajectories, for example, studies examining the links between linguistic and mathematical literacy [4], the functions of language in the math classroom [5] established the framework defining the four stages of mathematical learning: Receiving, Replicating, Negotiating meaning and Producing. However, few studies have investigated the language that Grade R students use to navigate the mathematics space to achieve the envisaged outcomes of the policy. The two questions that still need to be answered in this study are the following:

- Which language do Grade R students use to achieve the envisaged outcomes in the policy?

- How do Grade R students navigate the language space in the lesson?

Research shows that home language is important and it is acquired during early childhood, commonly before the age of three [6], it is at this stage that the child's development and acquisition of mathematical concepts is critical. Learning a language is not just a simple thing that happens effortlessly. Research argues that learning the first language is one of the unexplainable daily mysteries surrounding us [7]. Many people think that children put no effort to learn the language, but the truth is that there are several stages that a child must go through to learn a language. If learning mother tongue language is that difficult what more adding a foreign language to the child's mind? Across multiple contexts, research on the language of instruction reveals that where native language is used for mathematics learning, teaching and assessment, native speakers of the language of instruction achieve higher scores than the non-native language speakers [8–10].

In [11] behaviourist theory argues that the acquisition of language can be observed. Skinner believed that children are born with a blank slate of mind or tabula rasa. Children acquire the first language by responding to stimuli given to them and they respond through conditioned reinforcement. The innatist theorists including [12] believed that children have a blueprint for language acquisition called Language Acquisition Device (LAD). The LAD is responsible for swift mastery of the language, and this makes it possible even if a child is exposed to the abstract language. The innatist theorists refute Skinner's theory [13] theory also supports the innatist theorists' claims indirectly though, by arguing that the conversations that children engaged in constitute the origins of both language and thought, where thought is fundamentally internalised speech and speech develops in social interaction.

Even though many people advocate for the use of Home Language (HL) as the only medium of instruction, research heightens the importance of learning a second language as well. It is argued that bilinguals have more advantage in performance than monolinguals [14–16]. Second language acquisition increased working memory, and this enables second language learners to achieve higher in mathematics because maths achievements are influenced by the enhanced working memory [17, 18]. The acquisition of the second language is associated with the increase in the density of the grey matter in the brain, which enhances performance [19]. Piroozan et al. [20] study in Iran found out that the children who acquired a second language outperformed in mathematics tests their counterparts who were monolingual and knew their mother tongue only.

2. The South African curriculum and assessment policy statements

In South Africa, the Department of Education introduced the National Curriculum and Assessment Policy (CAPS) for the subjects listed in the National Curriculum Statement for Grade R-12. The CAPS was designed to shed more light on teachers on what and how they should teach students. According to [21] the National Curriculum Statements Grade R-12 envisaged producing students who can:

- identify and solve problems and make decisions using critical and creative thinking;
- work effectively as individuals and with others as members of a team;
- organise and manage themselves and their activities responsibly and effectively;
- collect, analyse, organise and critically evaluate information;
- communicate effectively using visual, symbolic and/or language skills in various modes;
- use science and technology effectively and critically showing responsibility towards the environment and the health of others; and
- demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation (p. 5).

To achieve the intended outcomes, the designed activities are expected to be minds-on and hands-on to develop diverse mathematical skills in students. Asmal [21] emphasises that the designed activities must not be 'keep busy' activities but must focus on meaningful mathematics content. The Grade R curriculum is designed in a way that the time a student exits Grade R is fluent in number sense and the four basic operations. The aim is to ensure that students are competent and confident with numbers and calculations [21].

For the deliverance of mathematics content meaningfully, the Language of Learning and Teaching (LoLT) plays a vital role, with this understanding, the DBE made a provision through [22], which is discussed in the section below.

3. The South African language in education policy on education

In this section, we present the LiEP and how it tends to drive education. In South Africa, during the Apartheid regime, access to education was not equal for all, especially black people were offered low-quality education, for example limited resources, overcrowded classrooms, insufficient infrastructure and ill-equipped teachers [23]. To redress such racial inequality in education, the department of education developed LiEP which stipulates the aims of education as:

- to promote full participation in society and the economy through equitable and meaningful access to education;

- to pursue the language policy most supportive of general conceptual growth amongst students, and hence to establish additive multilingualism as an approach to language in education;
- to promote and develop all the official languages;
- to support the teaching and learning of all other languages required by students or used by communities in South Africa, including languages used for religious purposes, languages which are important for international trade and communication and South African Sign Language, as well as Alternative and Augmentative Communication;
- to counter disadvantages resulting from different kinds of mismatches between home languages and languages of learning and teaching;
- to develop programmes for the redress of previously disadvantaged languages.

The [22] advocates for all languages to be considered equal and for students to learn in the language that they are comfortable with. Research argues that even though the government advocates for the use of mother tongue, if there is no support, students can still suffer because every medium of instruction needs adequate support to attain the intended outcomes [24].

The next section discusses mathematics as a language and how it must be presented to the students for easy access.

4. Related work on mathematics as a language

Even though there is LoLT, mathematics is a language that has its own syntax and symbols. Asmal et al. [21, 25] describe mathematics as a language that uses symbols, terminology and notations for describing numerical, geometric and graphical relationships to communicate information. To provide students with multiple opportunities to learn worthwhile mathematics, mathematics teachers need to understand the specialised language of mathematics learning and teaching [26]. For the students to pass mathematics, they must first understand basic concepts which are the building blocks of this subject. It is from those basic concepts that the bigger mathematical ideas emerge.

In the true sense of the matter, many African countries have been considering the language of the colonisers as more superior to their own native languages, such connotations are misconceptions because early mathematical concepts are easily understood at a young age when learnt in their mother tongue. The literature argues that forcing students to learn mathematics in the second language poses a threat to their ability to 'thrive' mathematically and, subsequently, undermines their interaction with the wider mathematics community [24, 27]. For years the government has been pushing children to learn mathematics in the ESL, but without adequately supporting them with resources to develop the required mathematical competencies [24]. Any language of learning and teaching needs adequate support for the students to access the information without any setbacks.

Language allows the possibility to link from one concept to another, it is from the link that the meaning of concepts is derived, if the language is weak, the ability to learn is negatively affected [28].

Likewise, [4] argues that language performs at least three critical roles in the classrooms:

- It is the medium of instruction. It is the main mode of communication.
- Students' understanding and processing of ideas are through language.
- We establish students' misconceptions and assess understanding by listening to their oral communication and by reading their mathematical works.

Failure to put much attention to the language issues simply means failing the society. The medium of instruction must be accessible to the students without putting much effort. Students individually have their own ways of learning mathematics. Each person is unique, and this is what teachers must take into consideration when designing learning activities. The section below horns on ways Grade R students learn mathematics.

5. Grade R students' ways of learning mathematics

Research highlights that the first 1000 days of child are critical to the child's future, that is where the child's foundation for healthy behaviour and learning is determined [29]. This implies that once the foundation of learning mathematics concepts is not well-grounded, the whole school life of the child is doomed. In support of this, [30] emphasised that the foundation for lifelong learning concepts, skills and attitudes is acquired during the early years. It further explains that even the development of emotional intelligence namely, confidence, curiosity, purposefulness, self-control, connectedness, capacity to communicate and cooperativeness is acquired during the early years. Feza [31] highlights the numerical abilities of young children prior Grade R possess that exceed the Grade R curriculum expectations supporting literature on the attainment of numerosity before formal learning.

The learning and teaching aspect in Grade R should focus on the holistic development of the child [21]. The teaching aspect should aim to develop the child's emerging numeracy through activities that develop cognitive (problem-solving, logical thinking and reasoning), mathematical language, perceptual-motor, emotional and social aspects. According to [21] the aspect highlighted in this paragraph can be learnt and developed through:

> *Stories, songs, rhymes, finger games and water play, educational toys including board games, construction and exploration activities (mass, time, capacity, measurement, etc.), imaginative play, outdoor play and 'playground games'. Many kinds of games and play could include aspects of numeracy, for example measuring during cooking or counting during shopping (p. 14).*

'Play' is undermined as one of the ways which children learn, yet it is essential to the development and strengthening of the child's creativity, imagination, dexterity, cognitive, social, physical, healthy brain and emotional well-being [32, 33]. The studies by [34] have shown that for young students from low-income backgrounds, their numerical knowledge can be promoted by playing a simple number board game. Furthermore, [35] explored cultural games' contribution to early years of mathematics, discovering their strength in developing number sense and sequencing. Barnard and Braund [36] argue that Grade R teachers continue to allow free play with no purpose although literature advocates for meaningful play. With intervention, this practice can improve towards meaningful goal-oriented play [24, 37]. This implies that Grade R teachers must be creative to instil the culture of learning through play in their centres of learning.

When children play, it means they are in contact with the environment. For mathematics to make meaning to the students, the teaching approach must be more immersed in context-based problems [38] that are meaningful and applicable to their background experiences [39]. Background experiences are important because when children learn to count, the newly acquired symbolic representations of numbers are made to fit onto pre-existing non-symbolic representations [40]. It is worth noting that Grade R come to school with the knowledge of informal numeracy, which needs to be expanded, enriched and developed through appropriately designed learning activities [41]. Learning and teaching that does not include play, rob students of their potential to learn. Games or songs need to be well planned that as they play or sing, mathematics concepts are acquired and developed.

Research highlights that a child learns mathematics informally in home environment; much of their learning is social in nature [42]; for example, it takes place with parents during time of meals, chores and shopping through one-to-one correspondence. The home environment is rich with numerical information [43]. Mathematics teachers must know that when planning for class activities, they plan for students who have some mathematical ideas from home. Home experiences must be taken as the framework upon which formal mathematics can be built.

To have minds-on and hands-on activities as envisaged by the DBE means Grade R teachers must be dedicated and creative in their preparations. As the mediator of learning the teachers must be proactive in everything to ensure that all students are catered for despite their differences. From what is presented, it can be emphasised that schools need well-trained qualified Grade R teachers who are creative enough in teaching mathematics.

6. Conceptual framework

This study is situated in a social and cultural context, and the sociocultural perspective provides a wider lens of how both the teacher and the school provide opportunities for students to learn mathematics. It also provides an opportunity to explore how students navigate through the language to access the intended mathematical content knowledge. The theoretical premise for the study is based on [13] theory of social constructivism. Ref. [13] argues that learning occurs when an individual internalises a social experience through interacting with a peer or an adult. In Vygotsky's cultural-historical theory, play is an essential part of early childhood. Vygotsky believed that play promotes cognitive, social, and emotional development in children. In mathematics education, students are expected to construct their own mathematical knowledge from previous experiences as they interact with peer or adult.

DOI: http://dx.doi.org/10.5772/intechopen.105446

7. Methodology

The study employed a qualitative approach guided by the case study design. The study's sample comprised eight Grade R students of mixed gender purposefully selected from the five primary schools in the Queenstown district of South Africa. Students in these schools belong to the same cultural group and speak the same home language. The data was collected using the video camera, and the video clips were then viewed to elucidate how Grade R students navigate the language space in the lesson. The data was coded and analysed thematically and reported in themes.

7.1 Instruments

The data was collected from the video clips which were captured in different schools when students were being engaged in different mathematical activities, for example, to identify the number of items per group as shown in **Figure 1** below, in **Figure 2** students were to identify numbers arranged in mixed order and to match the number of items on the right-hand side with the correct numerical value on the left-hand side. The questions were asked in learners' HL (IsiXhosa) one of the South African native languages.

Activity 1.

Researcher: Jonga ezi zam zisemfanekisweni iziciko (Look at my bottle-tops in the pictures).

Question 1: Researcher: Zeziphi ezininzi? (Which ones are many?)

Questionn2: Researcher: Khazibale sibone (Count them).

Question 3: Researcher: Xa uzidibanisa zonke zingaphi? (When you add them all, how many are there?)

After this activity students were further engaged in Activity 2 below, which sought to examine their language and numerical proficiency.

Activity 2.

Before the students were to match the number of items on the right-hand side with the correct numerical value on the left-hand side, they were asked to identify the numbers on the left-hand side arranged in mixed order.

Researcher: Khawutshatise inani ngalinye nomfanekiso walo? Sebenzisa icrayoni. (Match each number with its picture. Use a crayon).

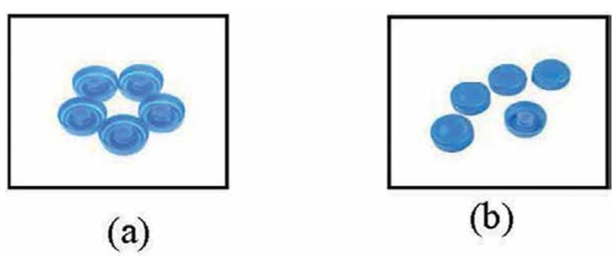


Figure 1.
(a) and (b) The two groups of five bottle-tops arranged in a different order.

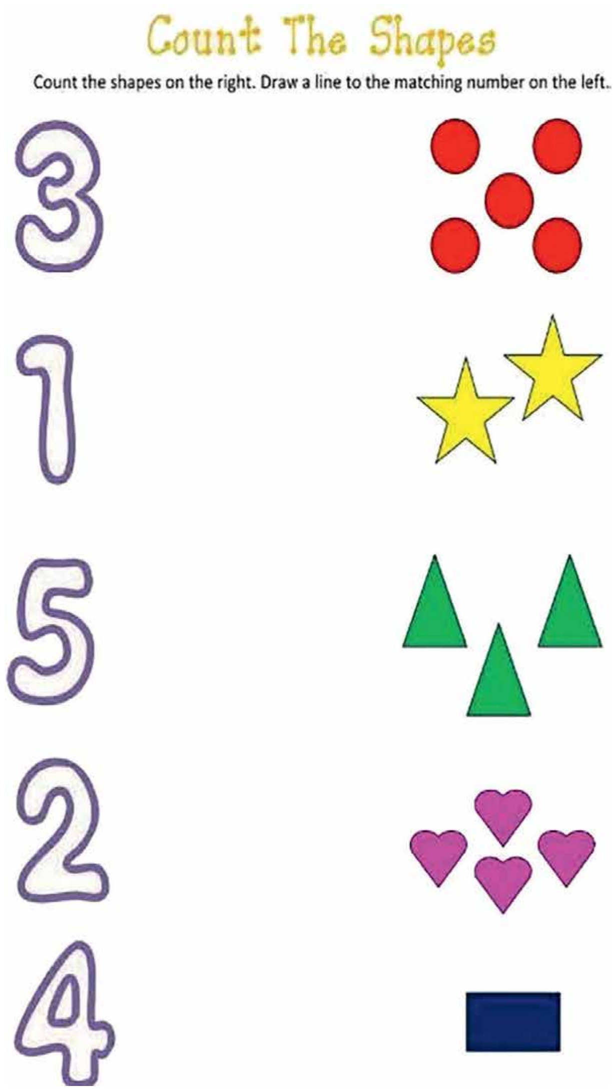


Figure 2.
Identification and matching activity.

8. Ethical issues

All the instruments used to collect data for the study were ethically cleared by the Central University of Technology.

The permission to collect data from the schools was sought and granted by the Queenstown district education office. Subsequently, the school principals of the schools in the project permitted the researchers to collect data without any hindrances.

Considering the age of the participants, the consent forms were distributed and signed by the parents of all the participants involved in the research project.

Participants' parents were assured of the anonymity that no real names of the participants were to be used when reporting the outcomes of the research project. The following codes were used: School 1: Student 1 (S1S1), School 1: Student 2 (S1S2), School 2: Student 1 (S2S1), School 2: Student 2 (S2S2), School 3: Student 1 (S3S1), School 3: Student 2 (S3S2), School 4: Student 1 (S4S1), School 4: Student 2 (S4S2), School 5: Student 1 (S5S1), School 5: Student 2 (S5S2).

9. Findings

When students were asked to compare the two categories of bottle-tops and identify the group that has many bottle-tops. Students' responses varied as shown in **Table 1**.

Table 1 shows how each of the eight students responded to the three questions of Activity 1. S1S1, S1S2, S2S1, S2S2 and S5S1 identified the number of bottle-tops in **Figure 1b** as greater than those in **Figure 1a** while S3S1, S4S1 and S4S2 considered the bottle-tops in **Figure 1a** to be more than those in **Figure 1b**. Responding to the second question, all other students counted the bottle-tops in English except S1S2 who counted in HL, but not in an orderly manner, the last number mentioned was 'shumi' (ten).

Student	Question 1: Zeziphi ezininzi? (Which ones are many?) Responses	Question 2: Khazibale sibone (Count them) Responses	Question 3: Xa uzidibanisa zonke zingaphi? (When you add them all, how many are there?)
S1S1	Bottle-tops in **Figure 1b** are more than those in **Figure 1a**	Couldn't count properly, counted in English but skipped some numbers	5
S1S2	Bottle-tops in **Figure 1b** are more than those in **Figure 1a**	Counted in Home Language (HL), IsiXhosa, but not in an orderly manner. The last number mentioned was 'shumi' (ten)	'Shumi' (ten)
S2S1	Bottle-tops in **Figure 1b** are more than those in **Figure 1a**	Counted the bottle-tops in English from 1 up to 12.	12.
S2S2	Bottle-tops in **Figure 1b** are more than those in **Figure 1a**	Counted the bottle-tops in English up to 11	11
S3S1	Bottle-tops in **Figure 1a** are more than those in **Figure 1b**	Counted the first set 1 to 5 And the second set 1 to 5 in English	No responses given
S4S1	Bottle-tops in **Figure 1a** are more than those in **Figure 1b**	Counted the bottle-tops in English	10
S4S2	Bottle-tops in **Figure 1a** are more than those in **Figure 1b**	Counted in English	11
S5S1	Bottle-tops in **Figure 1b** are more than those in **Figure 1a**	Counted in English	5

Table 1.
How students responded to questions 1 to 3 of Activity 1.

Student	3	1	5	2	4
S1S1	Linye	Mbini	Sixhengxe	Sibhozo	Ntandathu
S1S2	No response	No response	No response	No response	No response
S2S1	Three	Six	Five	Two	Four
S2S2	Four	Six	Seven	Eight	Nine
S3S1	Four	Two	Six	Seven	No response
S4S1	Three	One	Five	Two	Four
S4S2	Three	One	Five	Two	Four
S5S1	No response	No response	No response	No response	Five

Table 2.
How the students identified and named the given numbers (3, 1, 5, 2 & 4).

Responding to Question 3, S1S1 and S5S1 said that bottle-tops in **Figure 1a** and **b** combined together are 'ten' while S1S2 said that 'shumi' (ten). S2S2 and S4S2 responded that the bottle-tops combined are 11. S1S1 and S5S1 said that the total number of bottle-tops is five (5). S3S1 did not give any response to the question.

Table 2 illustrates how each of the students named the listed numbers. Of all the students in the sample, only S4S1 and S4S2 managed to identify the given numbers correctly. S2S1 managed to identify all other numbers except one which was identified as six. The responses given by S1S1 were in IsiXhosa (Home language, HL); even though HL was used, the students could not get the question correct. S2S2 could not be able to identify the given number correctly. S1S2 and S5S1 both students were not able to identify the first four listed numbers while the fifth number was identified by S5S1 as five, yet it is four and S1S2 gave no response to that.

The next question required students to match the number of items on the right-hand side with the correct numerical value on the left-hand side as shown in **Figure 2**. **Table 3** below illustrates how each of the students responded to the question.

The data presented in **Table 3** above illustrate students' responses to the matching item question. S2S1, S4S1 and S4S2 managed to match the given number of items to the correct responding numerical values.

Another group of three students, S2S2, S3S1 and S5S1 matched five items to a numerical value of 4. S3S1 provided unique responses as follows: matched two and three items to numerical values of five and two, respectively. No match was given to numerical values of three and one; one and four items.

S2S2 matched three and four items to a numerical value of five and no match was made for the numerical value of three. S5S1 matched four and one items to the numerical value of one while three items and a numerical value of three were not matched to anything.

Another unique response was given by S1S1 who straight matched the number of items on the right-hand side to the numerical values on the left-hand side as explained; three, one, five, two and four items were matched to the numerical value of five, two, three, four and one, respectively.

The last student S1S2 when asked to match the items to the corresponding items could not match any.

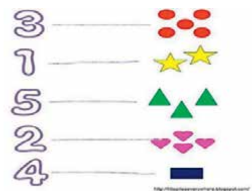
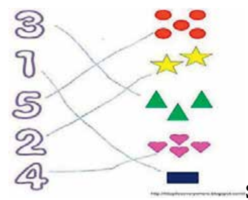
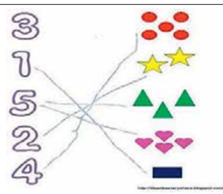
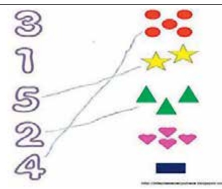
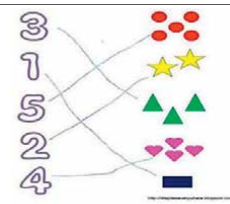
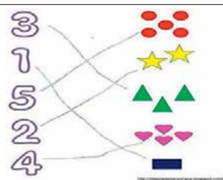
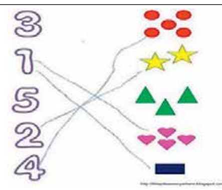
Researcher: Khawutshatise inani ngalinye nomfanekiso walo? Sebenzisa icrayoni. (Match each number with its picture. Use a crayon)		
 S1S1	 S1S2	 S2S1
 S2S2	 S3S1	 S4S1
 S4S2	 S5S1	

Table 3.
How students matched the group of items to the numerical value.

10. Discussion of the findings

The findings are discussed in this section. The discussion is based on how each of the students responded to the questions and what that means to the research community as far as learning and teaching early childhood mathematics is concerned.

The findings reveal that some of the students are comfortable with the use of HL to learn mathematics, i.e., S1S1 proved that by counting in HL as shown in **Table 1**. Even though the student was not accurate in the counting, but it showed the student had a bit of an understanding of the mathematical terms in HL, such ideas just need to be supported. This finding is consistent with [24] assertions that the principal use of HL represents an immeasurable fund of knowledge and an essential cognitive resource for mathematical sense-making for ESL speakers [24].

The ability to match the items to the given numerical values shows students' proficiency in counting. The researchers asked the students in HL, but S2S1, S4S1 and S4S2 responded in English and got the question correct, this reveals that some students are bilingual. From the findings of this study, it is also revealed that most students use both languages (English and HL, IsiXhosa) to navigate the learning concepts. This leads to suggest that students must be supported in being proficient in HL which can be used as a resource to learn the second language. Literature reveals that bilinguals benefit from advanced inhibitory control skills compared to monolinguals [14–16] as a result they perform better in mathematics than their counterparts (monolinguals).

For students like S1S1, S1S2, S2S2, S3S1 and S5S1 who had problems in matching the items to the correct numerical values, such problems emanate from a misunderstanding of mathematical language. It is argued that communicating mathematically requires an in-depth comprehension of the mathematical language and the multiple illustrations employed in communicating mathematical concepts [5].

Some of the students, for example, S1S1, S2S1, S4S2 and S5S1 when counting the bottle-tops in **Figure 1a** and **b** counted in English, listening carefully to their counting, skipped some of the numbers which is an indication that they are not yet conversant counting in English. Literature highlights that students in the advanced stage of language native-language acquisition can easily extend vocabulary, and good comprehension of the second language [5]. This implies that students need to be thoroughly developed in HL to have access to the Second Language (SL). Researchers argue that HL must be viewed as 'resources' if it needs to benefit the bi- or multilingual education system [9, 10].

The researcher used HL in all the questions, but surprisingly most of the students responded to the questions in English, for example, the counting of the items. Out of eight students involved in the study, one used HL to name the given numerical values, and the rest responded in English. For such instances, there is a need to support bilingual abilities because learning a second language assists in the growth of the density of grey matter in the left inferior parietal cortex of the brain, which leads to an improvement in performance. Research highlights that the acquisition of the second language at a young age, the denser the grey matter gets which is an advantage to the students [19].

11. Conclusion

The findings of this study led to the following conclusions:

i. Students failed to establish that the number of objects does change with the changed arrangement of the same number of objects.

ii. We have established that in Grade R students were able to understand questions asked in HL, yet their responses to the questions were in the second language (English).

12. Recommendations

Based on the findings of this study, we recommend the following:

i. Students must be engaged more in the use of visuals and manipulatives to enhance their mathematical skills, for example, visualisation and counting skills.

ii. Grade R students must be supported to be bilinguals because they have shown elements of understanding both languages. The first preference should be given to the mother tongue because it can be used as a resource to access mathematics concepts in the second language.

13. Limitations

These research findings cannot be generalised but can be transferrable to other contexts to strengthen the findings. It is advisable that other researchers should interpret the findings with caution as they are based on the data collected from the same cultural group that speaks the same home language. The replication of the same research with a different cultural group may yield different findings.

14. Suggested areas for further studies

We suggest that further studies can be conducted on:

- The language that Grade R teachers mostly use for teaching mathematics.
- Grade R teachers' competence in the teaching of mathematics using home language.
- How Grade R students of other cultural groups learn mathematics.

Acknowledgements

The authors would like to thank all the students who participated in the study to make it a success.

Declaration of interest

No potential conflict of interest was reported by the authors.

Author details

Shakespear M. Chiphambo[1*] and Nosisi N. Feza[2]

1 Walter Sisulu University, South Africa

2 University of Venda, South Africa

*Address all correspondence to: schiphambo@wsu.ac.za

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Jordan NC, Kaplan D, Hanich LB. Achievement growth in children with learning difficulties in mathematics: Findings of a two-year longitudinal study. Journal of Educational Psychology. 2002;*94*:586-598

[2] Zakaria Z, Aziz MS. Assessing students performance: The second language (English language) factor. The International Journal of Educational and Psychological Assessment. 2011;*6*:42-62

[3] Henry D, Nistor N, Baltes B. Examining the relationship between math scores and English language proficiency. Journal of Educational Research and Practice. 2014;*4*(1):11-29. DOI: 10.5590/JERAP.2014.04.1.02

[4] Thompson DR, Rubenstein RN. Learning mathematics vocabulary: Potential pitfalls and instructional strategies. Mathematics Teacher. 2000;*93*(7):568-574 Available from: http://www.jstor.org/stable/27971502

[5] Bossé MJ, Bayanga A, Fountain C, Young FS, DeMarte A. Mathematics learning through the lens of language acquisition. International Electronic Journal of Electronic Education. 2019;*12*(1):103-113. DOI: 10.26822/iejee.2019155342

[6] Nor NM, Rashid RA. A review of theoretical perspectives on language learning and acquisition. Kasetsart Journal of Social Sciences. 2018;*39*: 161-167. DOI: 10.1016/j.kjss.2017.12.012

[7] Gallaso J. First and Second Language Acquisition. Califonia, USA; 2003. Available from: http://www.csun.edu/galasso/lang1.htm

[8] Heugh KA. Language policy and education in Southern Africa. Encyclopedia of Language and Education. 2008;**1**:355-367. DOI: 10.1007/978-0-387-30424-3_26

[9] Planas N. Language as resource: A key notion for understanding the complexity of mathematics learning. Educational Studies in Mathematics. 2018;98(3):215-229. https://doi.org/10.1007/ s10649-018-9810-y

[10] Prediger S, Erath K, Moser Opitz EX. Language challenges for students with mathematics difficulties: An overview on research results and instructional approaches. In A. Fritz, V. Haase, & P. R s nen (Eds.), International Handbook of Math Learning Difficulties: From the Laboratory to the Classroom. Cham: Springer; 2019. pp. 437-455

[11] Skinner BF. Cognitive science and behaviourism. British Journal of Psychology. 1985;**2**:291-301

[12] Chomsky N. Verbal behaviour. Language. 1959;*35*(1):26-58

[13] Vygotsky LS. Interaction between learning and development. In: Cole M, John-Steiner V, Scribner S, Souberman E, editors. Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press; 1978. pp. 79-91

[14] Clarkson PC, Galbraith P. Bilingualism and mathematics learning-another perspective. Journal for Research in Mathematics Education. 1992;*23*(1):34-44

[15] Bialystok E. Cognitive complexity and attentional control in the bilingual mind. Child Development. *1999*;*70*(3):636-644. DOI: 10.1111/1467-8624.00046

[16] Bialystok E, Craik FIM, Klein R, Viswanathan M. Bilingualism, aging, and cognitive control: Evidence from the Simon task. Psychology and Aging. 2004;*19*(2):290-303

[17] De Smedt B, Jassen R, Bouwens K, Verschaffel, Boets B, Ghesquière P. Mathematics achievement: A longitudinal study from first grade to second grade. Child Psychology. 2009;**103**(2):186-201

[18] Meyer M, Salimpoor VN, Wu SS, Geary DC, Menon V. Differential contribution of specific working memory components to mathematics achievement in 2nd and 3rd graders. Learning and Individual Differences. 2010;**20**(2):101-109

[19] Mechelli A, Crinion JT, Noppeney U, O'Dohery J, Ashburner J, Frackowiak RS, et al. Structural plasticity in the bilingual brain. Nature. 2004;**431**:757. DOI: 10.1038/431757a

[20] Piroozan A, Fazeli R, Rezaei P. The relationship between second language acquisition and mathematics accomplishment among second graders. Hormozgan Medical Journal. 2015;*19*(6): 433-441

[21] Asmal K. Department of Education. Education white paper 5 on early childhood education. In: Education White Paper 5 on Early Childhood Education 2001, Meeting the Challenge of Early Childhood Education in South Africa. Department of Education; 2011. Pretoria, South Africa. Available from: https://www.gov.za/sites/default/files/gcis_document/201409/educ1791.pdf

[22] South African Department of Education (1997). *Language in Education Policy*. Department of Education. Pretoria, South Africa. Available from: http://www.education.gov.za/Resources/Policies.aspx[file LanguageEducationPolicy1997.pdf]

[23] Sayed Y, Kanjee A. *An overview of education policy change in post-apartheid South Africa*. In: Sayed Y, Kanjee A, Nkomom M, editors. The Search for Quality Education in Post-Apartheid South Africa: Interventions to Improve Learning and Teaching. Cape Town: HSRC; 2013. pp. 5-39

[24] Robertson S-A, Graven M. Language as an including or excluding factor in mathematics teaching and learning. Mathematics Education Research Journal. 2020;**32**:77-101. DOI: 10.1007/s13394-019-00302-0

[25] Setati M. Researching mathematics education and language in multilingual South Africa. The Mathematics Educator. 2002;12(2): 6-30. Available from: http://tme.journals.libs.uga.edu/index.php/tme/article/view/112

[26] Wilkinson LC. Teaching the language of mathematics: What the research tells us teachers need to know and do. The Journal of Mathematical Behavior. 2018;*51*:167-174. DOI: 10.1016/j.jmathb.2018.05.001

[27] Bourdieu P, Passeron JC. Reproduction in Education, Society and Culture. London: Sage; 1977

[28] Harrison D. Language Can Reshape our Economy. *News 24*; 2014. South Africa. Available from: http://www.news24.com/archives/city-press/language-can-reshape-our-economy-20150430

[29] The South African Early Childhood Review (2017), Ilifa Labantwana, The Children's Institute at the University of Cape Town, the Department for Planning, Monitoring, and Evaluation (DPME) in the Presidency, as well as Innovation Edge

[30] Asmal K. South African Government. Education White Paper 5 on Early

Childhood Education 2001, Meeting the Challenge of Early Childhood Education in South Africa. Pretoria, South Africa. [Accessed: 15 June 2021] Available from: https://www.gov.za/documents/education-white-paper-5-early-childhood-education

[31] Feza NN. Self-regulation in early years of learning mathematics: Grade R observed self-efficacy skills shared and aligned. In: Feza N, editor. Metagonition in Learning. United Kingdom; 2019:83-95. DOI: 10.5772/intechopen.788929

[32] Tamis-LeMonda CS, Shannon JD, Cabrera NJ, Lamb ME. Fathers and mothers at play with their 2- and 3-year-olds: Contributions to language and cognitive development. Child Development. 2004;**75**:1806-1820

[33] Ginsburg KR. The importance of play in promoting healthy child development and maintaining strong parent-child bonds. Pediatrics. 2007;**119**(1):182-191. DOI: 10.1542/peds.2006-2697

[34] Ramani GB, Siegler RS. How Informal Learning Activities Can Promote Children's Numerical Knowledge. Psychology, Cognitive Psychology, Educational Psychology, Developmental Psychology. Oxford Handbooks Online. United Kingdom. 2014

[35] Feza NN. Black students' rich mathematical experiences: Mathematics concepts and Xhosa cultural games for reception class. In: Farland-Smith D, editor. *Early Childhood Education*. 2019b:151-163. United Kindom. DOI: 10.5772/intechopen.73467

[36] Barnard E, Braund M. Strategies for the implementation of mathematics in grade R: Teachers' beliefs and practices. South African Journal of Childhood Education. 2016;**6**(1):a409. DOI: 10.4102/sajce.v6i1.409

[37] Hazell E, Spencer-Smith G & Roberts N. Improving Grade R Mathematics Teaching in South Africa: Evidence from an Impact Evaluation of a Province-Wide Intervention. Durban; 2019.

[38] Van den Heuvel-Panhuizen M, editor. Children Learn Mathematics: A Learning-Teaching Trajectory with Intermediate Attainment Targets for Calculation with Whole Numbers in Primary School. Rotterdam/Tapei: Sense Publishers; 2008

[39] Ginsburg H, Galanter M, Morgenlander M. Big Maths for Little Kids Workshops. New York: Teachers College Innovations; 2004

[40] Batchelor S, Keeble S, Gilmore C. Magnitude representations and counting skills in preschool children. Mathematical Thinking and Learning. 2015;*17*(2-3):116-135. DOI: 10.1080/10986065.2015.1016811

[41] Papadakis S, Kalogiannakis M, Zaranis N. Improving mathematics teaching in kindergarten with realistic mathematical education. Early Childhood Education Journal. 2017;**45**(3):1-10. DOI: 10.1007/s10643-015-0768-4

[42] Ramani G, Siegler R, Hitti A. Taking it to the classroom: Number board games as a small group learning activity. Journal of Educational Psychology. 2014;*104*(3):661-672. DOI: 10.1037/a0028995

[43] Saxe GB. Practices of quantification from a sociocultural perspective. In: Demetriou KA, Raftopoulos A, editors. Developmental Change: Theories, Models, and Measurement. New York, NY: Cambridge University; 2004. pp. 241-263

Chapter 6

A Method to Improve Comprehension and Learning in Science Education – A Case Study in Systems Engineering and Automation

Sergio Velázquez-Medina and Pedro Cabrera-Santana

Abstract

Difficulties are commonly detected in students with respect to the acquisition of certain specific competencies in a particular topic. One strategy to optimize the assimilation of knowledge and improve the learning results of students in a specific topic is through the use of the active learning process. Active learning can serve to facilitate autonomous and collaborative learning in specific topics as a complement to in-person classes. In this chapter, a method to improve comprehension and learning is developed and applied, using for this purpose both autonomous and collaborative works. The case study presented is undertaken for one of the subjects in the area of systems engineering and automation in one of the public universities of Canary islands (Spain). Different specific topics of the subject were selected. To check the effect of the application of the proposed method, a statistical analysis was performed. For this objective, t-test and the p-value statistical were used. As results, it was found that 100% of the students who presented some difficulty in relation to the general subject obtained higher relative results in the specific topics that they worked on when employing the proposed method, compared with their global result in the subject.

Keywords: integrated active learning, improve comprehension, autonomous learning, collaborative learning

1. Introduction

It is not uncommon to find that, for one reason or another, it is difficult to transmit certain knowledge of some subjects to the student, or that, because of the nature of such knowledge, its transmission entails certain difficulties [1–5]. In consequence, the skills derived from such knowledge may not be correctly acquired. In [3], a study of this question in relation to the particular case of students with difficulties in acquiring knowledge in topics related to energy conservation was undertook. They detected

IntechOpen

that students had difficulties in acquiring skills because of the presence of complex scientific concepts and because they found the topic to be monotonous. In [1], it was identified how the active learning process improves the cognitive engagement with concepts in the classroom.

Autonomous learning, accompanied by a close follow-up on the part of the teacher, is one of the strategies that can be used to achieve better learning results in certain specific topics and to optimize skills acquisition [2, 6–11].

In [11], the importance of autonomous learning was established, defining it as a process in which the individual takes the initiative, with or without the help of others, in diagnosing the learning needs, formulating the learning targets and identifying the human and material sources required for the learning process. In [7], the importance of the developing skills in autonomous learning by engineering students is pointed out, as a way to support life-long learning. In [8], the feasibility and functionality of the implementation of autonomous learning in Pakistan are analysed, studying for this purpose the particular case of the teaching of English in four universities in the country. The professors concluded that the implementation of autonomous learning techniques helps to make students more self-sufficient. In the implementation process of the techniques they used, they observed different obstacles that arose as result of particular features of the education system in their country, cultural precedents and certain psychological aspects of the students.

When autonomous learning is assimilated by a student, it can subsequently be transmitted to the rest of the students as a collaborative learning strategy [12] and as a complement to the classes of the teacher. The benefits of collaborative learning include: development of higher-level thinking, oral communication, self-management, leadership skills, promotion of student-faculty interaction; increase in student retention, self-esteem and responsibility and a better understanding of diverse perspectives [13]. In [14], the collaborative problem-solving games into spatial dialogues in a virtual cellular biology game is explored.

Various techniques found within the framework of active learning processes can be used in collaborative teaching as alternatives to traditional processes [12, 15–19].

In [12], a particular case of the teaching of mathematics is studied as part of the Business Administration Degree at the International University of Catalunya (Spain). They had noted a certain lack of motivation on the part of the students with respect to this subject and began to use game-based learning (GBL) techniques with the aim of stimulating interest in it. According to the authors, the results obtained were very promising. In [19], how collaborative inquiry learning offers educators a context within which support can be found for the understanding of scientific-technological concepts is analysed. In their case study in the United States, they used both GBL and problem-based learning (PBL) techniques.

From the analysis carried out on the scientific publications found, it can be deduced that all of them make exclusively a qualitative analysis from their experiences. In addition, in their studies they use a single technique in the collaborative learning process, generally game-based learning.

An interesting and useful technique for the transmission of acquired knowledge to the rest of the students when the number of students is high, and/or when insufficient time is available in the in-person class, involves the making of mini-videos (less than 10 minutes long) in which each student transmits the knowledge they have acquired [20–23]. Supervised and monitored by the teachers, these videos can subsequently be published in a virtual environment, open to the other students, so that they can view them and use them as an educational complement.

In the study presented in the present paper, a specific method is developed within the framework of the active learning process. The method is applied to the particular case of the learning of a topic related to systems engineering and automation. The original contributions of this study are as follows:

a. In the phase of collaborative learning, three different techniques have been used

b. The degree of improvement attained by each student during the development of the activity was quantified. The cases in which the improvement was particularly high were identified.

2. Methods and materials

2.1 Method

Among others, the Center for Teaching Innovation of Cornell University [13] defines different basic aspects that need to be considered when establishing an innovative method related to active learning. With this in mind, and for the particular case study presented in this paper, the method developed by the authors is structured into four stages (**Figure 1**).

- Activity preparation stage
- Autonomous work stage
- Collaborative work stage
- Assessment stage of the success of the method

The activity that is developed will serve as a complement to the classroom teaching, and the active learning during the autonomous and collaborative work stages will serve as reinforcement for the students in the assimilation of competencies.

2.1.1 Activity preparation stage

At the beginning of the term, a clear description and explanation of the activity and its purpose are given to the students. The rules for participation in the activity and the marking criteria are explained (**Figure 1**).

For the case study, the activity was obligatory and the mark given to it corresponded to 5% of the total mark for the subject.

The teacher, after looking at the historical data on the topics and/or concepts that have commonly presented certain assimilation difficulties on the part of students, designs related work activities. The random formation of groups with a maximum of two students is proposed. Each group is then randomly assigned the task of preparing a series of concepts linked with one of the specific topics (hereinafter referred to as STO). Work on concepts related to the same STO can be assigned to different groups.

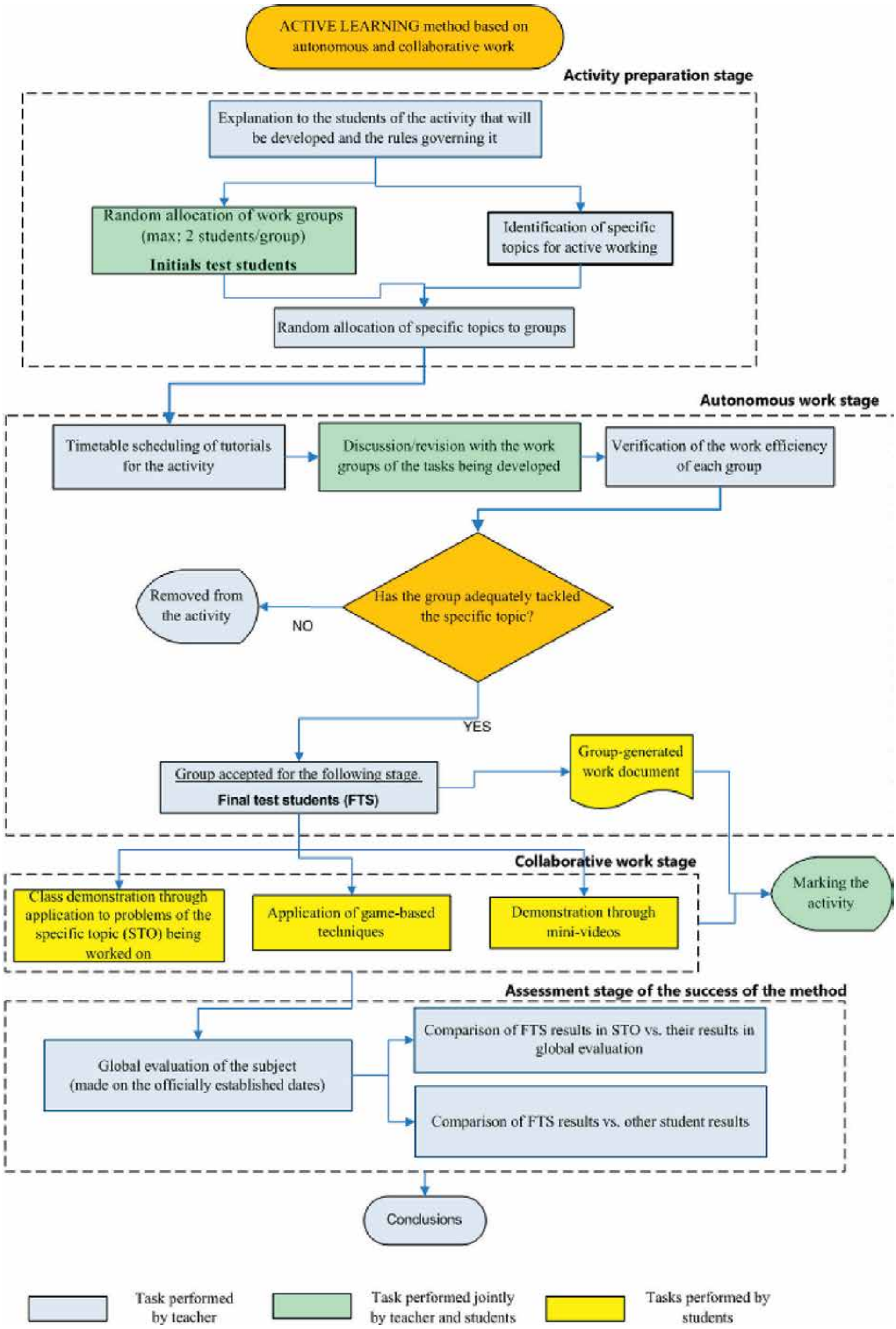


Figure 1.
Method applied to the case study.

Initially, in the case study, tasks linked to six STOs of the subject were assigned, ensuring that each STO was tackled by a minimum number of students.

For the development of the collaborative work stage, each group is assigned one of the following techniques: PBL directly in the classroom, the application of GBL directly with the rest of the students or the making of mini-videos with a maximum duration of 5 minutes which, after inspection by the teacher, are uploaded to the virtual environment of the subject in question to be shared with the other students who signed up for the subject.

2.1.2 Autonomous work stage

For the follow-up of the work of each group, the professor arranges voluntary tutorials at specific times and dates outside the teaching timetable.

For the case study, 4 h were allocated each week in the virtual environment for 15-minute sessions with each group should they require assistance with the task.

Each group can request a date and time through the virtual environment of the subject in question. In this stage, the professor monitors the work of each group to ensure the subsequent success of the collaboration stage, helping the students in the development of the required skills, the approach to typical problems, reflection techniques, etc. Any group that does not implement this stage in an appropriate way is removed from the activity and is given a mark of 0. The groups that perform this stage correctly advance to the collaborative work stage. Prior to commencement of the collaborative stage, the groups have to prepare and submit a document explaining the work that has been developed along with the guidelines they will follow for that stage. These documents are uploaded to the virtual environment of the subject in question which the other students will have access to.

2.1.3 Collaborative work stage

In this stage, each group has to transmit to the rest of the class the knowledge that they have acquired in the STO they have been working on. For this, they use the PBL, GBL or mini-video strategy. The mini-videos must be viewed individually by the other students in the class. This latter strategy is particularly useful when there are time restrictions and/or a large number of students have signed up for that particular subject.

2.1.3.1 Marking the activity

The student must have advanced to the collaborative work stage for the work developed to be evaluated and awarded a mark. The weight of the mark given is evenly split between the assessment of the professor and the assessment of the other students in the class (except for the second member of that student's work group). The mark given should take into consideration the document presented in the autonomous work stage as well as the activity developed in the collaborative work stage (see **Figure 1**).

For the assessment made by the students themselves of the work of their classmates, a questionnaire has been developed using a five-point Likert scale [24]: 1: Very poor; 2: Poor; 3: Sufficient; 4: Good; 5: Excellent. Aspects such as the following should be evaluated:

- The effort made by each group in the activity
- The clarity and the methodology followed in the work during the collaborative work stage.

2.1.4 Assessment stage of the success of the method

Finally, for the evaluation of the success of the method, the results from three of the six STOs were used. The groups which participated in the three STOs which were discarded had not performed the task in the prescribed manner (**Figure 1**). The students who worked on the selected STOs are given the name of final test students (FTSs).

The data considered for the assessment of the success of the method applied to the case study are the results obtained in the official examinations and on the official dates for the subject in question. For the purposes of the assessment, this official examination should clearly differentiate between the different STOs worked on in the learning activity, allowing a mark for all students for each STO as well as a global mark in the subject.

The following data are analysed in the assessment of the success of the method:

a. Comparison of the global mark obtained by each FTS in the official exam of the subject with the mean global mark of all the students.

b. Comparison of the mark obtained by each FTS in the official exam in the STO on which the FTS worked with the mean mark of all the students.

c. Comparison of the relative grades of each FTS obtained in the STO that the FTS worked on and in the global subject.

2.2 Materials

One of the subjects taught in the School of Industrial and Civil Engineering as part of the Industrial Organization Engineering Degree is Control Engineering. Within the structure of the degree course, it is considered part of the 'Automation' material. The degree comprises four academic years of two terms each, with a total of 240 ECTS (European Credit Transfer and Accumulation System) credits [25]. The Control Engineering subject is given in the second term of the third year of the course.

The degree meets all the official teaching regulations in Spain and has been subjected to and passed an evaluation process in accordance with the protocol established by the corresponding State and Autonomous Community agencies. It additionally complies with the quality criteria and standards established by the European Association for Quality Assurance in Higher Education (ENQA) [26] and is registered in the Spanish Registry of Universities, Centres and Qualifications (Spanish initials: RUCT) [27].

The so-called Verification Report (Memoria de Verificación in Spanish) is the reference document for each official qualification in the Spanish state. The document includes the objectives, competencies, academic structure, available resources, etc. for each qualification, including the reference degree of the present case study. In point 2 of the corresponding Verification Report, the competencies associated to the degree in question are listed, the following of which can be highlighted:

- Transversal competency G6: 'AUTONOMOUS LEARNING. Detecting deficiencies in one's own knowledge and overcoming them through critical reflection and choosing the best option to extend this knowledge'.

This competency is associated to the reference subject in its corresponding Teaching Programme.

The case study considered in the present paper was undertaken for the aforementioned subject of Control Engineering during the 2018/2019 academic year. The number of students included in the initial stage of the trial was 37, with a total of 20 groups being formed (see **Figure 1**). As an additional tool, the virtual work environment of the reference university was also used for the management of the activity.

3. Discussion of the results

Following the criteria established in the methodology (see section 2.1.4), a total of 17 students advanced to the collaborative work stage and were thus considered FTSs. These 17 students worked on three of the STOs that were initially proposed in the activity. **Table 1** shows the STOs that were finally evaluated and the corresponding number of FTSs.

Figure 2 shows the results of the comparison of the marks obtained by each FTS in the global examination of the subject with the mean mark obtained by all the students. It can be seen that some of the FTSs had general difficulties in assimilating concepts of the subject, while others appear to have found it easier.

Figures 3–**5** compare the mean grade obtained by each FTS in the specific parts of the global exam concerning the three STOs that were worked on with the mean grade of all students in the same STO. In general terms, it can be seen that whereas a total of 7 FTSs scored below the mean grade in the global exam of the subject (see **Figure 2**), for the case of the results in the STOs, only two of these (FTS-1 and FTS-5) were awarded a grade below the mean value of all students.

To better evaluate the improvement in the results of each FTS as the result of the application of the method developed in the present paper, the so-called relative grade (RG) metric was used (Eq. 1):

ID specific topic	Description	ID of the FTS
STO1	Stability of the response of dynamic systems. Root locus	FTS-1 to 7
STO2	Applications of control actions in industrial processes. PID control	FTS-8 to 11
STO3	Dynamic systems modelling	FTS-12 to 17

Table 1.
Description of specific topics (STOs) worked on by the final trial students (FTSs).

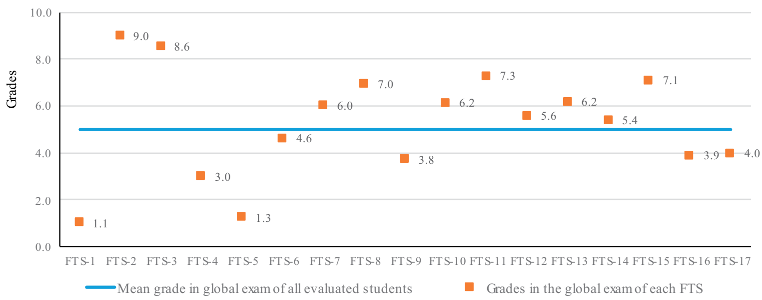


Figure 2.
Comparison of the grade of each FTS in the global exam with the mean grade of all students (minimum grade of 0 and maximum of 10).

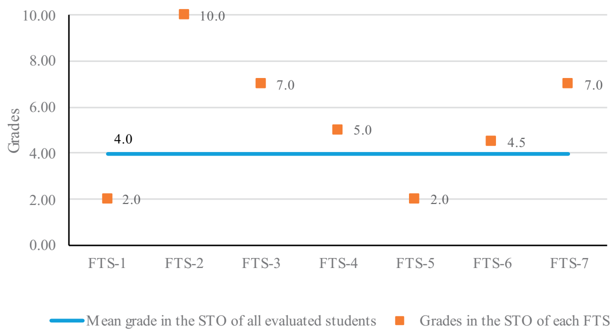


Figure 3.
Comparison of grade awarded in STO-1 by each FTS with the mean grade of all students ((minimum grade of 0 and maximum of 10).

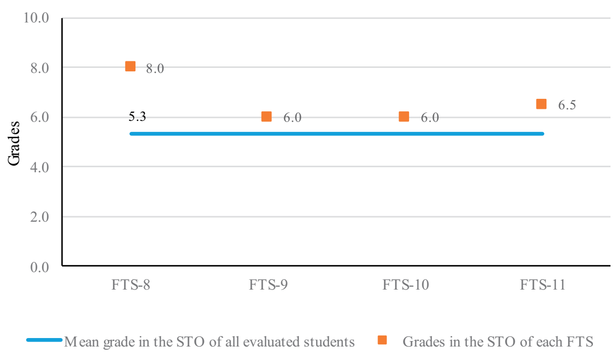


Figure 4.
Comparison of grade awarded in STO-2 by each FTS with the mean grade of all students ((minimum grade of 0 and maximum of 10).

$$RG = \frac{G\_FTS_i - \overline{Grade}}{\overline{Grade}} \quad (1)$$

where G_FTS_i is the grade obtained by each FTS, and $\overline{Grade}$ is the mean grade of all the students who sat the exam.

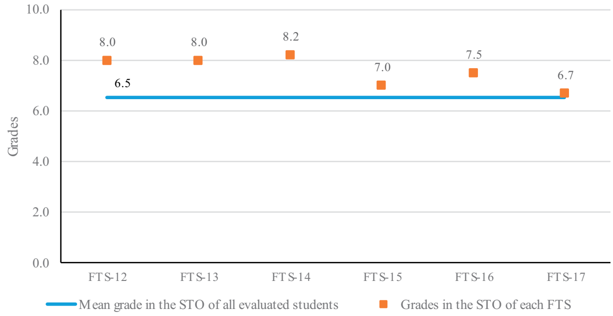


Figure 5.
Comparison of grade awarded in STO-3 by each FTS with the mean grade of all students ((minimum grade of 0 and maximum of 10).

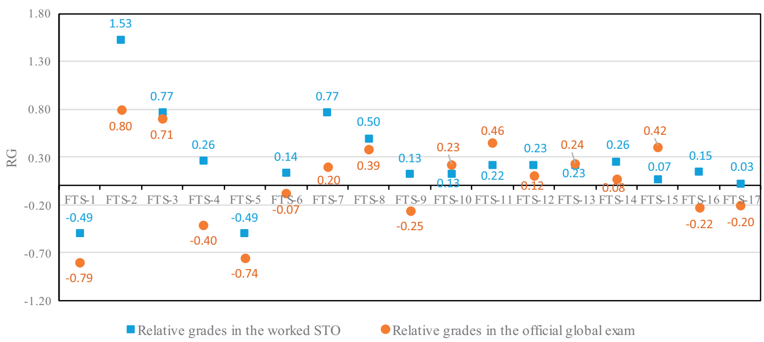


Figure 6.
Comparison of relative grades for each FTS.

Figure 6 compares the RGs for each FTS obtained in the global exam (**Figure 2**) with those obtained in the different STOs (**Figures 3–5**). It can be seen that 13 of the 17 FTSs improved their relative results as the result of the application of the innovative educational method developed. It should be highlighted that all the FTSs who had difficulties with the assimilation of concepts of the general subject (FTSs with values of RG<0 in the official global exam) improved their RGs in the STOs that they worked on.

Statistical analysis is performed to check the effect of the application of the proposed method. Since we want to evaluate the degree of association or independence between a quantitative variable and a categorical variable, the inferential statistical procedure resorts to comparing the means of the distributions of the quantitative variable in the different groups established by the categorical variable. Being this dichotomous, t-test with a significance value of 0.05 was used. Further, the parametric requirements are met, such as the normal distribution of the quantitative variable in the groups that are compared and the homogeneity of variances in the populations from which the groups come [28].

First, it was evaluated the difference between the results obtained for the RG in the worked STO with those in the official global exam (**Figure 6**). These values were compared with a null hypothesis where that difference was less than or equal to zero. So, it obtained a p value of 5.4E-3. This indicates that student improve their results when the proposed method was applied.

4. Conclusions

After application of the method developed in this paper, student assimilation of competencies which had historically presented certain difficulties improved in general. A total of 88.2% of the final test students (FTSs) who used the proposed method obtained higher grades in the specific topic they were working on than the mean grade of all the students. In addition, 76.5% of the FTSs obtained a higher relative grade (RG) in the specific topic they were working on with the proposed method than the RG they obtained in the global exam of the subject, with this value rising to 100% in the case of FTSs with the highest difficulty in the subject (with an $RG<0$ in the global exam).

The p value obtained in the statistical analysis guarantees the results obtained with the proposed method. It can be applicable to subjects in any branch of science, as a way to improve the assimilation of competencies that students tend to have difficulties with.

Acknowledgements

This research has been co-funded by ERDF funds, INTERREG MAC 2014-2020 programme, within the ACLIEMAC project (MAC2/3.5b/380). No funding sources had any influence on study design, collection, analysis or interpretation of data, manuscript preparation or the decision to submit for publication.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Author details

Sergio Velázquez-Medina[1*] and Pedro Cabrera-Santana[2]

1 Department of Electronics and Automatics Engineering, University of Las Palmas de Gran Canaria, Canary Islands, Spain

2 Department of Mechanical Engineering, University of Las Palmas de Gran Canaria, Canary Islands, Spain

*Address all correspondence to: sergio.velazquezmedina@ulpgc.es

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Wu SPW, Van Veen B, Rau MA. How drawing prompts can increase cognitive engagement in an active learning engineering course. Journal of Engineering Education. 2020;**109**:723-742

[2] Martínez-Rivero MD, Hernández-Castellano PM, Marrero-Alemán MD, Suárez-García L. Material didáctico sobre la selección de procesos de fabricación. In: V Jornadas Iberoamericanas de Innovación Educativa en el Ámbito de las TIC y las TAC. 2018

[3] Szu-Wei C, Chih-Hui Y, Keng-Shiang H, Shen-Li F. Digital games for learning energy conservation: A study of impacts on motivation, attention, and learning outcomes. Innovations in Education and Teaching International. 2019;**56**(1):66-76

[4] DeLisi J, Kook JF, Levy AJ, Fields E, Winfield L. An examination of the features of science fairs that support students' understandings of science and engineering practices. Journal of Research in Science Teaching. 2021;**58**:491-519

[5] Voon XP, Wong LH, Looi CK, Chen W. Constructivism-informed variation theory lesson designs in enriching and elevating science learning: Case studies of seamless learning design. Journal of Research in Science Teaching. 2020;**57**:1531-1553. DOI: 10.1002/tea.21624

[6] Gerard L, Wiley K, Debarger AH, Bichler S, Bradford A, Linn MC. Self-directed science learning during COVID-19 and beyond. Journal of Science Education and Technology. 2021;**31**:258-271. DOI: 10.1007/s10956-021-09953-w

[7] Marra RM, Hacker DJ, Plumb C. Metacognition and the development of self directed learning in a problem-based engineering curriculum. Journal of Engineering Education. 2022;**111**:137-161. DOI: 10.1002/jee.20437

[8] Musarat Y, Farhat N, Isamar CM. Teacher-directed learning to self-directed learning transition barriers in Pakistan. Studies in Educational Evaluation. 2019;**61**:34-40

[9] Oddone K, Hughes H, Lupton M. Teachers as connected professionals: A model to support professional learning through personal learning networks. The International Review of Research in Open and Distance Learning. 2019;**20**(3)

[10] Borg S, Al-Busaidi S. Teachers' beliefs and practices regarding learner autonomy. ELT Journal. 2012;**66**(3):283-292

[11] Knowles MS. Self-directed Learning: A Guide for Learners and Teachers. New York: Association Press; 1975

[12] Gil-Doménech D, Berbegal-Mirabent J. Stimulating students' engagement in mathematics courses in non-STEM academic programmes: A game-based learning. Innovations in Education and Teaching International. 2019;**56**(1):57-65

[13] Cornell University. Center for Teaching Innovation. Collaborative Learning. 2021. Available from: https://teaching.cornell.edu/teaching-resources/engaging-students/collaborative-learning [Last accessed: June 6, 2021]

[14] Uz-Bilgin C, Thompson M, Anteneh M. Exploring how role and background influence through analysis of spatial dialogue in collaborative problem-solving games. Journal of Science Education and Technology. 2020;**29**:813-826

[15] Polytechnic University of Madrid. IEA 6: Componentes de la innovación educativa. El símil de la silla" (in Spanish). 2013

[16] Naik N. The use of GBL to teach mathematics in higher education. Innovations in Education and Teaching International. 2017;**54**:238-246. DOI: 10.1080/14703297.2015.1108857

[17] Takeuchi H. The new dynamism of the knowledge-creating company. Knowledge Economy. 2006;**1**:1-10

[18] Sesen BA, Tarhan L. Active-learning versus teacher-centered instruction for learning acids and bases. Research in Science & Technological Education. 2011;**29**:205-226

[19] Saleh A, Yuxin C, Hmelo-Silver CE, Glazewski KD, Mott BW, Lester JC. Coordinating scaffolds for collaborative inquiry in a game-based learning environment. Journal of Research in Science Teaching. 2020;**57**:1490-1518. DOI: 10.1002/tea.21656

[20] Oseni Z, Than HH, Kolakowska E, Chalmers L, Hanboonkunupakarn B, McGready R. Video-based feedback as a method for training rural healthcare workers to manage medical emergencies: A pilot study. BMC Medical Education. 2017;**17**:1-11

[21] Reher V, Rehbein G, Reher P. Integrating video recording and self-reflection to enhance communication skills training for dental students. IFMBE Proceedings. 2020;**69**:715-719

[22] Young PW. Student-produced video of role-plays on topics in cell biology and biochemistry: A novel undergraduate group work exercise. Frontiers in Education. 2020;**5**:115. DOI: 10.3389/feduc.2020.00115

[23] Donkin R, Askew E, Stevenson H. Video feedback and e-Learning enhances laboratory skills and engagement in medical laboratory science students. BMC Medical Education. 2019;**19**(310):1-12. DOI: 10.1186/s12909-019-1745-1

[24] Fabila AM, Minami H, Izquierdo MJ. La Escala de Likert en la evaluación docente: acercamiento a sus caracterísiticas y principios metodológicos. Textos y Contextos. 2013;**50**:31-40

[25] European Comission. European Credit Transfer and Accumulation System. 2021

[26] European Association for Quality Assurance in Higher Education –enqa. 2021. Available from: https://www.enqa.eu/about-enqa/ [Last accessed: October 4, 2021]

[27] Spanish Ministry of Science, Innovation and Universities. Registry of University Centres and Qualifications. 2019

[28] Rubio-Hurtado M, Berlanga-Silvente V. Cómo aplicar las pruebas paramétricas bivariadas t de Student y ANOVA en SPSS. Caso práctico. REIRE, 5, n° 2. 2012. 10.1344/reire2012.5.2527 (in Spanish)

Chapter 7

Perspective Chapter: Active Learning Strategies in the Veterinary Medicine Programme under the Think4Jobs Project

Rita Payan-Carreira, Hugo Rebelo and Luís Sebastião

Abstract

Active learning has been introduced in the Universities to reinforce the students' skills development and increase their motivation and engagement while also fostering the transferability of knowledge into the profession, contrasting with a classical approach, where passive knowledge transfer occurs, and students act as sponges for information. Albeit not completely conceptualized, active learning demands the student's involvement with the learning activities, the analysis and ability to respond to specific situations, and a critical reflection on the learning process. In Health Sciences, case-based and cooperative learning are among the most used active learning strategies. They present multiple configurations and vary greatly in terms of implementation. Students' adherence to active learning depends on the perceived utility, level of effort requested by the activities, and self-confidence in the quality of achieved learning. Under the Think4Jobs, an Erasmus+ project, a University-Business collaboration was implemented to design work-based activities for pilot courses of the Veterinary Medicine program aiming to increase the students' adherence to active learning strategies while reducing any mismatch in students' competencies at graduation. In this chapter, we propose discussing how the collaboration was conceptualized and implemented. We also present some activities jointly designed to foster students' clinical reasoning/critical thinking and decision-making.

Keywords: skills development, competency-based education, work-based learning, university-business collaboration, learning activities, clinical reasoning, critical thinking

1. Introduction

Active learning has been the center of attention for researchers and teachers looking for less traditional meaningful learning activities. Active learning is an instructional approach that centers the learning process in the student. It uses different activities and situations designed to promote the acquisition of knowledge and skills, through the application of higher-order cognitive processing abilities, to construct new knowledge, train skills and competencies, and further reflect on their performance in the learning process [1].

During active learning, students are immersed in meaningful experiences, designed to conduct them toward the learning outcomes proposed, either in the domain of cognitive knowledge or skills development. The most interesting aspect of active learning is that it pushes the student to go beyond the factual knowledge to grasp conceptual and procedural knowledge, an "in-depth understanding". That will allow transferring factual knowledge into multiple and different situations.

The active learning concept embeds in the constructivism framework of learning since it empowers the student as the conscious constructor of his/her knowledge, allowing him/her to regulate the learning process [2] accommodating personal traits while also coping with the academic demands.

The interest in active learning has grown in the past decades. It contrasts with the classical teaching approach, where a passive knowledge transfer occurs, and students act as sponges for information [2], while the measurement of knowledge acquisition is usually focused on factual knowledge, focusing on memorization [3], without deep thinking of the content. In the classical passive learning, memorized knowledge is lost more quickly, making it more demanding for the student to translate it to solve new challenging situations, which command independent thought [4, 5].

Policymakers worldwide, including the OECD [6] demands educational systems thriving for more than factual or unreflective learning, fostering in the students the competencies need to understand the modern world and succeed in their profession. Those competencies encompass higher-order and complex thinking skills along with procedural knowledge and the ability to work in multidisciplinary teams. Two of the utmost sought skills in a broad scope of occupations are creativity and critical thinking., allowing the future professional to cope with the expanding digitalization and automation of the job market, and the multicultural aspect of the profession.

Active learning has been adopted by universities to reinforce the development of students' skills, and increase their motivation and engagement while also fostering the transferability of knowledge into the professional context [7]. Although not completely conceptualized [7, 8], active learning includes multiple learning strategies, as it also grows to adjust to the transformations occurring worldwide at multiple levels. Active learning demands the student's involvement with the learning activities, the analysis and ability to respond to specific situations, and a critical reflection on the learning process to be successful.

The closer to the professional context, the most motivational and enthralling the activity will be for students. Moreover, the need and importance of the course content become more explicit to students, which may be central in foundational courses [9]. It is generally accepted that active learning is a good way to train and enhance the students' abilities and competencies needed for the workforce. Besides, policymakers worldwide advocate the need to strengthen critical thinking in learners across all levels of education, preparing them as active and participative citizens, able to transpose into the labor market the competences developed during learning [6].

In the case of Veterinary Medicine graduation, Universities are constantly challenged to provide day one, job-ready graduates into the labor market, while also keeping pace with the rapidly expanding technical and scientific knowledge and meeting the business expectations about the minimum competencies mastered by day-1 graduates [10]. This means that Universities must ensure the development of cognitive knowledge (or hard skills) as well as inter-personal, social, and communication abilities (or soft skills) [11]. Albeit the universities often focus on the former to grade the students, the latter should not be forgotten when assessing students' performance. Besides, it is noteworthy to stress that not all the active learning methodologies will similarly develop specific cognitive or soft skills. Therefore, it may not be possible to use the same strategies to enhance soft skills and hard skills, and it may be necessary to select different active learning techniques, adapting them to the skills to be strengthened in students or the goals established [11].

Under the Erasmus+ project Think4Jobs (2020-1-EL01-KA203-078797), several focus groups (FG) were organized to gather the opinion of professionals' stakeholders and academics about an eventual mismatch in critical thinking competencies they found in recent graduates during traineeships. The FG showed that stakeholders have a different conceptualization about the skills and dispositions deemed as crucial in professional contexts than the academic representatives, even though they consider the trainees to possess a good level of cognitive knowledge [12]. Recently, it has been demonstrated that in most cases, the attendance of a university using the classical learning approach, is insufficient to promote students' creative and CT skills [13], somehow supporting the perceptions of the interviewed stakeholders.

Taking those findings into consideration a University-Business collaboration was implemented to design some work-based activities to be included in piloting course curricula for the master's Program in Veterinary Medicine at Univ of Évora.

In this chapter, we propose discussing how the collaboration conceptualized and implemented activities using a case-based strategy to reinforce critical thinking skills and dispositions in students. We also present some activities jointly designed to foster students' clinical reasoning, critical thinking, and decision-making.

1.1 Case- and problem-based learning as active strategies

In health sciences, case-based and problem-based learning (CBL and PBL, respectively) strategies, often developed cooperatively, are among the most common approaches to active learning. Both these strategies are based on problem or scenarios, but they present multiple configurations and varies greatly in terms of implementation and the content of the course. At their base, CBL and PBL present the students with situations that mimic real-life challenges or problems that need solving using core knowledge. By using a real work context in the activities, and requesting the students to engage with real-life tasks, would foster the transferability of the outcoming competences [14]. The problematization focus on the development of high-order thinking skills, teamwork, communication and other interpersonal skills, and the ability to act upon an informed, strong decision-making process. CBL and PBL strategies share common features and present also important differences. Still, in some situations developed in medicine and nursing, the format of the activities identified as CBL and PBL became similar and the limits between the conceptualization of the two strategies overlap.

Both strategies rooted in a constructivist approach to knowledge construction, allowing the students to combine theory with practice, to mobilize acquired knowledge and skills into the construction of a solution for an ill-defined situation issued from critical issues or case-scenarios faced by the workforce [15]. With time, CBL and PBL conceptualization suffered multiple adaptations; nowadays, in some situations is not always easy to distinguish between them. Still, in their purest forms, two main differences persisted [10, 16]: 1/ the possible solutions to the problem provided are roughly defined at the beginning (that is, the situation is somehow structured) and the student uses core knowledge previously acquired to solve the situation in CBL, whereas in PBL the student is requested to identify and acquire new knowledge that is necessary to reach a solution, which is usually not previewed at the beginning of the activity (i.e., the situation is less structured); 2/ PBL extension is usually longer (up to one semester/term)than in CBL, which generally demands a solution in a short time frame (few hours). **Table 1** summarizes the major similarities and differences between CBL and PBL.

In general, the students' perceptions about the use of PBL or CBL strategies in learning are positive [1, 17]. However, in the practice, it is often debated that students' adherence to PBL or CBL, as in other active learning strategies, is not always similar, and may depend on their perceptions of the components of the strategy used (including the relationship established with the teacher or tutor), the perceived utility,

Parameter	PBL	CBL
Activity goals	Aims at the development of students' skills in solving problems, collecting information, critical thinking and collaborative work	Mainly targets the students' learning based on clinical cases: how to reach a diagnosis, to prioritize information, medical management, how to select therapeutic approaches, etc.
Focus	The resolution of the problem is at the focus of the activity, not the content of the problem or scenario	The construction of knowledge related with the clinical practice (learn how to address a clinical situation, identify a disease or a health problem, to engage with the patient, to manage the patient) Albeit the solution for the clinical condition is often request, it may be in the second plan.
Type of problem/ scenario	Usually, the starting point is an ill-defined situation	Often, the problem or scenario is rather specific
Learning outcomes	The learning outcomes are poorly defined at the beginning of the activity. The students narrow them through the activity, generally after brainstorming meetings where the available solutions are discussed, and they select the one to use to solve the problem.	The learning outcomes are pre-determined, even if faintly, by the teacher at the beginning of the activity.
Learning	The acquisition of specific learning is a crucial goal of the activity; therefore, it is not presented at the beginning of the activity. Often request the mobilization or acquisition of a multidisciplinary knowledge Tutorial sessions are coordinated in small group of students.	Students are challenged to mobilize previously acquired knowledge, also defined before the activity begins. Nevertheless, it may be possible that students need to deepen the level of knowledge or acquire new information.
Student's role	Students are active participants. Expectably, students must raise questions and explore the topic. Students must enroll in self-learning supported by the tutorial sessions. The discussion of possible solutions drives from self-direct learning to support the learning outcomes definition directed to the solutions to propose. As a team member, the student should contribute to the team success	Students are active participants Expectably; students must prepare in advance and to raise questions directly respecting the problem or scenario. Ever so often, students may need to complete they knowledge, if the need arises. As a team member, the student should contribute to the team success

Parameter	PBL	CBL
Tutor/ teacher role	The tutor must provide the triggering situation or problem and any additional information according to the need. Expectably, he will have limited intervention regarding the alternatives or solutions offer. Instead, he should provide students with soft scaffolding questioning. The tutor should play a more passive role, more observational in nature, shepherding the group through impasses, and avoiding participating directly in the solution proposal.	The tutor must provide the situation or problem or scenario. Expectably, he orientates the discussion and the acquisition of specific knowledge, as well as the entire activity, so the learning outcomes may be reach. The tutor must maintain the students focus on the case provided, avoiding out-of-context discussions. He ensures that the correct answers are made aware of the participants.
Content	The activity usually lasts for multiple sessions (classes or weeks) as the focus is put in the process.	Often the activity is developed for a short time (one or two sessions or classes), around a case.
Activity outcomes	The outcomes should be assessed according to the defined for the learning outcomes, to determine the students' achievements.	The activity outcomes focus on the cognitive process besides the skills defined in the learning outcomes, and the assessment should encompass both.

Table 1.
Main differences between case-based and problem-based learning as used in health sciences.

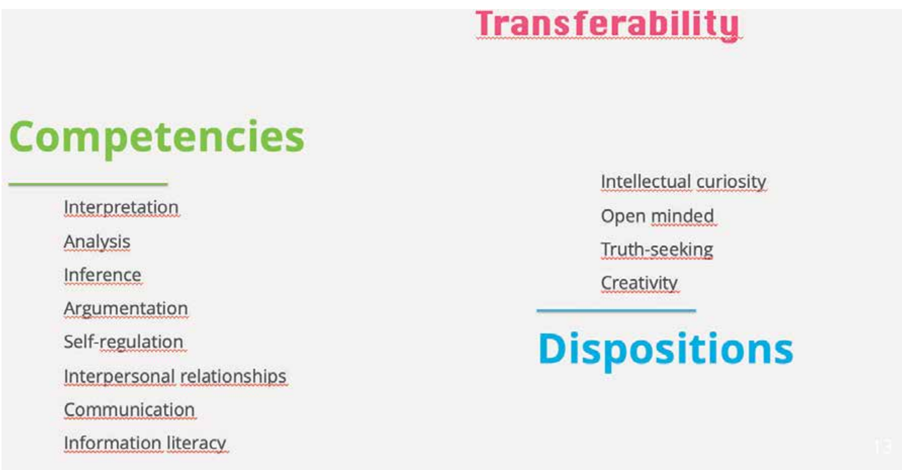


Figure 1.
Summary of the main competencies endorsed in PBL and CBL.

the level of effort requested when engaging in the activities, or their self-confidence in the quality of learning achieved [18, 19].

In addition to the acquisition of cognitive knowledge, PBL and CBL allow the student to develop multiple competencies, some of which are illustrated in **Figure 1**. Ideally, when assessing the activity outcomes, and considering that the student must be graded at the term end, the achievements in both cognitive and ex-cognitive competencies should be foreseen. **Table 2** presents available tools to be included in PBL and CBL activities that will be useful to assess the students' achievements.

Skills/learning outcomes	Assessment tool
Knowledge acquisition or application	Critical case-based assays, depicting the reasoning process, presenting identified difficulties or knowledge gaps, and explicating errors or missteps occurring across the activity and the way they were overcome.
	Written assessments
	Concept maps or diagnostic algorithms, constructed by students.
Problem solving and critical thinking competences	Triple Jump [*assessment method focusing both the quality of knowledge gained through the activity and how they learned it*] [20]
	Written assessments or assignments
	Viva voce/oral examinations, based in structured questions combined in cards that encompass different knowledge levels and skills
	Script concordance tests, that compare the degree of concordance between students' solutions with those of experts [21]
	Presentation of the proposed solution before a group of stakeholders or experts
Communication and teamwork skills	Participation in tutorials—via the reports of tutor and peers
	Auto- and hetero-evaluation questionnaires, used to the appraisal of the group performance.
	Written reports
	Role-playing [not necessarily as acting according to a role, but rather thinking form the position of someone in that scenario]
	Online blogs/chats/forums
Self-direct learning skills/ self-study	Independent study report
	Report of search strategies
	List of references (e.g., introduced in an assay or in other assignments)
	Oral presentation / written report
Reflection	Reflective diaries
	Oral presentation
	Portfolio

Adapted from Ref. ([22], p.175).

Table 2.
Tools available to assess the students' performance in active learning strategies.

2. Business-university partnership in the designing of active learning activities

Stage one of the Think4Jobs project established the recommendations for the Veterinary Medicine Program and allowed to identify the crucial competencies stakeholders deem as essential at the entrance of the final traineeships and in young graduates. Briefly, the competencies identified to fit the skills and dispositions already identified under the critical thinking concept [23] including the ability to question, the analytical skills, a structured way of reasoning, decision-making, autonomy, and self-correction [12]. These recommendations were used as a starting point for the design of the work-based activities, adequate for the course content, to be implemented in piloting courses on the master's Program in Veterinary Medicine. The ultimate purpose was to increase the students' adherence to active learning strategies while reducing any mismatch in students CrT skills and competencies at graduation, as perceived by stakeholders. Moreover, the activities aimed at representing situations currently found in the routine of the profession, bridging the course content directly to the critical reflection and decision-making often requested from a Veterinary Surgeon in a wide scope of occupations.

2.1 Conceptual aspects to consider when designing the activities

The activities were designed considering the following conceptual views:

1. Regarding the CrT instruction—the development of CrT competences followed a mixed approach, i.e., combining the Abrami et al. [24] definitions of an infusional (CrT is taught in an explicit way within a particular subject matter or content) and immersive (CrT is taught implicitly within a particular subject matter or content)

2. Regarding the blended-learning conceptualization—the activities were designed considering the methodical level (i.e., combining both self-directed with instructor-led learning, and the individual with cooperative learning) and the level of the media (ie., combining face-to-face with online elements) [25]

3. At the level of media used, the blended-learning design followed a low-impact blending model [26], i.e., extra online activities were added to an existing face-to-face course

4. The situations to be used in the blended activities would be retrieved from daily professional contexts and its selection would result from a previous discussion between HEI and LMO representatives. Until now, in the project, the *University of Évora* partnered with *Hospital Veterinario do Atlântico*, but the partnership will be extended to other LMO, because of the wide range of expertise areas tackled by the Veterinarians

5. The activities will be scaffolded with debates or questioning allowing a dynamic interaction between the student and the teacher and a critical reflection on the reasoning process, and the decision proposed by the students (from among different approaches, the student must select the one he/she considers the most adequate for a particular situation), while allowing the students to learn from mistakes and errors, in controlled settings [12].

6. Whenever necessary, the proposed activities can be bridged to additional activities of a practical and technical nature, to be developed during intramural traineeships (using entrustable professional activities—or EPA)

For the design process of the active strategies, and because most courses in the clinical area share common goals (the need for the critical assessment of a medical situation that needs solving through a corrective medical or surgical intervention—decision making), the HEI and LMO partners decide on proposing a common framework that could be used across multiple courses. By sharing the same framework, the differences in the clinical case used for stating the activity would provide wider flexibility to the process, promote multiple repetitions of the framework in different contexts which would likely foster the sought transferability of skills, and would also cope with the individual content of the syllabus of each course (which has been validated by a national entity that evaluates the programs' curricula).

In the veterinary daily practice, the professional intervention involves either well-structured situations (e.g., for vaccination or sanitary procedures, and some routine or elective surgeries) or ill-structured challenging situations (e.g., during emergency situations). The partners decide on the use of a moderately ill-structured situation for starting the proposed activities, allowing to use different difficulty levels to match the level of difficulty to the students' program level as well as to the topic at hand in a particular course or apprenticeship. Moreover, the activities aimed at the development of factual and conceptual knowledge and high-order thinking so in the end, they would enhance the student's autonomous decision-making.

The learning scenarios designed will support CrT skills and dispositions development and will allow students to switch their reasoning from a disease- or system-based thinking into patient-based thinking conductive of a successful medical decision-taking for problem-solving [12].

2.2 Proposed activity framework for courses in the clinical areas

The framework for the learning scenarios aims at engaging students in the analysis of clinical condition-issued from everyday practice of a veterinary hospital and to decide on the best intervention possible for the clinical condition considering the animal and owner context, resourcing to high-level reasoning, scaffolded by questions. Overall, this approach will contribute to the enhance students' CrT skills.

The case scenario used as starting point is purposely left blank allowing the teacher to select particular situations, adapted to the course content, considering the targeted species or the medical specialties (e.g, Gynecology and Obstetrics, Infectious Diseases, Ruminants Clinics, Small Animals Clinics, Surgery in Companion Animals). The elements to be included in the scenarios and the activity steps follow a medical model [27].

These activities can be implemented during classes, but they may also be transposed into a traineeship context, and to improve the discussion of clinical situations during the clinical rotations. Through the activities, students are encouraged to develop their autonomy in core medical procedures (e.g., collection of clinical history, deciding on the complementary exams needed to direct the diagnosis, discussing available therapeutic approaches with a third party, and engaging in smaller entrustable professional activities mimicking those performed during external traineeships). In the later, students will train communication, empathy, inquisitiveness, systematicity, autonomy, and self-confidence, as well as self-assessment.

The proposed activities are limited in time; they were designed to be completed in 3 h or 2×2h, and they can repeat twice or thrice during the semester. The framework proposed herein was devised to be developed in the courses of the 4th and 5th level of the master's program in veterinary medicine, and in a face-to-face format, even though some support can be provided in a blended approach. For the activities, students will be grouped in cohorts of five elements, which will also reinforce the development of teamwork competencies.

The steps of the framework are detailed in **Table 3**, along with the skills and dispositions they address.

2.3 Additional support during implementation

The implementation of the activities requests the production of supporting materials, to be developed by the teacher and made available to students some days in advance, for preparing their participation. Among the course material to be provided

Activity step by step			CT skills	CT dispositions
General action		Specific action		
Step 1	Present the patient's problem	Depict the patient's initial story, question, complaint, or evident symptoms before history taking.	Interpretation Inference	Systematicity Cognitive maturity
		Identify the focus of the problem [Why the animal was brought to the consultation]		
		Provide all the hypothesis that may be associated with the problem [I: likely, II: less likely, III: not very likely]		
Step 2	Choose the questions to be asked to discriminate between the most relevant hypotheses	Query differential diagnoses Assess the quality of the information collected	Inference Evaluation	Communication Autonomy Evaluation Inquisitiveness Open-mindedness
Step 3	Provide the patient's clinical history information	Revise how the information influence the differential diagnosis	Analysis Interpretation Evaluation	Cognitive maturity Analyticity Systematicity
		Consider of the focus of the clinical problem has changed		
		Rank the most important information according to the value to raise the differential diagnostic list		
		Contrast the diagnostic approaches		
Step 4	Deliver additional information on request	Ponder if additional parts of the clinical exam are now required in order to exclude some unlikely, but important hypotheses	Analysis Interpretation	Systematicity Analyticity Communication Truth-seeking
		Discuss how the findings contributed to redefine the diagnostic list (if it changed)	Interpretation Evaluation	
		Discuss the additional exams necessary to confirm the most likely hypothesis and to discriminate between others	Analysis Interpretation Evaluation	Analyticity
		Interpret the findings from the diagnostic Tests	Evaluation Inference	
		Identify the discarded hypotheses on the bases of the additional information provided. Present your diagnosis	Interpretation Inference	

Activity step by step			CT skills	CT dispositions
General action		**Specific action**		
Step 5	Therapeutic options	Discuss the therapy that is now indicated, given this diagnosis and patient circumstances	Analysis Evaluation Interpretation Explanation	Communication
		Select the most suitable treatment for a particular situation (consider the animal background, animal problem, co-related health issues, etc.) Identify arguments to support the selected therapeutic options using a SWOT matrix		
Step 6	Schedule the follow-up	Present your prognosis Discuss it with the teacher/trainer	Inference explanation	Systematicity analyticity
		Provide a timeframe for when you expect to see the results of the treatment		
		Describe the changes expected and the timeline for those changes		
		Schedule the moments when the animal should be observed for the condition improvement [either for ambulatory or non-discharged animals in hospital care]		
Step 7	Metacognition	Revise your reasoning: verify your diagnosis	Inference self-regulation metacognition	Analyticity open-mindedness
		Suppose that the animal fails to show health improvements or presents additional complications. Detect what could have been wrong		
		Anticipate the critical point(s) in the animal' tutor compliance [time in treatment; effort; costs of treatment; failed expectations for the animal value]. Propose a mitigation plan for them		

Table 3.
Framework to be used in the case-based activities developed for courses in the clinical area in the veterinary medicine program.

to students, we include a list of recommended scientific or academic publications, to be used during self-study to construct background and specialty-specific knowledge; a regulatory document, setting the topic, the learning outcomes, and requirements, with an estimation of the time spent in preparing the activity, and defining the outputs to be used for assessment, and also presenting the rubrics to assess the competencies set for the activity.

During the activity, it is critical to have all files related to the case in analysis: the case vignette, the complementary information pertinent to the case analysis (to be provided upon the students' specific request and justification), and the file containing the guiding questions.

2.4 Assessment of the activities

The assessment of the students' performance during the activities must match the proposed outcomes, meaning that the rubric to be used should address both the cognitive knowledge and the CrT skills and dispositions. The evaluation will use the documents produced by students. These documents represent a critical assay of the reasoning process the students engaged with across the activity; scaffolded by the questioning provided by the teacher, the rational underlying the analysis of the situation and data from complementary exams, and the decision made regarding the solution proposed for resolution of the primary condition and the proposed schedule for follow-up interventions should be detailed, in an approach resembling the "think aloud" method.

The questions provided to support the analysis, and the corresponding rational, are categorized as factual, conceptual, procedural, and metacognitive knowledge, for scoring using a 4-point rubric for evaluation of the quality of reasoning. The knowledge categories have different ponderations: 1.5× for the factual; 2× for conceptual knowledge; 2.5× for procedural knowledge and 3x for metacognition [28].

3. Implementation of the activities and anticipated challenges

These activities have been implemented in the current term in the course of Gynecology, Andrology, and Obstetrics (8th semester of the Veterinary Medicine Program), in a piloting test. At this very moment, two activities were developed (namely for the themes andrology and gynecology) with 45 students distributed in five-elements groups.

From the application of this framework, we found that the perception of the closeness of the requested tasks to the ones Veterinary Practitioners perform daily in a clinical context engages and motivates the students to learning experiences that both increase their cognitive learning and empower them with other skills or dispositions requested in the workplace. Students themselves recognize that the activities are good strategies to increase their learning.

Besides, the involvement of LMO representatives in the construction and modulation of the activities brings work-based learning opportunities into the classroom. Based on Business-University Cooperation, these activities allow bridging the distance between the academy and the workplace, without the need to send students to extramural workplaces during their academic track.

Still, some constraints must be anticipated. Both the students and teachers are strange about these kind of learning activities. They request the students a different level of investment in the self-study routines and are critically dependent on their self-regulation skills; moreover, they will not guarantee the same performance (grading) as a memorizing-based assessment of student's cognitive skills, since the focus on students' reasoning competences will be placed on the assessment and accounts for their learning outcomes; thereby, including the CrT skills in the final assessment might impact the grades the student are used to obtain. The major positive effect—not always clear for students at this stage—may be a softer transition into the demands of the workplace, better integration into larger teams, and an improved quality in decision-making and animal healthcare.

As it is viewed by some as a liability, the proposed activities will be more time-consuming to teachers in comparison with the traditional teaching and learning styles, may compromise long syllabus teaching, and certainly increase the teach-related workload, while also imposing the need to be self-confident, open-minded, non-conformist and not be afraid of being challenged. Moreover, it will request constant contact with the routine and reality of the profession, to build networks with LMO along with coping with the rapidly changing workplace and the ever-growing advancement of science and technology.

4. Conclusion

This chapter describes the rational and the design of learning activities based on clinical case scenarios, as conceptualized under the Think4Jobs project. The activities were designed to reinforce students' clinical reasoning and critical thinking, recreating work-based experiences that can occur in the everyday activity of a veterinary practitioner. The current study presents some limitations: the conceptualized model is not yet tested for veterinary medicine courses, and only has been piloted during the current semester; therefore, no results are available yet to analyze its suitability or its success. Despite that fact, the current research contributes to the discussion of the topic of active learning strategies and provides the first steps for a framework that can be applied longitudinally and transversal to the courses in the clinical area. Therefore, the proposed framework is still pending validation, which will be performed in the near future.

Finally, some issues may be anticipated when introducing new and different activities that might impact the students' grades or the teacher workload. On the one hand, activities like the one described herein will request the students to develop new and unclear (unperceived) skills, such as self-regulation and autonomy, as well as to embark on a different way of studying, driving a resistance toward active participation. On the other hand, teachers may need further support, either regarding their own empowerment and confidence, as well as to be able to respond in time to the added responsibilities to develop the activities and provide timely feedback to students.

Still, using activities like the ones contemplated in this framework will contribute to better preparation of graduation students to the labor market expectations.

Acknowledgements

This work has been supported by the "Critical Thinking for Successful Jobs—Think4Jobs" Project, with the reference number 2020-1-EL01-KA203-078797, funded by the European Commission/EACEA through the ERASMUS Programme.

"The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein."

Author details

Rita Payan-Carreira[1]*, Hugo Rebelo[2] and Luís Sebastião[2]

1 Comprehensive Health Research Centre and Department of Veterinary Medicine, University of Évora, Évora, Portugal

2 Research Center in Education and Psychology, University of Évora, Évora, Portugal

*Address all correspondence to: rtpayan@uevora.pt

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Prince M. Does active learning work? A review of the research. Journal of Engineering Education. 2004;**93**: 223-231. DOI: 10.1002/j.2168-9830.2004.tb00809.x

[2] Anthony G. Active learning in a constructivist framework. Educational Studies in Mathematics. 1996;**31**(4):349-369. http://www.jstor.org/stable/3482969

[3] DiCarlo SE. Too much content, not enough thinking, and too little FUN! Advances in Physiology Education. 2009;**33**(4):257-264. DOI: 10.1152/advan.00075.2009

[4] Roberts D. Higher education lectures: From passive to active learning via imagery? Active Learning in Higher Education. 2019;**20**(1):63-77. DOI: 10.1177/1469787417731198

[5] Hazel SJ, Heberle N, McEwen M-M, Adams K. Team-based learning increases active engagement and enhances development of teamwork and communication skills in a first-year course for veterinary and animal science undergraduates. Journal of Veterinary Medical Education. 2013;**40**(4):333-341. DOI: 10.3138/jvme.0213-034r1

[6] OECD. PISA 2018 Results (Volume I): What Students Know and Can Do, PISA. Paris: OECD Publishing; 2019. p. 354. DOI: 10.1787/5f07c754-en

[7] Lombardi D, Shipley TF. The curious construct of active learning. Psychological Science in the Public Interest. 2021;**22**(1):8-43. DOI: 10.1177/1529100620973974

[8] Driessen EP, Knight JK, Smith MK, Ballen CJ. Demystifying the meaning of active learning in postsecondary biology education. CBE Life Sciences Education. 2020;**19**(4):ar52. DOI: 10.1187/cbe.20-04-0068

[9] McFee RM, Cupp AS, Wood JR. Use of case-based or hands-on laboratory exercises with physiology lectures improves knowledge retention, but veterinary medicine students prefer case-based activities. Advances in Physiology Education. 2018;**42**(2):182-191. DOI: 10.1152/advan.00084.2017

[10] Andrea G, Laszlo VF, Abdelfattah N. A review of some innovative teaching concepts and methods used in the field of veterinary medical education. Dairy and Veterinary Sciences Journal. 2019;**8**(5):555749. DOI: 10.19080/JDVS.2019.08.555749

[11] Betti A, Biderbost P, García DA. Can active learning techniques simultaneously develop students' hard and soft skills? Evidence from an international relations class. PLoS One. 2022;**17**(4):e0265408. DOI: 10.1371/journal.pone.0265408

[12] Dumitru D, Christodoulou P, Lithoxoidou A, Georgiadou T, Pnevmatikos D, Drămnescu AM, et al. Think4Jobs Toolkit: Ten work-Based Learning Scenarios. Greece: University of Western Macedonia; 2021. p. 150. ISBN: 978-618-5613-01-3. URL: https://think4jobs.uowm.gr/results/intellectualoutput1 [Accessed: 2022-04-15]

[13] Silva H, Lopes J, Cruz G, Dominguez C, Morais E. Does university attendance affects students' critical and creative thinking skills? A longitudinal research with pre-service teaching and psychology undergraduates. Higher Education Research & Development. 2022. [ahead of print] DOI: 10.1080/07294360.2022.2057448

[14] Nadershahi NA, Bender DJ, Beck L, Lyon C, Blaseio A. An overview of case-based and problem-based learning methodologies for dental education. Journal of Dental Education. 2013;**77**(10):1300-1305. DOI: 10.1002/j.0022-0337.2013.77.10.tb05603.x

[15] Sistermans IJ. Integrating competency-based education with a case-based or problem-based learning approach in online health sciences. Asia Pacific Education Review. 2020;**221**:683-696. DOI: 10.1007/s12564-020-09658-6

[16] Aldriwesh MG, Alyousif SM, Alharbi NS. Undergraduate-level teaching and learning approaches for interprofessional education in the health professions: A systematic review. BMC Medical Education. 2022;**22**:13. DOI: 10.1186/s12909-021-03073-0

[17] Trullàs JC, Blay C, Sarri E, Pujol R. Effectiveness of problem-based learning methodology in undergraduate medical education: A scoping review. BMC Medical Education. 2022;**22**:104. DOI: 10.1186/s12909-022-03154-8

[18] Groves M. Problem-based learning and learning approach: Is there a relationship? Advances in Health Sciences Education. 2005;**10**:315. DOI: 10.1007/s10459-005-8556-3

[19] Amerstorfer CM, Freiin von Münster-Kistner C. Student perceptions of academic engagement and student-teacher relationships in problem-based learning. Frontiers in Psychology. 2021;**12**:713057. DOI: 10.3389/fpsyg.2021.713057

[20] Mtshali NG, Middleton L. The triple jump assessment: Aligning learning and assessment. In: Barrett T, Moore S, editors. New Approaches to Problem-Based Learning: Revitalising Your Practice in Higher Education. New York: Routledge; 2011. pp. 187-209. DOI: 10.4324/9780203846

[21] Lubarsky S, Dory V, Duggan P, Gagnon R, Charlin B. Script concordance testing: From theory to practice: AMEE guide No. 75. Medical Teacher. 2013;**35**(3):184-193. DOI: 10.3109/0142159X.2013.76003

[22] Pettigrew C, Scholten I, Gleeson E. Using assessment to promote student capabilities. In: Barrett T, Moore S, editors. New Approaches to Problem-Based Learning: Revitalising Your Practice in Higher Education. New York: Routledge; 2011. pp. 171-186. DOI: 10.4324/9780203846926

[23] Dominguez C. A European Collection of the Critical Thinking Skills and Dispositions Needed in Different Professional Fields for the 21st Century. Vila Real: UTAD; 2018. ISBN: 978-989-704-256-0. https://repositorio.utad.pt/bitstream/10348/8319/1/CRITHINKEDU%20O1%20(ebook).pdf [Accessed: 2022-05-15]

[24] Abrami PC, Bernard RM, Borokhovski E, Waddington DI, Wade CA, Persson T. Strategies for teaching students to think critically: A meta-analysis. Review of Educational Research. 2015;**85**(2):275-314. DOI: 10.3102/0034654314551063

[25] Trapp S. Blended learning concepts—A short overview. In: Proceedings of the Workshop on Blended Learning and SMEs, held in conjunction with the 1st European Conference on Technology Enhanced Learning. Crete, Greece: EC-TEL; 2006. pp. 28-35

[26] Alammary A, Sheard J, Carbone A. Blended learning in higher education: Three different design approaches. Australasian Journal of Educational Technology. 2014;**30**(4):440-454. DOI: 10.14742/ajet.693

[27] ten Cate O, van Loon M. Writing CBCR cases. In: ten Cate O, EJFM C, Durning SJ, editors. Principles and Practice of Case-based Clinical Reasoning Education: A Method for Preclinical Students. Innovation and Change in Professional Education. Vol. 15. Cham (CH): Springer; 2018. pp. 95-108. DOI: 10.1007/978-3-319-64828-6_8

[28] Payan-Carreira R, Dominguez C, Monteiro MJ, Rainho MC. Application of the adapted FRISCO framework in case-based learning activities. Revista. Lusófona de Educação. 2016;**32**:175-191

Section 2

Active Learning for Society, Culture and Inclusive Education

Chapter 8

Perspective Chapter: The Role of Learning Styles in Active Learning

Armando Lozano-Rodríguez, Fernanda Inez García-Vázquez and José Luis García-Cué

Abstract

Active learning has a wide range of definitions, depending on the authors who define it. However, it can be understood as an instructional method that involves students in the learning process. Learning styles refer to the preferences that students have in their learning process. Learning styles emerge due to our genetics, life experiences and the demands of our current environment. These preferences can be classified and applied in activities that actively and passively require the participation of students. This chapter will attempt to describe active learning and learning styles separately. After that, the theoretical-practical intersections of active learning and learning styles are presented. Students' learning preferences may (or may not) be accommodated by active learning practices. Sometimes the nature of the style results in an innate passivity in the student. What follows is the teacher's action to engage students in a more active learning environment despite their predominant style. Based on research, some suggestions are presented in this regard.

Keywords: active learning, learning style, educational settings, technology, strategies

1. Introduction

There are different ways in which a person can learn, not only because of the circumstances in which it occurs but also because of the cognitive structures of each person [1]. In this sense, individual differences emerge as a key element that supports the idea that each person has a different pace and way of learning. Therefore, everyone cannot be taught the same way [2]. Individual differences include aspects beyond the cognitive area; For example, some differences can be detected with the naked eye, such as height, weight, complexion, skin color, eye color or hair type. Other differences, such as attitudes, personality traits or preferences, may not be readily apparent unless a person is asked about them [3].

In a specific school setting, such as the classroom, student preferences may go beyond cognitive ones. In other words, a learner may prefer to work individually, but the teacher requests that they work in small teams. There will be a difference between what you prefer and what you get in a classroom. Herein lies the importance of recognizing the particular learning preferences of students. Not all students have the same learning preferences, just as not all teachers have the same teaching preferences.

Preferences and tendencies have been pointed out as common features to differentiate learning styles from cognitive styles [4]. Preferences have been classified in various ways. Dunn & Dunn's work identifies what they call stimuli but refer directly to preferences: environmental, emotional, sociological, physiological and psychological. The first has to do with sound (those who like to study in silence or with some noise or music), light (those who prefer white light or darkness), temperature (those who like cold places or temperate) and how the classroom is arranged (desks in a row or a half circle) [5]. On the other hand, tendencies have been associated with cognitive processes with two poles [6]. Several authors do not agree to discriminate learning styles from cognitive ones. The evidence indicates that most theories of cognitive styles refer to two opposite poles: the works of Witkin and Goodenough with field dependence/independence, and Kagan's proposal with reflection/impulsivity, to mention a few examples [4].

This chapter is intended to show the relationship and importance of learning styles in what has been called active learning. Since there are many learning style theories, we will try to rescue various concepts from some of them to illustrate their possible applications in an instructional model that addresses the active mode of learning.

2. What is a learning style? How can it be used in the teaching-learning process?

Learning style is a common personal and preferred method of acquiring, processing and maintaining new data and skills [7], more recently defined as a combination of distinctive cognitive, affective and psychological variables that indicate how an apprentice observes and interacts with a learning environment [8].

Style is defined as a set of preferences, tendencies and dispositions that a person has to do something and that manifests itself through a behavioral pattern and different strengths that make it stand out from others [4]. Learning styles also can be defined as cognitive, affective, physiological traits, preferences for the use of the senses, environment, culture, psychology, comfort, development and personality. These serve as relatively stable indicators of how people perceive, relate and respond to their learning environments and their methods or strategies in their way of learning [9, 10].

The learning styles have a huge influence on the educational field, and one of its main goals is to improve the results of the teaching-learning process, both in the short and long term [11]. These characteristics play an important role in electing the most suitable methods and learning strategies [12]. Also, the comprehension of these styles enhances the elaboration and development of more effective curricula and programs [13].

These styles considerably impact teachers' creation of material, instruction alternatives, evaluations and students' class material process. Therefore, it is important to connect learning styles and teaching practices, for example, through music, visuals or experiential activities [14]. Employing a set of teaching methods is founded on the postulation that, to some extent, some of the course content should be provided in a way that suits every type of learner [15].

Learning styles could provide a basis and a profitable framework that captures students' diverse cognitive and affective characteristics. This framework may serve to encourage differences among students [16].

Another important issue consists of the implications of these preferences in educational environments. A transition from traditional settings to environments that consider the different learning styles is necessary. The individual variations in educational environments must consider the student's differences and teachers' diversity due to the important role of these factors in the teaching-learning settings [17].

Although most of the time learning styles are widely related to sensory preferences (visual, auditory and kinesthetic), it is important to highlight that there are a large number of theories that have focused on different types of preferences, like the Dunn & Dunn model [18]. Some conceive models of learning styles in packages of four; among them are the works of Anthony Gregorc [19], David Kolb [20], Honey and Mumford [21], Catalina Alonso and Domingo Gallego [22] and Berenice McCarthy [23], to mention a few. Others establish packages of five and six, as is the case of Anthony Grasha [24] and Richard Felder and Linda Silverman [25], respectively. Furthermore, others propose up to 16 styles, as is the case of Myers et al. [26].

Learning styles theories have been classified by different authors. The first was proposed by Lynn Curry [27, 28] with the metaphor of the layers of an onion. The first layer refers to instructional preferences: how the student likes to receive a lesson or learn content in a classroom (Grasha's model and Dunn & Dunn's model fit very well here). The layer that follows has to do with social interaction preferences, that is, those individuals who like to interact with others or who prefer to remain isolated (the MyersBriggs and Dunn & Dunn models are clear examples). The third layer has to do with information processing preferences, that is, whether learners learn by steps or by intuitive jumps, whether they acquire information in isolation or together, etc. (Theories that allude to processes of perception and information processing appear here, such as the models of Kolb, Gregorc, Alonso and Gallego and McCarthy). The last layer has to do with personality preferences, that is, if a learner is introverted or extroverted and other similar characteristics that model the personality of an individual (the MyersBriggs model fits here).

Another proposal for classifying theories was proposed by Sternberg and Grigorenko [29]. His classification of the different style theories responds to those that existed before the 1990s. The first approach is centred on cognition, which located the theories of cognitive styles. Among them were authors such as Witkin (dependence - field independence), Kagan (reflection - impulsiveness), Smith and Klein (flexible control - constrictor control). Most of these theories shared the fact that styles were seen as trends rather than preferences. A typical characteristic of this conglomerate was that since it contained only two style possibilities, its values could be visualized in a continuum, in such a way that a person could move in the line without having one hundred per cent of a particular style.

The second approach is focused on personality. This approach can include the theory of the sixteen styles of Myers-Briggs [26], which in turn had been based on the Swiss psychologist Carl Jung's model of types. Not only how an individual learns is identified but also attitudes, roles and lifestyle. Also, in this group, the model of Gregorc can be located [19]. The third and final approach is activity-focused. Here are many theories of learning styles that, from the point of view of Sternberg and Grigorenko [29], do not have the same theoretical weight as the two previous approaches. They mention Dunn's model and Kolb's.

Some theories of learning styles for virtual environments have appeared in recent years. One of these theories was proposed by Melaré-Vieira [30], which identifies four styles in the use of virtual space. The first style is participatory and likes discussion forums and chats, and it is proactive and risky. The second style is called search and investigation, and it likes to investigate, organize content and synthesize information. The third style is structuring and planning, it likes theory, enjoys projects and is methodical and farsighted. Finally, the last style is called concrete and production, It likes to discover new software, enjoys social networks, multitasks and likes to do things online (electronic banking, hotel reservations, etcetera.).

For their part, Lozano-Rodríguez, Tijerina-Salas and Valenzuela-González [31] proposed a model that considers preferences related to the use of computer equipment. In addition to chronobiological, sensory, psychological and dependency preferences, a section was included to consider technological preferences. From this attempt, Lozano-Rodríguez, Tijerina-Salas and García-Cué [32] proposed another instrument to measure learning styles in online environments. The difference with the previous one was that this initiative rescued the essence of attendance. However, the set of specified preferences could be applied to face-to-face and virtual environments alike. The proposal included four types of preferences: perception, autonomy, orientation and sensory preferences.

3. What is active learning?

Active learning does not have a singular definition. Karamustafaoglu [33] mentions that this concept can be defined 'as any instructional method that engages students in the learning process' (p. 28). This practice implies active involvement in the learning process and not a passive attitude [34]. Also, active learning activities require students to think about what they are doing. The teacher's role in the student's active learning should not be overlooked. It is important to keep it in the setting where the teaching-learning process takes place.

The word 'active' implies activities requiring students' involvement beyond mere reception, such as listening to an explanation or narration. Being active involves the student manipulating something, moving the body, executing different movements or doing something more than just contemplatively or passively watching something [35, 36].

Active learning has often been related to teaching techniques, such as problem-based learning or project-oriented learning [37–39]. The underlying idea is that these techniques involve collaborative learning as an active way of learning. Students are encouraged to interact with each other by exchanging points of view and perspectives on a particular issue.

Interaction in small groups entails applying different social skills, such as negotiation, conflict resolution, argumentation and agreement [40, 41]. Each student learns based on her active participation in the discussion. Usually, problem-based learning includes a series of steps or stages that students go through until they reach the point of preparing a final report. On the other hand, in project-oriented learning, students focus on the product they must deliver at the end of the day.

Other teaching techniques involving active learning are challenge-based learning [42, 43] case study, and collaborative learning per se [44]. In the first one, students sometimes analyze a challenge, which can be a situation that previously occurred in a given setting or was invented by the teacher. The purpose here is to solve a difficult situation in a real or imaginary scenario.

In the second one, students address the case as an independent study phase and then a small group discussion leading up to a plenary discussion. In the third one, collaborative work can be reflected in the approach to a challenge, problem, project or case. In other words, collaborative learning is the common denominator of the four previous teaching techniques (see **Figure 1**). In the same way, it was found that medical students who worked with team-based learning had better academic performance than those who did not [45]. In addition, there was an involvement of the students in their learning.

The notion of representing a type of active learning in the form of didactic techniques mentioned above is equivalent to the fact that the passive aspect of the student, where he/she acts as a receptacle of information or knowledge. The same dynamic of interaction involved in each technique avoids this feature. There is an activation of knowledge, reflection, connections with other prior knowledge and, most importantly, social exchange of ideas encourages active participation [46].

In addition to teaching techniques, the construction of models and mock-ups is a clear example of how to promote student learning in an active and participatory way. A study was designed where medicine and nutrition of students worked with the elaboration of models to illustrate the different processes of human physiology [47]. Through presentations in small teams, students had the opportunity to visualize concepts more clearly that could be more abstract than they seemed.

The practical aspect highlighted in the experience of building models and mock-ups fosters the understanding and recall of the information learned. The inclusion of games in non-playful contextual environments is another way of visualizing a form of active learning. Alsawaier [48] highlights the importance of gamification as an alternative to increasing motivation and engagement. Students see their participation

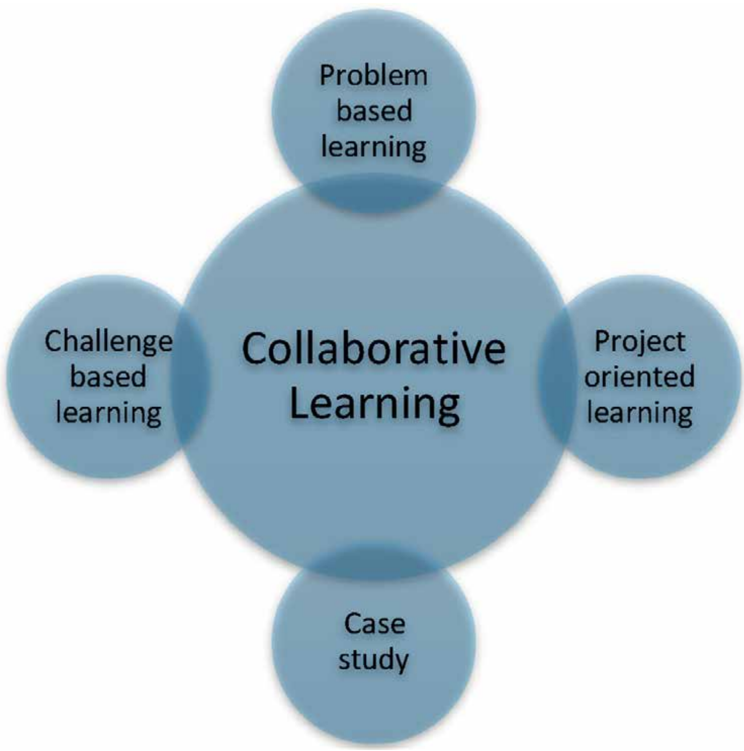


Figure 1.
Teaching techniques for active learning.

increase due to the adrenaline of wanting to beat others or obtain a characteristic badge of this modality. In the same way, another study was designed with active learning experiences through the use of puzzles for teaching dentistry [49]. The experimental group students were exhorted to work with crosswords and word search puzzles. Their results suggest an increase in student participation versus those in the control group who did not use them. Students became more excited by using a resource that had not been used before.

The use of concept maps can also evidence a form of active learning since the student puts into play their acquired knowledge in the form of representing it on a map. A study with pathology students suggests that the implementation of concept maps favored academic achievement [50]. Besides the teacher's oral presentations, the students made a concept map each week as a closing learning activity. Also, Clarkson [51] points out that using IPad in the classroom promotes a more collaborative and authentic learning experience and improves critical thinking. According to this author, active learning strategies focus on the student, facilitate collaboration and reflect workplace practices that can help develop the necessary skills. Finally, Rodis and Locsin [52] applied a series of active learning strategies based on peer-learning and peer-teaching in English-language dental students from Japan. The students reported that the activities had contributed significantly to their training as dentists and they preferred active learning styles.

On the other hand, empirical evidence shows that active learning techniques do not necessarily increase academic achievement [36]. However, it has been shown that active learning positively influences the student's involvement in what he/she learns, and his/her motivation is also increased [53]. Considering that not all students prefer the active mode of learning, it is possible to assume that active learning techniques do not necessarily work the same way for everyone. For example, in the theory of learning styles of sensory preferences, kinesthetic students will like activities that require them to move or manipulate objects. In contrast, visual or auditory students prefer to be spectators of a demonstration or an explanation. It sounds logical? The truth is that the same type of student cannot be generalized for any instructional technique, whether active or not.

4. Types of active learning activities

Not all active learning activities are the same. There are differences in the intentions, the cognitive demands and the involvement that students can have. Chi [54] proposes a difference between learning activities classified into active, constructive and interactive categories. The first ones fit the concepts that have been previously mentioned about active learning; that is, when the student physically executes something or manipulates objects, there is direct involvement. The second one is focused on the construction of things or products. Writing a sentence, writing a story or generating a product are examples of construction. The latter refers to students exchanging points of view, opinions and perspectives with their peers. In fact, the interactivity part is more than evident in the didactic techniques. Learning acquires a social nuance that accompanies individual participation.

An alternative proposal would have to do with the nature of the learning activities in terms of the cognitive demands placed on the student. So far, we have talked about teaching techniques involving collaborative learning, learning activities involving gamification, concept maps, crossword puzzles and models and mock-ups. To the

Types of active learning activities		
Type	**Activities**	**Category**
Teaching techniques	Problem-based learning	Interactive
	Project-oriented learning	
	Case study	
	Challenge-based learning	
	Collaborative learning	
Use of electronic resources	Interactive videoclips	
	Gamification	Active
	Flipped classroom	
	Puzzles	Constructive
	Crosswords and Word Search	
Physical resources and actions	Models and mock-ups making	
	Handicraft	
	Concept maps and mind maps	
	Written products (reports, essays, narratives, etcetera)	
	Role-playing	Interactive
	Theatrical performances	
	Debates	
	Guided discussions	
	Peer-teaching	

Table 1.
Types of active learning activities.

above, theatrical performances, body language exercises, debates and the flipped classroom, to name a few, could also be integrated (see **Table 1**). It is important to mention that this list is not exhaustive and that it is intended to serve as a reference framework for instructional designs.

The instructional design of a specific course should consider the inclusion of active learning activities. However, selecting which type of activity is required will depend on the nature of the discipline to be taught and the educational level. The examples that will be addressed below have a lot to do, mainly with the areas of medicine and health.

5. The intersection between active learning and learning styles

Some learning style theories include styles that consider the active factor. For example, in perceptual preferences, the kinesthetic style refers to the possibility that the student can move or perform actions aimed at the learning process. Boctor [55] points out that nursing students are kinesthetic learners. They prefer a hands-on, movement involvement, active approach to education. However, in that sense, what happens with the other styles of learning? Are visual and aural learning styles out of the active learning? The answer could be affirmative, as long as the student's activity is limited to passive viewing or listening, but it is not the case all the time. What happens when there are possibilities to make active what is considered passive? For instance, Palis and Quiros [56] observed that traditional classes in medical school, where the teacher explains a topic or a concept, could be enriched with some learning principles such as the needs of the student, the interaction in the classroom and the connection of the new knowledge with the old. The lectures can be classified as passive, but the difference in making them active lies in their learning principles-based complements. According to medical students, lecturers can promote deeper learning since reflection during lectures may be encouraged through debates, dialogs and questions.

In learning the laws of Physics through WebQuest, students who show active learning styles have better results in terms of their academic achievement, especially when it comes to science or mathematics subjects [57]. It is important to note that students who exhibit passive learning styles can still be encouraged to participate in active learning activities unless there is a physical difficulty or disability. Added to this, it was pointed out that also, in learning geometry through a creative process, students with an active learning style had a certain performance [58]. However, there was no way to compare it to other learning styles that were not active.

Research in computer science indicates that students in this area are inclined to be visual/intuitive learners. In these cases, an active environment is essential for the mastery of learning material. Based on this idea, a laboratory course was created to stimulate an active learning environment using techniques, such as frequent in-class problem solving, lab sheets and discussions. The results showed improved student grades and greater satisfaction with the course [59].

Having a passive learning style and turning it into an active one depends on many factors. Can it be achieved? It was found that some pharmacology residents changed their learning styles as they moved into practice outside of the residency [60]. However, the study suggests that an opportunity is needed to guide pharmacists towards more active learning preferences through residency curricula, learning facilitation and mentoring.

One of the learning styles theories, which has undoubtedly had a profound impact on conceptualizing the different preferences for learning in a cyclical model (through perception and processing of information), is referred to by David Kolb [20]. Initially, this author distinguished only four learning styles: diverging, assimilating, accommodating and converging. The first and the last style had to do with concrete experience, where manipulation and social interaction have a lot to do with it. In terms of action, these styles are suitable for active learning. The second and third styles had more to do with contemplation and abstract abstraction; here, only reflective observation is highlighted. On the contrary, these styles are more related to passive ways of learning. However, more recently, this theory was upgraded to a nine-style scheme, proposed by Kay Peterson, Lisa DeCato and David Kolb [61]. In this new proposal, elements of effort are included and indicated in a continuum with two opposite values. These comprise the flow that goes from the free one to the restricted one, the weight that goes from the light one to the heavy one, the time that goes from the gradual one to the urgent one and an approach that goes from the indirect way to a direct one. At least five styles in this new model have to do with active learning.

It is important to highlight that almost half of the learning styles of this or other style models consider the possibility of carrying out activities that lead to an active character [18, 20, 24]. However, it has also been seen that there are styles that prefer passivity at all times in their learning process. The underlying idea is to realize the importance of inviting those students to explore styles other than their own.

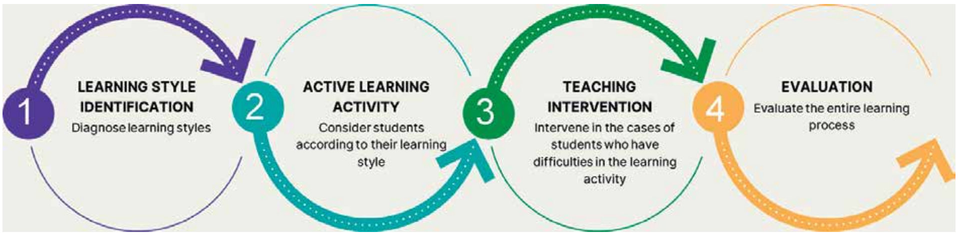


Figure 2.
Teaching steps considering learning styles in active learning.

Sternberg [62] already pointed out that styles can change over time and that they could also be socialized. If a student is invited by his/her teacher to explore new ways of learning, he/she will likely have no choice but to follow the recommendation. Many students discover new learning possibilities and make them their own, while others prefer to stay in their comfort zone. The teacher's figure is also important because many students take him as a role model.

One of the first ideas that emerges from the relationship between learning styles and active learning is the necessity to identify students who really like active learning activities (see **Figure 2**). In other words, those students will voluntarily enjoy active learning activities. Those who present passive styles should be encouraged and persuaded to participate. In a second moment, the teacher faces the challenge of convincing these students to get involved with their own learning in a style that is not their own. Several models of learning styles propose that students activate all their styles when they are in a learning activity since no one has an absolute style but rather a collection of several [5, 62].

The teacher's intervention could be necessary when he/she detects that certain students are presenting difficulties in their learning process [63]. Sometimes it is not enough to observe them directly during their performance in some activity, but ask them directly if they have problems advancing in their objectives. In the end, an evaluation process will be required to identify areas of opportunity for subsequent activities.

The model of learning styles chosen will depend on the educational level and the characteristics of the class. As already mentioned, the variety of theories is very wide and should not be restricted to sensory preferences only.

6. Conclusions

The design of active learning activities must consider, at all times, the learning styles of the students. In this way, teaching efforts can be capitalized on to obtain the best results in terms of academic achievement. In this sense, applying an instrument to measure learning styles is highly recommended. Teacher knows the learning styles of their students is a powerful tool to be able to influence the teaching-learning process.

On the other hand, the inclusion of individual and team activities should have a similar weight throughout a course. In other words, not all activities are individual, nor are they all collective. Implementing teaching techniques is highly desirable, but so is the possibility that students alone can face a learning situation that challenges their intellect, imagination, creativity and critical thinking. Concept maps, mind maps, crossword puzzles and the creation of models and mock-ups are some recommendations.

In addition, with an overview of the class on the types of learning styles that students have, the teacher can make more organized combinations of students distributed in teams. Instructors can also pinpoint which students need more attention to achieve the course objectives, support those with more passive learning styles and encourage more active ones. Only this way can there be better results in terms of learning.

In summary, learning styles can be a great ally in the design of active learning activities, not only because they can enhance the result obtained but also because it allows students to enjoy the learning process more. The more the learning activities are adjusted to the styles of the students, the greater the possibility of academic achievement.

Acknowledgements

We would like to express our special thanks of gratitude to our educational leader, Dr. María Luisa Madueño-Serrano as well as our principal Dr. Guadalupe De la Paz Ross-Arguelles who gave us the support to do this project. We are really thankful to them.

Conflict of interest

The authors declare no conflict of interest.

Author details

Armando Lozano-Rodríguez[1*], Fernanda Inez García-Vázquez[1]
and José Luis García-Cué[2]

1 Sonora Institute of Technology, Obregón, México

2 Postgraduate College, Texcoco, México

*Address all correspondence to: armando.lozano@itson.edu.mx

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Bilbao N, López de la Serna A, Tejada E, Romero A. Analysis of learning styles (Kolb) in students of the degrees in early childhood education and primary education within the Faculty of Education. TEM Journal. 2021;**10**:724-731. DOI: 10.18421/TEM102-29

[2] Price L. Individual differences in learning: Cognitive control, cognitive style, and learning style. Educational Psychology. 2004;**24**:681-698. DOI: 10.1080/0144341042000262971

[3] Ashton M. Individual Differences and Personality. 3rd. ed. London: Elsevier; 2017. p. 404

[4] Lozano-Rodríguez A. Los estilos de aprendizaje y enseñanza. Un panorama de la estilística educativa. 2nd. Ed. Trillas: Ciudad de México; 2010. p. 126

[5] Guild P, y Garger, S. Marching to Different Drummers. 2nd. ed. Alexandria, Virginia: Association for Supervision and Curriculum Development; 1998. p. 193

[6] Riding R, Cheema I. Cognitive styles—An overview and integration. Educational Psychology. 1991;**11**:193-215. DOI: 10.1080/0144341910110301

[7] Reid J. Learning Styles in the ESL/EFL Classroom. New York: Heinle & Heinle Publications; 1995. p. 264

[8] Nguyen L. A new approach for modeling and discovering learning styles by using hidden markov model. Global Journal of Human Social Science Linguistics & Education. 2013;**13**:1-10

[9] García-Cué JL. Estilos de aprendizaje. In: García Cué JL, Jiménez Velázquez MA, Martínez Saldaña T, Sánchez Quintanar C, editors. Estilos de aprendizaje y otras perspectivas pedagógicas del siglo XXI. México: Fundación COLPOS; 2013. pp. 17-72

[10] Gallego D, Alonso C. Acción pedagógica postdiagnóstico de los estilos de aprendizaje. In: García Cué JL, Jiménez Velázquez MA, Martínez Saldaña T, Sánchez Quintanar C, editors. Estilos de aprendizaje y otras perspectivas pedagógicas del siglo XXI. México: Fundación COLPOS; 2013. pp. 187-200

[11] Diago ML, Cuetos MJ, González P. Análisis de las herramientas de medición de los Estilos de Aprendizaje. Revista de Educación. 2018;**381**:95-115. DOI: 10.4438/1988-592X-RE-2017-381-382

[12] Cimermanová I. The effect of learning styles on academic achievement in different forms of teaching. International Journal of Instruction. 2018;**11**:219-232. DOI: 10.12973/iji.2018.11316a

[13] Brown T, Zoghi M, Williams B, Jaberzadeh S, Roller L, Palermo C, et al. Are learning style preferences of health science students predictive of their attitudes towards e-learning? Australasian Journal of Educational Technology. 2009;**25**:524-543. DOI: 10.14742/ajet.1127

[14] Zhou M. Learning styles and teaching styles in college English teaching. International Education Studies. 2011;**4**:73-77. DOI: 10.5539/ies.v4n1p73

[15] Romanelli F, Bird E, Ryan M. Learning styles: A review of theory, application, and best practices. American Journal of Pharmaceutical Education. 2009;**73**:1-9. DOI: 10.5688/aj730109

[16] Davidson GV. Matching learning styles with teaching styles: Is it a useful concept in instruction? Performance and Instruction. 1990;**29**:36-38

[17] Karatas E, Yalin HI. The impact of matching learning-teaching styles on students' academic achievement. Eurasian Journal of Educational Research. 2021;**92**:377-402. DOI: 10.14689/ejer.2021.92.19

[18] Dunn R, Dunn K. Teaching Students through their Individual Learning Styles. Reston, VA: Reston Publishing; 1978. p. 431

[19] Gregorc AF. Gregorc Style Delineator: Development, Technical, and Administation Manual. Maynard, MA: Gabriel Systems; 1982. p. 41

[20] Kolb D. Experiential Learning Experiences as the Source of Learning Development. Upper Sadle River, New Jersey: Prentice Hall; 1984. p. 256

[21] Honey P, Munford YA. Using your Learning Styles. London: Maidenhead; 1986. p. 84

[22] Alonso C, Gallego D. Los estilos de aprendizaje: Procedimientos de diagnóstico y mejora. Madrid: Mensajero; 1995. p. 222

[23] McCarthy B. About Teaching: 4MAT in the Classroom. Wauconda, IL: About learning, Inc; 2000. p. 183

[24] Grasha A. Teaching with Style. San Bernadino, CA: Alliance; 1996. p. 186

[25] Felder RM, Silverman LK. Learning and teaching styles in engineering education. Engineering Education. 1988;**78**:674-681

[26] Myers IB, McCaulley MH, Quenk NL, Hammer AL. MBTI Manual (a Guide to the Development and Use of the Myers Briggs Type Indicator). 3rd ed. Palo Alto, CA: Consulting Psychologists Press; 1988. p. 420

[27] Curry L. An organisation of learning styles theory and construct. Educational Research Information Centre (ERIC). 1983;**Document, 235**:185

[28] Curry L. Integrating Concepts of Cognitive and Learning Styles: A Review with Attention to Psychometric Standards. Ottawa, ON: Canadian College of Health Services Executives; 1987. p. 92

[29] Sternberg RJ, Grigorenko EL. Are cognitive styles still in style? American Psychologist. 1997;**52**:700-712

[30] Barros MV, D. Estilos de uso do espaço virtual: novas perspectivas para os ambientes de aprendizagem online. Revista de Estilos de Aprendizaje. 2010;**3**:103-127

[31] Lozano-Rodríguez A, Tijerina-SalasBA,Valenzuela-GonzálezJR. Pentavalent inventory to measure learning styles. Journal of Psychological and Educational Research. 2016;**24**:17-36

[32] Lozano-Rodríguez A, Tijerina-Salas BA, García Cué JL. Implementación del instrumento Quirontest para medir estilos de aprendizaje en estudiantes de pregrado en línea. Revista de Estilos de Aprendizaje. 2016;**2016**(9):240-267

[33] Karamustafaoglu O. Active learning strategies in physics teaching. Energy Education Science and Technology Part B: Social and Educational Studies. 2009;**1**:27-50

[34] Drew V, Mackie L. Extending the constructs of active learning: Implications for teachers' pedagogy

and practice. Curriculum Journal. 2011;**22**:451-467. DOI: 10.1080/09585176.2011.627204

[35] McConnell DA, Chapman LC, Czajka D, Jones P, Ryker K, Wiggen J. Instructional utility and learning efficacy of common active learning strategies. Journal of Geoscience Education. 2017;**65**:604-625. DOI: 10.5408/17-249.1

[36] Crogman H, Crogman MT. Modified generated question learning, and its classroom implementation and assessment. Cogent Education. 2018;**5**:1-45. DOI: 10.1080/2331186X.2018.1459340

[37] Musikhin IA. Encouraging active learning when teaching geospatial sciences. Geo-spatial Information Science. 2014;**17**:219-228. DOI: 10.1080/10095020.2014.989655

[38] Hartman P, Renguette C, Seig M. Problem-based teacher-Mentor education: Fostering literacy Acquisition in Multicultural Classrooms. Interdisciplinary Journal of Problem-Based Learning. 2018;**12**:1-12. DOI: 10.7771/1541-5015.1659

[39] Purba J, Situmorang M, Silaban R. The development and implementation of innovative learning resource with guided projects for the teaching of carboxylic acid topic. Indian Journal of Pharmaceutical Education and Research. 2019;**53**:603-612. DOI: 10.5530/ijper.53.4.121

[40] Filho WL, Shiel C, Paço A. Implementing and Operationalising integrative approaches to sustainability in higher education: The role of project-oriented learning. Journal of Cleaner Production. 2016;**133**:126-135. DOI: 10.1016/j.jclepro.2016.05.079

[41] Chassidim H, Almog D, Mark S. Fostering soft skills in project-oriented learning within an agile atmosphere. European Journal of Engineering Education. 2018;**43**:638-650. DOI: 10.1080/03043797.2017.1401595

[42] Willis S, Byrd G, Johnson BD. Challenge-based learning. Computer. 2017;**50**:13-16. DOI: 10.1109/MC.2017.216

[43] Gallagher SE, Savage T. Challenge-based learning in higher education: An exploratory literature review. Teaching in Higher Education. 2020:1-23. DOI: 10.1080/13562517.2020.1863354

[44] Zúñiga-Escobar, M. La estrategia didáctica: Una combinación de técnicas didácticas para desarrollar un plan de gestión de riesgos en la clase. Revista Educación 2017. 41; 1-18. DOI: 10.15517/revedu.v41i1.1778

[45] Punja D, Kalludi SN, Pai KM, Rao RK, Dhar M. Team-based learning as a teaching strategy for first-year medical students. Australasian Medical Journal. 2014;**7**:490-499. DOI: 10.4066/AMJ.2014.2244

[46] Roche M, Adiga IK, Nayak AG. PBL trigger design by medical students: An effective active learning strategy outside the classroom. Journal of Clinical and Diagnostic Research. 2016;**10**:6-8. DOI: 10.7860/JCDR/2016/21813.9015

[47] Albarrán-Torres F, Urrutia Martínez M, Ibarra Peso J, Miranda-Díaz C, Meza Vásquez S. Maquetas como estrategia didáctica en estudiantes de la salud. Educación Médica. 2020;**21**:198-206. DOI: 10.1016/j.edumed.2018.08.003

[48] Alsawaier RS. The effect of gamification on motivation and engagement. International Journal of Information and Learning Technology. 2018;**35**:56-79. DOI: 10.1108/IJILT-02-2017-0009

[49] Nirmal L, Ms M, Prasad M. Use of puzzles as an effective teaching–learning method for dental undergraduates. International Journal of Clinical Pediatric Dentistry. 2020;**13**:606-610

[50] Bhusnurmath SR, Bhusnurmath B, Goyal S, Hafeez S, Abugroun A, Okpe J. Concept map as an adjunct tool to teach pathology. Indian Journal of Pathology & Microbiology. 2017;**60**:226-231. DOI: 10.4103/0377-4929.208410

[51] Clarkson G. Evaluating the potential of iPads to engage paramedicine students. Australasian Journal of Paramedicine. 2018;**15**:1-9. DOI: 10.33151/ajp.15.1.548

[52] Rodis OM, Locsin RC. The implementation of the Japanese dental English core curriculum: Active learning based on peer-teaching and learning activities. BMC Medical Education. 2019;**19**:1-7. DOI: 10.1186/s12909-019-1675-y

[53] Marrone M, Taylor M, Hammerle M. Do International students appreciate active learning in lectures? Australasian Journal of Information Systems. 2018;**21**:1-20. DOI: 10.3127/ajis.v22i0.1334

[54] Chi M. Active-constructive-interactive: A conceptual framework for differentiating learning activities. Topics in Cognitive Science. 2009;**1**:73-105

[55] Boctor L. Active-learning strategies: The use of a game to reinforce learning in nursing education. A case study. Nurse Education in Practice. 2013;**13**:96-100. DOI: 10.1016/j.nepr.2012.07.010

[56] Palis AG, Quiros PA. Adult learning principles and presentation pearls. Middle East African Journal of Ophthalmology. 2014;**21**:114-122. DOI: 10.4103/0974-9233.129748

[57] Alias N, DeWitt D, Siraj S. An evaluation of gas law WebQuest based on active learning style in a secondary School in Malaysia. Eurasia Journal of Mathematics, Science & Technology Education. 2014;**10**:175-184. DOI: 10.12973/eurasia.2014.1074a

[58] Ferdiani RD, Manuharawati., & Khabibah, S. Activist learners' creative thinking processes in posing and solving geometry problem. European. Journal of Educational Research. 2022;**11**:117-126. DOI: 10.12973/eu-jer.11.1.117

[59] Briggs T. Techniques for active learning in CS courses. Journal of Computing Sciences in Colleges. 2005;**21**:156-165

[60] Loewen PS, Jelescu-Bodos A, Yeung J, Lau T. The effect of transitioning from residency to pharmacy practice on learning style. American Journal of Pharmaceutical Education. 2014;**78**:1-5. DOI: 10.5688/ajpe788147

[61] Peterson K, DeCato L, Kolb D. Moving and learning: Expanding style and increasing flexibility. The Journal of Experimental Education. 2014;**38**:228-244. DOI: 10.1177/1053825914540836

[62] Sternberg RJ. Thinking Styles. New York: Cambridge University Press; 1997. DOI: 10.1017/CBO9780511584152

[63] Cooper P. Teacher strategies for effective intervention with students presenting social, emotional and behavioral difficulties: An international review. European Journal of Special Needs Education. 2011;**26**:71-86. DOI: 10.1080/08856257.2011.543547

Chapter 9

Perspective Chapter: New Active Learning Models in Africa

Fred Awaah, Cosmas Lambini Kombat and Emmanuel Okyere Ekwam

Abstract

This desk review draws from the active learning literature to establish that the Culturo- Techno-Contextual Approach is a new active learning model of African origin that holds the key to students understanding of concepts within the continent. The chapter argues that the tripod of culture, technology, and context form the basis of the CTCA and are all triggered by engaging peers, community, teachers, and other active learning partners to ensure students understand concepts. Anchored on Hofstede's cultural dimensions, we argue that the five-step teaching processes used in the CTCA further involve students engaging with their communities, peers, friends and relations, technology, and others to enhance their understanding of concepts. We conclude that the CTCA is an active learning model that enhances students understanding of concepts in schools. We further propose the Collectivism, Culture & Context Framework (3C Framework) as one that can further enhance active learning and students' understanding of concepts.

Keywords: active learning, Culturo- techno-contextual approach, learning models, Hofstede's cultural dimensions, education

1. Introduction

Instructor roles are shifting from information presenter to designer of active learning processes, environments, and experiences that increase student engagement [1]. The more dynamic a lesson is, the more academically and emotionally engaged students will be in the learning activities. Many active learning processes are built on the foundation of cooperative learning. Cooperative learning refers to utilising small groups in the classroom to help students maximise their own and each other's learning. Students must work cooperatively in small groups to attain joint learning goals in most active learning methods, such as problem-based, team, collaborative, and peer-assisted learning strategies [1].

In recent years, political, instructional, and academic interest in active learning has been expanding. Active learning, on the other hand, has many definitions. The learning outcomes have been mostly positive, but the measurement methods are not without problems [2].

IntechOpen

Active learning is an umbrella word that is not particularly beneficial in developing research on learning. It is widely used to offer an alternative to lectures and does have a purpose in higher education classroom practice [3]. Lombardi et al. [3] believe that undergraduate students should be active class participants and that, in addition to cognitive knowledge production, the social construction of meaning plays a significant role for many students.

Active Learning Classrooms (ALCs) are learning spaces specially designed to optimise the practice of active learning and amplify its positive effects on learners, from young children to university-level learners [4].

From the afore, we assert that active learning is a teaching method that involves keenly engaging students in the learning process from the study material and assignments, enabling for asking questions, discussion, and role-play, among others. The idea of active learning involves entrusting core learning responsibilities to the student to ensure their active involvement in the learning process. Within an African culture of active learning, we choose Hofstedes' cultural dimension as the theoretical base of our study.

2. Hofstede's cultural dimensions theory

This study presents the Culturo-Techno-Contextual Approach (CTCA) as an active learning model of African origin. We, therefore, have adopted Hofstede's cultural dimensions as our theoretical base. Geert Hofstede, a Dutch management scholar, developed Hofstede's Cultural Dimensions Theory in 1980. Hofstede [5] proposed four cultural characteristics that could distinguish how a society's culture influences the actions and values of its people. These are power distance, uncertainty avoidance, individualism or collectivism, and masculinity or femininity. However, he later added two more dimensions [6]. These are long or short term orientation and indulgence or restraint. The collectivism dimension of [6] model is relevant to this study.

Even if there are diverse individuals within a group, the collective philosophy of one group can be homogeneous and vary from one group to the next; thus, [6] defines culture as "the collective programming of the mind that distinguishes the members of one group or category of people from others." This finds relevance to our study since the CTCA has its anchor on culture as a tool for enhancing students understanding of concepts.

Collectivism is how people in a community are integrated into groups. It is a social, not an individual, feature. Individualist societies have loose relationships: everyone is expected to take after themselves and their immediate family. On the collectivist side, people are integrated from birth into strong, cohesive in-groups, frequently extended families (including uncles, aunts, and grandparents) that continue to protect them in return for unquestioning allegiance and oppose others [6]. Later in the CTCA, this collectivist principle will be seen as students are expected to cooperate in groups to attain academic success.

3. Studies in active learning in Africa

Because of the large number of first-year students, lecturers have adopted coping tactics such as direct-transmission mode teaching and reduced time for practicals and assessment [7]. Assert that several strategies have been implemented to improve student participation and active learning in South Africa; however, these changes have to be facilitated and fostered by faculty and administrators. Consequently, they presented the implementation, results, and feedback of a new first-year course run from 2005 to 2008. The number of lectures was reduced in the course, and the number of more cooperative tutorials and practical based sessions was increased. These changes aimed to promote students' active participation and encourage them to take responsibility for their learning. Wilson [7] report that, although there were some initial difficulties, most students and faculty were enthusiastic about the learning experience, and the abilities learned were thought to be transferable to other science courses.

Lecturers could have different reasons for choosing a specific teaching strategy, including the government policy, education institution policy, or management directive [8]. Despite these issues, they report that lecturers might choose to use Active learning methodologies on their own rather than because they are told to. Their qualitative interpretive case study sought to learn about the motivations of 11 lecturers from three different faculties in a private higher education university in South Africa: Faculty of Commerce and Law, Faculty of Social Science, and Faculty of Applied Science in implementing Active learning methodologies in their courses. Their findings suggest that lecturers use Active learning because they believe that: Active learning prepares students for the workplace by developing required skills; Active learning supports learning in the classroom; Active learning transforms boring passive learning classes into engaging, enjoyable active classes in which students want to participate; and their personal experience as students has had a lecturer who used Active learning strategies in their classes that worked for them.

The Federal Democratic Republic of Ethiopia's administration also announced a new curriculum reforming the educational sector [9]. The program aimed to replace teacher-centred teaching practices with student-centred, active learning strategies. The findings revealed that most students' learning styles were evenly distributed throughout the two dimensions of the ILS scales. They also found significant differences in the students' learning styles and attitudes towards active learning regarding their gender, education level, and the types of schools.

4. The Culturo: techno-contextual approach (CTCA)

A new Afrocentric teaching model, which emphasises the use of digital technology in methodology and delivery and the relevance of partnerships in meeting the continent's higher education demands, provides an effective teaching and learning paradigm, especially during the COVID-19 lockdowns [10]. In many studies, researchers have proffered different approaches to teaching. However, a recurrent theme in recent literature is the Culturo-Techno-Conceptual Approach, which suggests using indigenous/cultural models in teaching and learning to foster student understanding of concepts. Okebukola [11] proposed that the model amalgamates culture, technology and the context (environment), as shown in **Figure 1**.

The Culturo-Techno-Contextual Approach is a teaching method based on culture, technology, and the context or the environment in which teaching and learning occur [11]. The relevant philosophies that the approach is grounded in are Kwame Nkrumah's (ethnophilosophy) for culture, Martin Heidegger's (techno-philosophy) for technology, and Michael Williams' (Contextualism) for the contextual element of CTCA.

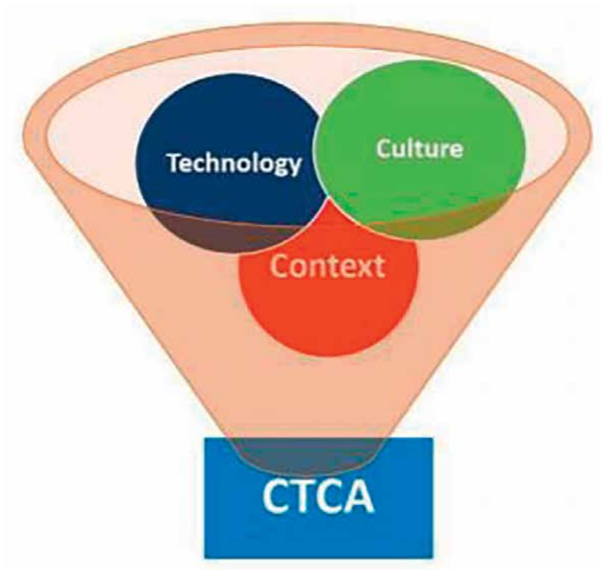


Figure 1.
Culturo-techno-contextual approach. Sourced from Okebukola (2020).

In this context, ethno-philosophy is based on Kwame Nkrumah's idea of the African people's uniqueness and culture, which he pioneered. Nkrumah believed that African culture is distinct from European ways of living but not inferior to them [12].

The CTCA's 'techno' component is profoundly anchored in the 'Heideggerian' notion of technology as a technique for unveiling the world, a revelation in which individuals take control of reality.

CTCA's context element is based on the philosophical framework of Contextualism. Contextualism asserts that our actions, utterances, or expressions, as well as our learning, can be understood only in the context in which they occur. When using CTCA to teach students, the explanations, situations, and examples should be relevant to their immediate surroundings to assimilate the information fast.

5. The CTCA and active learning

Unlike the lecture method that seems to emphasise the teachers as a repository of knowledge, the CTCA has a definite procedural teaching style that encourages interactions and active learning (see **Figure 2**).

In a CTCA class, the teacher does not teach in the first meeting with the students. The teacher introduces the topic and encourages the students to find out the cultural elements relating to the topic from their parents, relatives, elders, grandparents (culture), internet sources (technology) and their immediate environment (context). This aspect of the CTCA engages the students in knowledge finding from their perspectives before the teacher teaches the topic in the next lecture. Students can explore the topic from diverse sources, including cultural, technological and contextual perspectives, unveiling positive interactive learning between the students and the community and the internet even before the classroom engagements with the teacher on the subject or topic.

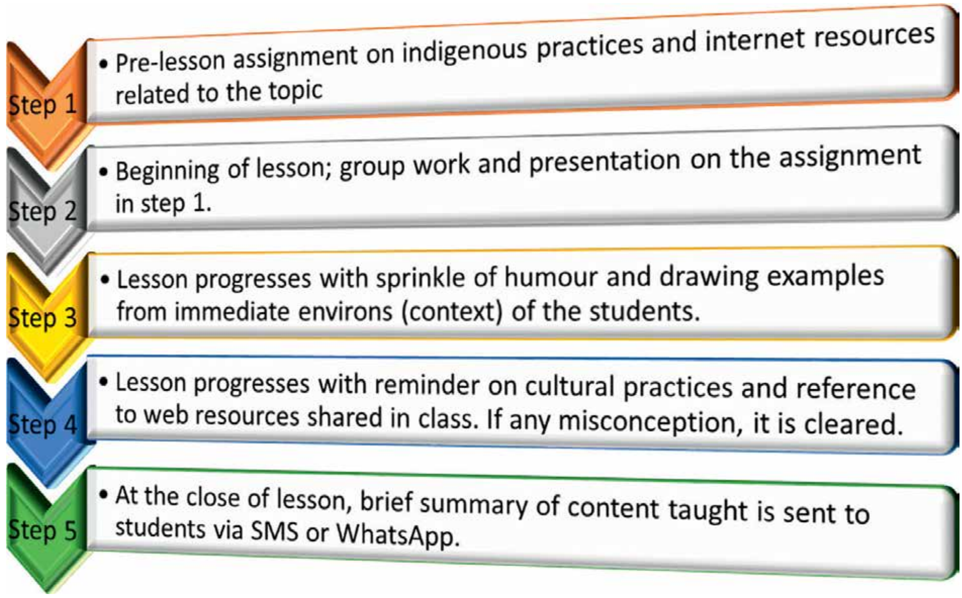


Figure 2.
Steps involved in teaching using the CTCA. Sourced from [13].

In the next class with the teacher, the teacher groups the students in numbers not exceeding 10 with mixed sexes and mixed abilities. These groups brainstorm on the cultural knowledge found from the parents and others together with the internet sources and the environment. This constitutes active learning since the students, in their interactions, agree and disagree on narrations that are right and those that are wrong from their views.

The next stage of the learning process entails leaders of each group presenting the results from their groups elaborating on the cultural perspective found from their parents, technology and the environment. While this is done, other group members note what they agree with and those they do not agree with to comment on when the opportunity arises. It should be noted that this aspect of teaching using the CTCA also unveils an opportunity for active learning since it is more of a peer learning process at this stage.

The teacher then takes over when all the groups are done presenting their findings on the topic from the cultural perspectives of their parents, technology and the environments. At this juncture, the teacher emphasises the correct narrations from the individual presenters while correcting viewpoints that were not right. This aspect of the teaching enhances clarity since students are likely to misinterpret their findings. This aspect of the teaching also brings to bear the issue of interactive learning.

Amidst these, the teacher sprinkles the teaching with some humour to ensure the students are at ease and relaxed to absorb the contents and o to ask questions when need be. Following that, students are relaxed. They can interact with the teacher and ask questions and critique the perspectives of their colleagues. This brings out the interactive component of the CTCA, which is worth reporting.

The teacher subsequently summarises the entire lecture and sends it to the students at the close of the day through the appropriate technological medium (email, WhatsApp, SMS). This also shows evidence of active earning since, after class, the teacher still engages the students electronically with the study's contents within the day.

6. Methodology

This study is a desk review. The active learning literature provided baseline information on how African countries have used active learning models and the effects such have had on the continent's education. The study specifically reviewed the literature on active learning in South Africa, Ethiopia, Nigeria and Ghana. The anchor model is the Culturo-Techno-Contextual Approach. A full bibliography of information sources reviewed is reported in the references section.

7. Evidence of the effectiveness of the CTCA as an active teaching model

Several studies have examined the efficacy of using the Culturo-Techno-Contextual Approach (CTCA) in breaking difficulties in concepts in different research fields. This section reviews such studies in indigenous knowledge systems, emphasising the CTCA.

In a survey of 5032 secondary biology students and their teachers (n = 311) in Lagos State on the impact of the Culturo-Techno-Contextual Approach (CTCA) in tackling under-achievement in difficult concepts in Biology, [14] found that the value associated with Wilks' lambda is [F = 15.63; p.05], confirming the significance of the MANCOVA and justifying a deeper probe into the F values relating to the study's independent variable on the dependent variables of achievement and attitude; providing a foundation for the efficacy of CTCA and validation of its potency.

Awaah [13] also found that the experimental group (Mean = 22.20 and SD = 5.10) outperformed the control group (Mean = 20.45 and SD = 8.01) in politics and bureaucracy (p = .000) in a study of public administration students at the University of Professional Studies – Accra (UPSA) [p = 000; F (1, 130) = 14.07]. The results reveal that CTCA has the potential to improve undergraduate students' performance in difficult public administration concepts. Within the study's limitations, particularly the small sample size and short duration of the experiment, the study recommends (a) an exploratory use of CTCA for teaching public administration in undergraduate classes in Ghana's university system; (b) a deeper look into the factors that influence CTCA's potency; b) conducting more testing on larger groups of pupils in Ghana and other African countries; (d) using the Awaah indigenous paradigm for overcoming learning difficulties in public administration studies.

Similarly, [15] emphasises that it is vital for students to succeed in developing a sense of cultural belonging. Students need to find commonalities with their own life and living situations. They need to see a similarity with their context. This sense of belonging can be enhanced by including cultural practices in the educational curriculum.

Adewusi [15]'s position finds semblance with that of [16] that science teachers initiate the process of thinking more about providing teachers with CTCA know-how in the quest for culturally and contextually appropriate methods of effective delivery of science. This finds further support in Egerue 2019 that teachers explore using the CTCA to enhance learners' accomplishment in scientific explanations. Ogunbanwo [17] aptly takes a similar stance when he argues that teachers should adopt the CTCA teaching methodology to help pupils enhance their academic performance, attitudes and motivation.

Further, in a survey of 60 senior secondary three biology students on the potency of the Culturo-Techno-Contextual Approach on students' achievement and attitude towards mutation and variation in Biology, [18] found that there was an impact of the Culturo-Techno-Contextual Approach as pieces of evidence showed the experimental group students performed better than the control group students on the achievement measure and attitude towards mutation and variation.

Gbeleyi and Egerue [19, 20] believes that using indigenous (cultural) knowledge in the computer studies/ICT classroom can facilitate meaningful learning and cultural sustainability in his study on flowcharting. To bridge the gaps and spaces that pupils experience in their thoughts, indigenous knowledge must be integrated. He adds that the most interesting experience for students is discovering that, after all, "their ancestors'" and "their direct parents'" view of the world does not always contradict that of modern science. When there are disagreements, the teacher explains the many points of view. He hopes that his findings will be useful to other scholars and educators interested in learning more about the indigenous strategy for cultural survival and advancement.

This is in line with [18]'s findings that the Culturo-Techno-Contextual Approach had a significant impact on achievement, as experimental students outperformed their control group peers on the achievement scores. The finding supports [7]'s notion that in order for effective teaching to occur, specific principles and ideas must be explained to connote ideas from the immediate environment that the students are already familiarised with in order to achieve inclusive learning and a positive behavioural change in the learner's life (s). Learners understand better when they learn about concepts within their immediate environs by asking elders, family, tribespeople and friends. However, [19, 20] cautions that students should not allow traditional and religious beliefs to interfere with the scientific explanation of concepts. In today's world, when students may be enticed to sacrifice scientific truth in favour of indigenous knowledge, [19, 20]'s viewpoint is timely.

The culture of Africans permeates every fibre of African lives, including politics, and this culture had been harnessed for the continent's benefit before the introduction of anything western [21]. This observation confirms [22]'s observation that, in the era of globalisation and contemporary technological development, the people of Ghana must recognise that their culture is the basis of and the most important factor in the nation's human history and material development.

8. The collectivism, culture & context framework (3C framework)

Inferring from the literature reviewed and evidence from the communal lifestyles of Africans where this study is situated, we argue that contextual culture is a catalyst to active learning. We draw our inspiration largely from the works of Okebukola and Hofstede. In the Okebukolan model, the cultural and context components of the CTCA have catalogued evidence of students engaging in active learning, which has registered numerous studies to back its efficacy.

The work of Hofstede also finds relevance in our new proposition. Hofstede situates the culture between collectivism and individualism. We find that largely collectivism represents values reflective in every sphere of the African lifestyle, including education. This notion had registered many positives in the classroom when the CTCA encouraged collaborative engagements as a tool for understanding concepts.

Our preposition defines contextual culture as relative to a given society and not generic. In this instance, even as this study is African specific, there is the understanding that Africa also has unique cultures peculiar to specific African societies that are not practised in other parts of the continent. To ensure interactive learning, teachers will need to encourage the use of cultures specific to the environment they teach to ensure students can identify with such cultures to enhance their understanding of concepts. For instance, if winter or summer are used as examples in a classroom in northern Ghana, it is likely to impede students' understanding of the teaching weather and seasons. Alternatively, when the rainy season or dry season are used, the students will understand within the context of their environment because winter and summer are alien to them while raining and dry seasons are notions they are familiar with.

Contextual culture will thus include the use of examples relative to the given environment where teaching is taking place, situating teaching within the cultural practices of the environment within which learning is taking place, and minimising the usage of cultures foreign to the environment within which teaching is taking place, encouraging the use of indigenous examples by students, comparable at intervals the culture of the teaching settings with those of other jurisdictions to give students global worldview of the concepts being taught.

Further, collectivism, as espoused in our preposition, relates largely to the Ubuntu principle of Africans that encourages communal achievements as opposed to individualism, as re-echoed in the works of Hofstede. In this regard, we argue that if students are encouraged to learn collectively (collaborative learning) and emphasise group achievements instead of individual achievements in the classrooms, the student will be encouraged to learn interactively towards achieving academic success.

While our preposition is hinged on existing literature and our observations, it is important to note that the preposition may not be effective for active learning in individualistic societies that value individual achievements without recourse to collectivism.

From the afore, we suggest the framework (see **Figure 3**) as a model that will foster active learning in the educational sector.

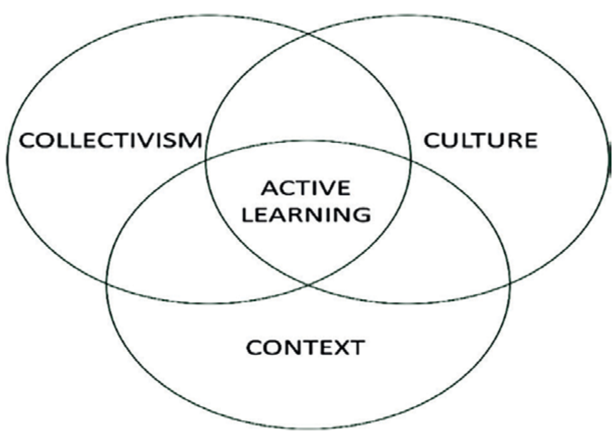


Figure 3.
The collectivism, culture & context framework.

9. Conclusion

This study draws from existing literature on active learning in Africa to make a case for the Culturo- Techno-Contextual approach as an efficient active learning model of African origin. We demonstrate that using culture, technology and context, as espoused by [11], holds the key to active learning. Drawing from his work and the Hofstede culture dimensions, we propose the collectivism, culture, and context framework.

Abbreviations

ALC	Active Learning Classrooms
CTCA	Culturo-Techno-Contextual Approach
UPSA	University of Professional Studies – Accra
3C Teaching Framework	The Collectivism, Culture & Context Teaching Framework

Author details

Fred Awaah[1]*, Cosmas Lambini Kombat[2] and Emmanuel Okyere Ekwam[1]

1 University of Professional Studies, Accra, Ghana

2 University of Development Studies, Ghana

*Address all correspondence to: akaphari@yahoo.com

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Johnson DW, Johnson RT. Cooperative learning: The foundation for active learning. In: Active Learning—Beyond the Future. United Kingdom: Intech Open; 2018

[2] Hartikainen S, Rintala H, Pylväs L, Nokelainen P. The concept of active learning and the measurement of learning outcomes: A review of research in engineering higher education. Education Sciences. 2019;**9**(4):276

[3] Lombardi D, Shipley TF, Astronomy Team, Biology Team, Chemistry Team, Engineering Team, Geography Team, Geoscience Team, and Physics Team. The curious construct of active learning. Psychological Science in the Public Interest. 2021;**22**(1):8-43

[4] Talbert R, Mor-Avi A. A space for learning: An analysis of research on active learning spaces. Heliyon. 2019;**5**(12):e02967

[5] Hofstede G. Culture's Consequences: International Differences in Work-Related Values. Beverly Hills, CA: Sage; 1980

[6] Hofstede G. Dimensionalising cultures: The Hofstede model in context. Online Readings in Psychology and Culture. 2011;**2**(1):1-26

[7] Wilson TD. On user studies and information needs. Journal of Documentation. 1981;**37**(1):3-15

[8] Fraser WJ, Beyleveld M, De Villiers JJR. The use of active learning in a private higher education institution: The lecturer's perspective. South African Journal of Higher Education. 2019;**33**(2):16-28

[9] Mihrka AA, Mihrka AA. Learning Styles and Attitudes towards Active Learning of Students at Different Levels in Ethiopia (Doctoral Dissertation). Pretoria, South Africa: University of South Africa; 2014

[10] Awaah F. Indigenous (cultural) knowledge related to the concept of politics as a difficult topic in public administration. In: Okebukola PA, editor. Breaking Barriers to Learning: The Culturo Techno-Contextual Approach (CTCA). Slough, UK and Delhi: Sterling; 2020. pp. 182-192

[11] Okebukola PA, editor. Breaking Barriers to Learning: The Culturo Techno-Contextual Approach (CTCA). Slough, UK and Delhi: Sterling; 2020

[12] Hountondji PJ. African Philosophy: Myth and Reality. India: Indiana University Press; 1996

[13] Awaah F. Experimental Assessment of the Potency of Culturo-Techno-Contextual Approach in Enhancing Performance in Difficult Concepts in the Ghanaian Undergraduate Public Administration CuHrriculum (PhD. Thesis the University of Burundi). Burundi: University of Burundi; 2021

[14] Okebukola PAO, Ige K, Oyeyemi A, Olusesi O, Owolabi O, Okebukola F, et al. Exploring the impact of Culturo-techno-contextual approach (CTCA) in tackling under-achievement in difficult concepts in biology. In: Proceedings of the 2016 Conference of the National Association of Research in Science Teaching (NARST). USA: Baltimore; 2016

[15] Adewusi MA. Refractive index as a difficult topic for secondary school physics students: Harnessing the power of indigenous (cultural) knowledge for its understanding. In: Okebukola PA,

editor. Breaking Barriers to Learning: The Culturo Techno-Contextual Approach (CTCA). Slough, UK and Delhi: Sterling; 2020. pp. 218-229

[16] Okebukola PA. Quality or Quantity: Positioning the Nigerian University System for the Challenges of Science and Technology in the new Millennium. Nigeria: A paper presented at the 6th Convocation Lecture of Adekunle Ajasin University, Akungba-Akoko (AAUA); 2015

[17] Ogunbanwo G. Relative Effectiveness of the Culturo-Techno-Contextual Approach on Students' Performance in Genetics and Evolution (Bachelor's Thesis). Ojo, Lagos Nigeria: Lagos State University; 2019

[18] Adam U. Potency of Culturo-Techno-Contextual Approach on Students' Achievement in and Attitude towards Mutation and Variation. Research Report Submitted in Part Fulfilment of the Bachelor of. Nigeria: Science Education (Biology), Lagos State University; 2019

[19] Gbeleyi OA. Flowcharting, algorithm and logic gate as difficult topics for secondary school students: Harnessing the power of indigenous (cultural) knowledge for their understanding. In: Okebukola PA, editor. Breaking Barriers to Learning: The Culturo Techno-Contextual Approach (CTCA). Slough, UK and Delhi: Sterling; 2020. pp. 239-252

[20] Egerue IC. Impact of Sociocultural Factors on Scientific Explanations in Genetics and Ecology Offered by Senior Secondary Students in Lagos State (Doctoral Thesis). Nigeria: Lagos State University; 2019

[21] Awaah F. Towards an Afrocentric Teaching Model. United Kindom: University World News; 2020

[22] Awaah F. Emerging issues and threats to cultural security in Ghana: Women and youth to the rescue. In: Okebukola PA, editor. Women, Youth, Culture and Development in Africa. Abeokuta, Nigeria: Institute for African culture and international understanding; 2014. pp. 3-17

Chapter 10

Student Perceptions of Open Pedagogy and Community-Engaged Service Learning

Christian Williams

Abstract

Open pedagogy is an approach to instruction that places the student as a partner in the learning environment moving beyond traditional methods of instructional delivery that center the instructor as the expert. Open pedagogy allows for student contributions to the classroom that move beyond traditional instructional methods such as disposable assignments and educator led classroom discussions that are created by faculty to provide students with a learning experience. Instead, open pedagogy facilitates a student-centered learning environment that engages students as co-creators of learning and allows them to play a role in the facilitation of the learning environment. This paper focuses on the role of open pedagogy in community engaged service learning and is based on a quasi-experimental research study that explored student perceptions of community engaged service learning with and without an open pedagogical approach. The results report student satisfaction with the experience, perceived value, and the likelihood that they would take a course that combines these pedagogies in the future.

Keywords: open pedagogy, community partnerships, open educational resources, praxis

1. Introduction

In the face of shifting educational and societal terrains, it has become increasingly important to evaluate teaching and learning approaches to maximize student learning, engagement, and performance outcomes. Traditional teaching models that have emphasized the educator as the expert at the center of the learning experience are often being replaced with active and experiential learning models. No longer is the preferred method of information delivery the instructor as the "Sage on the Stage" being replaced with active and experiential learning models that extend learning beyond the classroom and emphasize the students' role as central to the learning process. Active and experiential learning models have gained widespread acceptance and have been found to increase student attendance [1], engagement [1–3], and enhance learning [4]. Learning by doing approaches to classroom design has also been connected to increased retention of concepts and knowledge [5] and a deeper connection to the course content through practical application and reflection [6]. When classrooms are designed with active and experiential approaches to teaching, there is a significant shift in the learning environment that allows students to be actively engaged as co-constructors of the learning experience alongside their instructors and peers. While there are many iterations of models of active learning, the current study focuses on Community Service Learning (CSL) pedagogy and Open Pedagogy.

Community Service Learning (CSL) has been widely implemented and continues to gain traction in educational communities as a way to enhance student learning opportunities and create active engagement [7, 8]. CSL is a well-researched and established pedagogical approach that connects course learning to community-based service through an ongoing commitment to civic engagement, experiential learning, and reflective practice [9]. CSL course activities are designed to create an integrated approach that connects theoretical course content to practice by engaging in organized community service that meets an identified community need area [7]. Outcomes reported for CSL include enhanced student engagement, improved student learning, increased social skills in students [10], and positive student perspectives on service activities [11, 12].

Another student-centered emerging trend in educational pedagogy includes open educational practices such as the use of open educational resources (OER) to increase student centered learning approaches and equity in education by decreasing barriers to access of course materials and content. These practices are centered around the concept of openness include the use of free and accessible resources that not only decrease student costs and increase access and equity but also includes practices that empower students to be creators of the learning community and creators of knowledge [13–15]. Open pedagogy in practice has been described as shifting the classroom from a place where instruction is delivered to students who absorb it to one where learning is co-created and student centered [14, 16].

This paper explores a study that was designed using archival student satisfaction data. It compares students' perceptions of community engaged service-learning projects with and without the use of open pedagogy. The purpose of this study was to explore how open pedagogy, and particularly the use of non-disposable assignments, would influence students' satisfaction with and perception of, community engaged service-learning projects.

2. Community service learning

CSL combines traditional classroom delivery methods of education with community based practical service experiences [17]. This practical application increases critical thinking skills as students are challenged to explore and problem-solve real world challenges [4, 12, 18]. Further it has a positive impact on students' understanding of social justice issues [19] and development of cross-cultural understanding [20, 21]. CSL has long been accepted in the educational field as a pedagogical approach that creates meaningful ways to facilitate students' engagement in service and thereby increasing their commitment and internalization of civic responsibility. It serves as a connection point for students between the academic classroom and their roles as thoughtful citizens in the community [21].

CSL presents a shift in traditional reliance on knowledge as preparation for future occupations and community life to emphasizing the role of experience and practice in the enhancement of critical thinking, communication, and problem-solving skills [22–24]. Further CSL has been found to enhance student learning environments, and has been tied to increased academic success, positive impacts on student learning outcomes [4, 21, 23, 24], moral development, and critical thinking skills [23]. Previous research has found that CSL positively influences students' academic performance when compared to traditional classroom content delivery methods of instruction [4]. Particularly, evidence suggests that engagement in learning activities outside of the classroom increases critical thinking skills and collaboration that is not traditionally fostered in lecture-based courses [4, 18, 21, 24].

This approach is more than just combining hands on experiences with traditional class materials for students, it also provides opportunity for critical reflection on service experiences and facilitates a deeper understanding of course content and in many cases the field of study than compared to traditional learning methods [4, 23]. This pedagogical approach can assist students particularly in helping professions to be more prepared for the work they will do in the future [19, 23], providing them opportunities to engage with and be of service to individuals from vulnerable populations and community organizations [19, 25]. Students engaged in CSL community collaborations were found to have increased empathy and understanding of working with individuals with disabilities [26]. Additionally, Deck and colleagues also found that service-learning opportunities increased student perceptions of their self-efficacy [19].

While CSL is an accepted and common practice across a variety of educational settings, there continues to be little consensus as to the best practices in course implementation and outcomes directly related to how the pedagogy is implemented. Further, there is little literature that measures the outcomes for students in a manner that is tied into implementation strategies [27]. There are numerous resources available to faculty to utilize when designing a CSL course or project, yet concerns exist that they are not utilized consistently [4]. CSL is best implemented when the community engaged assignments and the course content are cohesive, allowing for each to assist with synthesizing the information [23] and promoting deeper understanding. Most traditional renditions of CSL facilitate the practical application of course knowledge by engaging in community collaboration with a partner organization that identifies needs that the course and students can help to fill. Course instructors can ensure the success of these collaborations by facilitating reciprocal relationships for students, providing opportunities for transformative learning. It is important that CSL programming and design is centered around being flexible and responsive to meet the changing needs of community partners [28]. An approach that is adaptable to the needs of the community has been positively correlated with enhancing student capacity for critical thinking [28].

Student perceptions related to effective implementation include course content that is closely in line with the service-learning experience and in class reflection and class discussions that facilitates the integration of practice and course content build deeper connections [23]. Further students reported that service-learning projects helped them to have a more complete understanding of content and issues presented in the course and service project, thereby increasing their own personal reflection on their experiences and their role in problem solving [23].

CSL has many overlapping qualities with open educational approaches, particularly open pedagogy, which has been gaining increased presence and acceptance in educational settings, making the exploration of student perspectives on the integration of these pedagogical approaches is timely. These include fostering classroom environments that empower students to think critically about their performance and to monitor progress and adjust as necessary [4]. Additionally, student centered learning that focuses on problem-solving and critical thinking are important attributes of both pedagogical approaches.

This specific study implemented a course-specific community engaged service-learning project in two courses with different groups of students. One course implemented traditional instructional community service-learning methods and the assignment was presented as disposable. The second course implement an open pedagogical approach with the assignment being presented as renewable with a lasting impact and availability to the broader community.

3. Open pedagogy

The use of OER and its application to praxis through open pedagogy has gained momentum in higher education as a pedagogical approach that has the capacity increase equity, access, and student agency. In the wake of challenging and shifting educational terrains over the past few years, it is important that educators and systems of education find ways to not only respond to these changing needs but that we recognize the contexts that students exist in and work to break down barriers to engagement [29]. Open pedagogy grew out of the open education movement, which initially gained traction through the use of open educational resources (OER) to increase equity and access in education and decrease barriers related to cost of materials for students [30, 31]. OER has allowed for increased and expanded access to educational materials using open licensing that allows for no-cost access and permits the adaptation of the materials to suit the needs of the user and the course [16, 30]. The open education movement has included the implementation of open educational practices and the inclusion of OER that allow students to retain, reuse, remix, revise, and redistribute materials via open copyright licensing [32]. OER also allow for increased individualization of instruction to meet the needs of students [33], promoting inclusion, which is increasingly important in the wake of educational disruption from the global pandemic.

Much like CS, open pedagogy seeks to enhance student engagement with the course material by creating conducive educational environments where learning is student centered and the student is co-creator of knowledge with learning as a process rather than a product of teacher delivery [34, 35]. This shift in power dynamic present in open pedagogy assists in the goal of deepening student engagement with subject matter by increasing the development of critical thinking skills, enhancing the capacity for collaboration [16], and providing opportunities for self-direction in the learning process [14, 15, 36]. Further, empowering students to take ownership and direction of their learning process increases confidence and self-efficacy [30, 35, 36]. OER pedagogy creates a milieu where students can explore real issues and engage in collaborative solution focused problem-solving [31, 35]. Quote my article here.

Open educational practices have taken on many forms and faculty have used vast implementation strategies some of which include creating opportunities for students to create course content that will be available for continued access to future students and beyond through open licenses [16, 30, 37, 38] rather than the traditional approach of disposable assignments completed only for the purposes of a grading mechanism and are then discarded [37]. These types of open projects have included creating editing Wikipedia pages, developing multiple choice quizzes, providing demonstration examples or tutorials, social annotation, student created syllabi and assignments, co-authoring textbook entries, and much more. Previous research has found significant value in renewable assignments for students including an increase in their proactive completion of assignments and the added value for future endeavors such as applications for employment and further education should the assignments be available for public consumption [30].

This shift in approach to resources that not only decrease educational expenses and increase availability of resources, has also been tied to increased student engagement in the class. Open Pedagogy has been generally found to be positively regarded by students and to have a meaningful impact on the sense of pride students experienced about their work [29, 30]. While previous studies have not found a significant difference in overall course learning outcomes for open pedagogy studies on this have been limited and have yet to consider if the areas of overall skill improvement via open pedagogy may not be adequately captured by course specific learning outcomes.

Research has identified the potential for open pedagogy to benefit student learning and facilitate meaningful engagement and participation within the classroom, yet there continues to be a gap in the literature regarding student perceptions of specific iterations of open pedagogy, particularly the comparison between assignments delivered with traditional and open approaches [29, 37, 38]. Pavotti and colleagues [39] shared the results of a research that looked at the experience of open practices by educators who did not design the course as with the intention of open pedagogical design. However, this study used a community engaged project online and reported data from all parties on their perspectives of the assignment and overall satisfaction [39]. Overall students reported a positive experience with the course yet identified practical barriers to group work outside of the classroom, highlighting the need to ensure that course design has adequate support and set up to ensure success [39].

When looking at the influence of open approaches to CSL there is limited exploration of student perceptions of satisfaction and their desire to engage in future CSL and service-related activities. This is particularly true of for student satisfaction and their willingness to engage in future. The present study builds upon existing research and explores student perceptions of project based CSL assignments one using traditional CSL pedagogy with a disposable assignment and the second employing open pedagogy to the project based CSL assignment. Students in the latter course engaged in dialog about open pedagogy, the role of renewable assignments, and how the CSL assignment fit into this approach. The decision to include the same assignment with two groups was to decrease the possibility of student perceptions of the project being measured rather than the experience of open pedagogy.

4. Methods

The goal of the current study was to compare students' perceptions of community engaged service-learning projects when implemented using traditional methods and disposable assignments versus when an open pedagogical approach was used. In the open pedagogy rendition, students were aware that their project would be publicly shared and were able to view other examples of similar student work in the repository. The research question addressed was: Does the use of open pedagogy contribute to students' perceptions about a CSL project-based assignment.

The sample included students from a small, catholic, liberal arts institution who were enrolled in and completed courses that employed CSL projects as part of the pedagogical approach. Anonymous self-administered survey responses are regularly collected about CSL courses at the University to measure student perceptions of the course and CSL integration into the classroom. Archival data from two CSL courses taught by the same instructor in the Fall of 2021 and Spring of 2022 was accessed and utilized for the purposes of this project with approval of the Assumption University's Institutional Review Board. Since the surveys were initially anonymous and completed with the purpose of program evaluation by the Community Service-Learning department at the University, concerns for students' openness were minimized due to the lack of connection to the individual instructor and potential influence on their grade in the course.

Overall, 47 survey responses students' responses were utilized 33 from Fall of 2021 and 14 from Spring of 2022. Exposure to community service-learning as a pedagogical practice varied among the group of students with the majority of the students (n = 27) were taking a CSL course for the first time (Fall = 18, Spring = 9), 5 students reported having taken 2 prior CSL courses (Fall = 4, Spring = 1), and 13 students reported that they had taken one previous CSL course (Fall = 11, Spring = 2). Only 2 students reported having taken 3 or more CSL courses and both were in the Spring Cohort. Of the students in the Spring cohort, only one student reported having heard of open pedagogy before this course (7.1%), with the majority of students (n = 13) being exposed to open pedagogy and OER for the first time.

4.1 Procedures

While the data utilized was archival in nature, the educational design of the two courses was similar except for the introduction of open pedagogy to the CSL project in the Spring 2022 iteration. Specifically, each course shared the same educational objectives as well as contact hours, both classes met face-to-face and utilized the same teaching approaches and techniques. Each course shared identical implementation of reflective practice and assessment methods related to the CSL project including collaborative class presentations and journals entries, all of which contributed to their final grade. Students in the Spring 2022 iteration of the course were engaged in dialog about open pedagogy and the difference between disposable and renewable assignments and how their project fit into this approach.

Following this conversation, the students completed their community based CSL course in the same manner as students in the Fall of 2021.

4.2 Measures

At the end of each CSL course, students are asked to complete an anonymous CSL Academic Goals Survey (See Appendix A) by the CSL department on campus. Due to the anonymous nature of the survey, it is not possible to identify which students completed the survey or to ensure that all students in the course did. Therefore, in the Fall of 2021 there were 44 students enrolled in the course across 2 sections and 75 percent (n = 33) completed the survey. In the Spring of 2022, there was 15 students enrolled in the course and all but one completed the survey (n = 14, 93%).

As this study is based on archival data it utilized data was garnered from surveys completed by students that were not integrated into the course experience rather they are asked to complete it as part of their CSL experience via an online platform where the questionnaire is stored. The CSL Academic Goals Survey asks students to answer questions indicating their satisfaction with the CSL portion of the course, specifically if the service experience enhanced their understanding of the other subject matter in the course, if the other subject matter in the course enhanced their understanding of the service experience, if after the course they would consider taking another CSL course, if after the course they were more likely to do community service in the future, and if they would recommend this CSL course and project to other students. Individual items are measured on a 5-point Likert scale that ranges from 1 (strongly disagree) to 5 (strongly agree). The reliability of the scale was positively evaluated as acceptable using the Cronbach's alpha coefficient (0.847). The participants were asked an additional open-ended question to add any comments that they had about the course, CSL project, or community partner.

4.3 Data analysis

Descriptive statistics were used to identify the students' previous experiences with CSL courses and open methods of instruction. Assumptions for homoscedasticity and normality were not met, therefore Mann Whitney U non-parametric statistics were sample t-tests were used to assess the influence of open pedagogy on student's perception of a CSL class project versus traditional means of CSL instruction. Analysis of Covariance (ANCOVA) was used to control for the influencing factor of previous CSL courses taken on student perceptions. ANCOVA requires an assumption of normality that was not met in the current study, therefore, a nonparametric rank ANCOVA as designed by Quade [40] was utilized. This nonparametric test does not assume normal distribution of data making it an appropriate choice. Data analysis was conducted using SPSS 27 for both the Mann Whitney U and the nonparametric ANCOVA. Additionally, thematic analysis was also used to analyze student open responses to identify and similarities in experiences and feedback.

5. Results

5.1 Students' perspectives on service-learning enhancing understanding of the other subject matter in the course

A Mann–Whitney U test was run to determine if there were differences in student perceptions of CSL between the open pedagogy and traditional learning methods students. Impact of service learning on their understanding of the other subject matter in the course. Distributions of scores for students in the fall and spring were similar, as assessed by visual inspection. Median engagement scores were not statistically significantly different between the fall students (5.00) and spring students (4.50), $U = 179.50$, $z = -1.394$, $p = .163$.

5.2 Students' perspectives on the other subject matter in the course enhancing their understanding of the service experience

A Mann–Whitney U test was run to determine if there were differences in student perceptions of the impact of the course content on their understanding of the CSL project between the open pedagogy and traditional learning methods students. Distributions of scores for students in the fall and spring were similar, as assessed by visual inspection. Median engagement scores were equal between the fall students (5.00) and spring students (5.00), $U = 222.50$, $z = -.230$, $p = .818$.

5.3 Students' perspectives on if they would consider taking another CSL course

A Mann–Whitney U test was run to determine if there were differences in students' consideration of another CSL course between the open pedagogy and traditional learning methods students. Distributions of scores for students in the fall and spring were similar, as assessed by visual inspection. Median scores were equal between the fall students (5.00) and spring students (5.00), $U = 263.00$, $z = .874$, $p = .382$.

5.4 Students' perspectives on the likelihood that of engaging in future community service

A Mann–Whitney U test was run to determine if there were differences in the likelihood that students would engage in community service in the future between the open pedagogy and traditional learning methods students. Distributions of scores for students in the fall and spring were similar, as assessed by visual inspection. Median scores were insignificantly different between the fall students (4.00) and spring students (5.00), $U = 260.50$, $z = .763$, $p = .455$.

5.5 Student's future recommendation of the course or CSL project

A Mann–Whitney U test was run to determine if there were differences in students' recommendation of the CSL course, project, or community partner between the open pedagogy and traditional learning methods students. Distributions of scores for students in the fall and spring were similar, as assessed by visual inspection. Median engagement scores were not statistically significantly different between the fall students (5.00) and spring students (4.50), $U = 179.50$, $z = -1.404$, $p = .160$ (**Table 1**).

5.6 Covariates and additional analysis

Since many of the students had taken previous CSL courses, which may influence their perceptions of CSL and the likelihood of taking future CSL courses, it was important to

	Fall 2021 traditional (n = 33)	**Spring 2022 open pedagogy (n = 13)**			
Student perspectives	**Mean Rank**	**Mean Rank**	**U**	**Z**	**P**
CSL enhanced understanding	5.00	4.50	179.50	1.394	.163
Course enhanced CSL	5.00	5.00	222.50	.230	.818
Would take another CSL	5.00	5.00	263.00	.874	.382
Future comm service	4.00	5.00	260.50	.763	.455
Would recommend course/project	5.00	4.50	179.50	1.404	.160

Summary of differences between fall and spring students on Mann–Whitney U test.
Note. $^{*}p < .05$.

Table 1.
Summarizes Mann–Whitney U test results.

explore this as a possible covariate. Due to the potential impact on reported differences between groups, a nonparametric analysis of covariance was conducted to control for the impact of previous exposure on student perceptions [40]. When controlling for how many CSL courses students had previously taken, differences in student perceptions remained statistically insignificant.

Analysis of student open responses on the prompt "Please add further comments concerning the course, service project, or agency." were reviewed and were not included in the current study due to not providing additional insight into the research questions. Student open responses were overly positive about the CSL experiences highlighting their enjoyment "I enjoyed this because I got to me new people" "Great CSL", the value of the experience "I truly think this opportunity is worthy trying for all students,", and the opportunity to increase their exploration of information that they may not have otherwise been exposed to "It allows for the experience and knowledge to be further explored in areas that we may not have known."

6. Discussion

The current study aimed to compare students' perceptions of CSL courses when they were implemented with open pedagogy versus traditional teaching approaches. The results revealed insignificant differences between these groups of students. The results of this research are in line with previous research that has found open pedagogy approaches to instructional design are as effective as traditional means [37] with the findings from the current study showing that the application of open pedagogy did not have a significant impact on the CSL project and student perceptions of its place in the classroom.

It is important to recognize that pedagogical models are not in and of themselves avenues to increasing student engagement and enhancing academic skills, they must be implemented in such as way that facilitates the spaces where students can engage deeper with course content and collaborate with faculty and peers. The body of literature that identifies open approaches as being positively regarded by students and faculty does not account for the lack of cohesiveness in implementation and the continued resistance regarding pedagogical change [15]. Implementation of open pedagogy has at-times been found to be time consuming for students and faculty alike [15] and ensuring that considerations for technology, simplicity, and ease of engagement are explored prior to implementation can have significant impacts on faculty and student perspectives [34].

Another potential influencing factor may be the students previous experience with open education and open pedagogy and any hesitancy towards this new pedagogical approach. Previous research has found that some of the challenges to the implementation of open pedagogical approaches have been student hesitancy to have their work reviewed and evaluated by others as well as widely available after the course ends [39]. Throughout the course of the semester, students in the Spring course shared that they were anxious about the renewable assignment portion of the assignment, questioning if their work was good enough to be shared with the general public, a sentiment not expressed by the fall group where the CSL projects took the form of disposable assignments. While the data did not find that previous CSL experience had a statistically significant impact on the current results, future research should account for student comfortability with open pedagogy when attempting to measures its impact on student perceptions. Only one student in the present study had exposure to open pedagogy prior to the spring semester. The shift in relationship between student and instructor may be felt by students who are not used to a more collaborative mentor role and feel more familiar with instructors who view their role as imparting information [37].

While the data is not statistically significant in highlighting differences in student perceptions of the CSL project with open pedagogy approaches, students also did not report less satisfaction and therefore we can assume that this approach was at least equal to that of traditional CSL assignments. Additionally, Bloom found that faculty found themselves more comfortable and effective in implementing open pedagogy the second time they engaged this way [41], which may be similar for students and should be considered as an area for future inquiry.

At the very least the recognition by educators of the potential for discomfort can create opportunities for important dialog with students regarding the role of openness. Faculty should discuss any benefits and risk factors that they should consider when deciding to publicly license their work and researchers have debated the benefits of providing students with opportunities to complete alternative assignments or decline to make assignments renewable [38]. When students are expected to partner in the creation of the learning and assessment process, it is important to assist them in setting and understanding reasonable benchmarks to avoid preoccupation with a grading process that deviates from traditional methods [38]. This is supported by evidence that has found that faculty implementation of open practices does not improve student outcomes in and of itself, students must also be informed of the benefits, rational, and strategies for successful engagement otherwise this confusion cannot only impact the classroom environment but their willingness to engage with open approaches [39]. Effective classroom practices engage students by providing them dialog to understand why different teaching strategies are being used and their overall role in the class including for assessment purposes.

6.1 Limitations

While this study attempts to minimize some of the limitations by having the same faculty member for each rendition of the CSL project, there are still several limitations that must be considered. The sample size of the current study is relatively small and limited to one small catholic liberal arts university therefore, generalizations cannot be readily made to a larger student population. These students were all engaged in face-to-face learning models within person community engagement, however, pivots to hybrid instruction continue to be present to manage the spread of COVID-19 which may influence student perspectives on the course. This study utilized archival data, which protected against concerns about students feeling pressured to answer in a positive manner due to worries for their grades, it is limited to the data that has been previously collected. It was not possible to explore other potential covariates such as how many semesters they have been enrolled at the university, previous experience with community-service, perspectives on engagement, and comfortability with the assignments. Further questions directly related to the experience of open pedagogy as it intersects with CSL was not collected and would be an important avenue for future research.

Due to the lack of consensus on implementation of open pedagogy and varying practices of faculty, results may not be easily implemented by other educators who may have differing views on openness. Future research should consider pedagogical approaches that are being implemented as open pedagogy and seek to provide guidance regarding effective approaches in to creating open classroom communities. Additionally, research that explores open pedagogy learning designs as they are experienced by students may help to develop guidelines for implementation that can be added to the tools currently available for faculty.

7. Conclusions and implications

While the present study did not find statistically significant differences between CSL projects that are implemented with traditional means such as disposable assignments and those that were implemented with open pedagogy, this paper has highlighted the significant overlap in these pedagogical approaches. This is encouraging for educators who seek to increase the experiential learning opportunities that they facilitate for their students. Previous research on CSL and open pedagogical practices highlight student positive perceptions of their learning experience as well as increased outcomes both for the specific course material as well as attainment of academic skills such as critical thinking and collaboration. There is limited research that has explored the intersection of service-learning and open pedagogical practices and should be explored further as a possible avenue for increase student efficacy, engagement, and ownership of course outcomes. Further, the exploration of student connectedness to future career paths via CSL and open pedagogy is another important area to consider as contributions to the field of practice prior to graduation may enhance students' perceptions of their readiness to enter the field and their career trajectories.

Conflict of interest

The authors declare no conflict of interest.

A. Community service-learning (CSL): academic goals survey

Term:
Course:
List Community Partner:
Please answer the following questions to indicate your satisfaction with the CSL component of this course.
How many CSL course(s) have you taken (check one) in previous semesters?
___ none, this is my first CSL course __________ 1–2 ___________ 3 or more.
Indicate the nature of CSL requirements:
____________ Project-based.
____________ Service provided at the agency in a series of individual visits.
For the following statements, please rate the degree to which you agree with the statement. Select a number that best matches your agreement.

	Strongly disagree (1)	Somewhat disagree (2)	Neutral (3)	Somewhat agree (4)	Strongly agree (5)
The service experience enhanced my understanding of the other subject matter in the course					
The other subject matter in the course enhanced my understanding of my service experience.					
After this course, I would consider taking another CSL course					
After this course, I am more likely to do community service in the future					
I would recommend this placement or project to other students					
Please add further comments concerning the course, service project or agency. We appreciate your feedback.					

Author details

Christian Williams
Assumption University, Worcester, United States of America

*Address all correspondence to: ce.williams@assumption.edu

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Venton BJ, Pompano RR. Strategies for enhancing remote student engagement through active learning. Analytical and Bioanalytical Chemistry. 2021;**413**(6):1507-1512. DOI: 10.1007/s00216-021-03159-0

[2] Strachan R, Liyanage L. Active student engagement: The heart of effective learning. In: Layne PC, Lake P, editors. Global Innovation of Teaching and Learning in Higher Education: Transgressing Boundaries. Cham: Springer International Publishing; 2015. pp. 255-274. DOI: 10.1007/978-3-319-10482-9_16

[3] Munna AS, Kalam MA. Impact of active learning strategy on the student engagement. GNOSI: An Interdisciplinary Journal of Human Theory and Praxis. 2021;**4**(2):96-114. Available from: http://gnosijournal.com/index.php/gnosi/article/view/96

[4] Deal B, Hermanns M, Marzilli C, Fountain R, Mokhtari K, McWhorter RR. A faculty-friendly framework for improving teaching and learning through service-learning. Journal of Service-Learning in Higher Education. 2020;**10**:3-11. Available from: https://eric.ed.gov/?id=EJ1242880

[5] Brail S. Experiencing the city: Urban studies students and service learning. Journal of Geography in Higher Education. 2013;**37**(2):241-256

[6] Brail S. Quantifying the value of service-learning: A comparison of grade achievement between service-learning and non-service-learning students. International Journal of Teaching and Learning in Higher Education. 2016;**28**(2):148-157. Available from: http://www.isetl.org/ijtlhe/

[7] Mason MR, Dunens E. Service-learning as a practical introduction to undergraduate public health: Benefits for student outcomes and accreditation. Frontiers in Public Health. 2019;**7**:63. DOI: 10.3389/fpubh.2019.00063

[8] Cashman SB, Seifer SD. Service-learning: An integral part of undergraduate public health. American Journal of Preventive Medicine. 2008;**35**(3):273-278. DOI: 10.1016/j.amepre.2008.06.012

[9] Seifer SD. Service-learning: Community-campus partnerships for health professions education. Academic Medicine. 1998;**73**(3):273-277. DOI: 10.1097/00001888-199803000-00015

[10] Afzal A, Hussain N. Impact of community service learning on the social skills of students. Journal of Education and Educational Development. 2020;**7**(1):55-70. Available from: http://jmsnew.iobmresearch.com/index.php/joeed/article/view/10

[11] Weiss D, Hajjar ER, Giordano C, Joseph AS. Student perception of academic and professional development during an introductory service-learning experience. Currents in Pharmacy Teaching and Learning. 2016;**8**(6):833-839. DOI: 10.1016/j.cptl.2016.08.016

[12] Bender G, Jordaan R. Student perceptions and attitudes about community service-learning in the teacher training curriculum. South African Journal of Education. 2007;**27**(4):631-654

[13] Hegarty B. Attributes of open pedagogy: A model for using open educational resources. Educational

Technology. 2015;**55**(4):3-13. Available from: https://www.jstor.org/stable/44430383

[14] DeRosa R, Robinson S. From OER to open pedagogy: Harnessing the power of open. In: Open: The Philosophy and Practices that are Revolutionizing Education and Science. London: Ubiquity Press; 2017. pp. 115-124. DOI: 10.5334/bbc.i

[15] Baran E, AlZoubi D. Affordances, challenges, and impact of open pedagogy: Examining students' voices. Distance Education. 2020;**41**(2):230-244. Available from. DOI: 10.1080/01587919.2020.1757409

[16] Hilton J III, Wiley D. Defining OER-enabled pedagogy. The International Review of Research in Open and Distributed Learning. 2018;**19**:134-146. DOI: 10.19173/irrodl.v19i4.3601

[17] Sivalingam P, Yunus MM. Nurturing 21st century skills through service learning: From isolation to connection. International Journal of Social Sciences. 2017;**3**(1):346-356. DOI: 10.20319/pijss.2017.31.346356

[18] Loes C, Pascarella E. Collaborative learning and critical thinking: Testing the link. The Journal of Higher Education. 2017;**88**:726-753

[19] Deck SM, Conner L, Cambron S. Students' perceptions of service-learning in an advanced research course. Advances in Social Work. 2017;**18**(2):456-473. DOI: 10.18060/21548

[20] Watson B, Reierson F. Best practice in international service learning (ISL): Aspects of risk and impact. TEACH Journal of Christian Education. 2017;**11**(1): 29-36. Available from: https://research.avondale.edu.au/teach/vol11/iss1/8

[21] Warren JL. Does service-learning increase student learning?: A meta-analysis. Michigan Journal of Community Service Learning. 2012;**18**(2):56-61

[22] Bell S. Project-based learning for the 21st century: Skills for the future. The Clearing House: A Journal of Educational Strategies, Issues and Ideas. 2010;**83**(2):39-43. DOI: 10.1080/00098650903505415

[23] Becnel K, Moeller RA. Community-embedded learning experiences: Putting the pedagogy of service-learning to work in online courses. Open Learning: The Journal of Open, Distance and e-Learning. 2017;**32**(1):56-65

[24] Levesque-Bristol C, Knapp T, Fisher B. The effectiveness of service-learning: It's not always what you think. The Journal of Experimental Education. 2011;**33**:208-224

[25] Lawson J, Olson M. International service learning: Occupational therapists' perceptions of their experiences in Guatemala. The Open Journal of Occupational Therapy [Internet]. 2017;**5**(1):1-12. Available from: https://scholarworks.wmich.edu/ojot/vol5/iss1/11

[26] Lawson JE, Cruz RA, Knollman GA. Increasing positive attitudes toward individuals with disabilities through community service learning. Research in Developmental Disabilities. 2017;**69**:1-7. DOI: 10.1016/j.ridd.2017.07.013

[27] Filges T, Dietrichson J, Viinholt BCA, Dalgaard NT. Service learning for improving academic success in students in grade K to 12: A systematic review. Campbell Systematic Reviews. 2022;**18**(1):e1210. DOI: 10.1002/cl2.1210

[28] Tijsma G, Hilverda F, Scheffelaar A, Alders S, Schoonmade L, Blignaut N,

et al. Becoming productive 21st century citizens: A systematic review uncovering design principles for integrating community service learning into higher education courses. Educational Research. 2020;**62**(4):390-413

[29] Clinton-Lisell V. Open pedagogy: A systematic review of empirical findings. Journal of Learning for Development. 2021;**8**(2):255-268. Available from: https://jl4d.org/index.php/ejl4d/article/view/511

[30] Abri MHA, Dabbagh N. Testing the intervention of OER renewable assignments in a college course. Open Praxis. 2019;**11**(2):195-209. DOI: 10.5944/openpraxis.11.2.916

[31] Lambert SR. Changing our (dis) course: A distinctive social justice aligned definition of open education. Journal of Learning for Development. 2018;**5**(3):225-244. Available from: https://jl4d.org/index.php/ejl4d/article/view/290

[32] Wiley D, Hilton J. Defining OER-enabled pedagogy. The International Review of Research in Open and Distance Learning. 2018;**19**(4):133-147. DOI: 10.1080/01587919.2020.1757409

[33] Brown M, Croft B. Social annotation and an inclusive praxis for open pedagogy in the college classroom. Journal of Interactive Media in Education. 2020;**2020**(1):8. DOI: 10.5334/jime.561

[34] Scannell C. Intentional teaching: Building resiliency and trauma-sensitive cultures in schools. Teacher Education in the 21st Century - Emerging Skills for a Changing World. London: IntechOpen; 2021. Available from: https://www.intechopen.com/chapters/undefined/state.item.id

[35] Werth E, Williams K. Learning to be open: Instructor growth through open pedagogy. Open Learning: The Journal of Open, Distance and e-Learning. 2021:1-14. DOI: 10.1080/02680513.2021.1970520

[36] Tillinghast BH. Developing an open educational resource and exploring OER-enabled pedagogy in higher education. IAFOR Journal of Education. 2020;**8**(2):159-174. DOI: 10.22492/ije.8.2.09

[37] Bloom M. Assessing the impact of "open pedagogy" on student skills mastery in first-year composition. Open Praxis. 2019;**11**(4):343-353. DOI: 10.5944/openpraxis.11.4.1025

[38] Paskevicius M, Irvine V. Open education and learning design: Open pedagogy in Praxis. Journal of Interactive Media in Education. 2019;**2019**(1):10. DOI: 10.5334/jime.512

[39] Paviotti G, D'Angelo I, Giaconi C, Cavicchi A. Open pedagogy practices: A case study in undergraduate education. Journal of E-Learning and Knowledge Society. 2020;**16**(4):1-10. DOI: 10.20368/1971-8829/1135321

[40] Quade D. Rank analysis of covariance. Journal of the American Statistical Association. 1967;**62**:1187-1200. DOI: 10.2307/2283769

[41] Martin T, Kimmons R. Faculty members' lived experiences with choosing open educational resources. Open Praxis. 2019;**12**(1):131-144. DOI: 10.5944/openpraxis.12.1.987

Chapter 11

Perspective Chapter: Ungrading, Grading Contracts, Gamification and Game-Based Learning

Gregory Garvey

Abstract

This chapter will explore considerations for the adoption of grading contracts with the possible addition of the mechanics of game design, game-based learning, or gamification. The motivation for this approach is to ensure equity and inclusion in the classroom by creating a compassionate environment to enhance student engagement and learning. When introduced in the appropriate way, teachers can track students' progress without the imposition of the added stress and fear that conventional assessment practices engender. Sometimes referred as "ungrading," the adoption of these strategies prioritizes the progress of each individual student and re-envisions learning as a series of achievements that students complete and level-up to take on a series of successive challenges based on previous accomplishments not unlike the playing of a video game. If virtual reality can be called an empathy machine, a well-crafted video game is a learning and engagement machine. In other words, the magic "sauce" of video games is that players put in untold hours and effort to learn new skills and are rewarded by the sense of mastery and achievement.

Keywords: teaching, learning, ungrading, labor-based grading, game-based learning, gamification, games, mechanics

1. Introduction

In "A Proposal to Abolish Grading" Paul Goodman [1] describes the problem with grading: "For most of the students, the competitive grade has come to be the essence. The naïve teacher points to the beauty of the subject and the ingenuity of the research; the shrewd student asks if he is responsible for that on the final exam." Packed into Goodman's statement is the assertion that the emphasis on grading leads to students focusing only on the grade and not on learning and the mastery of the subject. Completely absent is the love of learning for knowledge's sake. Goodman also addresses the question of why do we have a regime of grading? His answer: "It is uniformly asserted, however, that the grading is inevitable; for how else will the graduate schools, the foundations, the corporations know whom to accept, reward, hire. How will the talent scouts know whom to tap?" Goodman wrote this critique more than 50 years ago. His prescription was to eliminate grading but keep testing "for pedagogic purposes as teachers see fit."

In Growing Up Absurd [2] Goodman provided a much broader critique of American Society. Just a few years later in 1971, Ivan Illich [3] went further, calling for "deschooling" and a program of reconstructing education. Illich described a "hidden curriculum" that caused learning to align with grades and accreditation rather than placing importance on skill acquisition.

Also published in 1971, Wad-Ja-Get? The Grading Game in America [4] reviewed over 60 years of scholarship on grading. The authors posed the simple question: "Is the traditional system of grading—the one most of us experienced throughout many years of schooling—the most educationally useful system of evaluation?"

In the forward to new edition of Wad-Ja-Get? [5] published in July 2020 Barry J. Fishman summarized the impact of this seminal book with "Changing how we think about, and practice grading is crucial to redesigning education systems to be more just, more equitable, and more focused on learning." At about the same time Bloom [6] advocated for mastery learning which called for identifying specific objectives broken down into smaller learning units. Unit objectives required mastery through simple feedback/corrective procedures and formative assessments compared to standards of mastery in a field.

Schinske and Tanner [7] trace the emergence and evolution of grading practices along with a review of the literature on grading. The still current practice of assigning letter grades appears to have been already adopted by 1883. F for failure was introduced at Mount Holyoke College in 1898 driven in part by need for standardization between institutions of higher education. The letter grades we use today gained wider adoption by the 1940s but as the authors point out remain controversial to this day. The authors acknowledge that their review of the shortcomings of grading paints a "bleak outlook on the process of grading and its impact on learning."

In A Century of Grading Research: Meaning and Value in the Most Common Educational Measure [8] Brookhart et al. point to a "what's wrong with teachers" as a type of research bias into grading but yet conclude that "One hundred years of grading research have generally confirmed large variation among teachers in the validity and reliability of grades, both in the meaning of grades and in the accuracy of reporting."

A common thread of the critiques of grading is the suppression of natural curiosity through grading. Knowledge becomes a commodity that is instrumentalized toward achievement rather than be driven by curiosity and a quest to understand. Paulo Freire [9] emphasizes an education based on "I wonder" rather than simply "I do." Grades reinforce the later.

In Pedagogy of the Oppressed [10] Freire critiqued the "banking" concept of education. Students should not be seen as empty vessels to receive knowledge. Education should rather be the process of raising consciousness of their condition so they are empowered to take action (praxis). Freire advocates for students to critically appraise the conditions of their education through dialogics to "recognize connections between their individual problems and experiences and the social contexts in which they are embedded." Education is seen as a critical pedagogy as empowerment and liberation. "Praxis involves engaging in a cycle of theory, application, evaluation, reflection, and then back to theory. Social transformation is the product of praxis at the collective level." A focus on grades undermines this project. Educators like Giroux, McLaren, Hooks, Shor, and others [11–14] have advocated for and expanded critical pedagogy, a discussion of which goes beyond the scope of this chapter.

To this day, students' fixation with grades remains a problem in higher education. In the United States, the A–F scale with its many variations and GPA equivalents, has a long history [15]. A simple search of the web reveals this grading system persists in many institutions of higher education. In the Moral and Spiritual Crisis in Education Purpel [16] observed in 2004, that grade fixation "produces anxiety, cheating, grade grubbing, and unhealthy competition." Quantitative correlational studies of grade obsession by Jacqueline Thomas [17] propose four predictor variables: "financial anxiety, the need to receive academic recognition, parental interest and internal pressure." Thomas summarizes the challenge to educators with "the mission of education to promote a holistic student experiences comes under a threat when grades take priority over traditional educational values."

Michael H. Romanowski [18] in pointing to similar factors such as fear of losing scholarships, parental pressures for success and accountability argues that there are "issues that are deeply embedded in America's ideology of success and achievement." Alfie Kohn [19], reviewed hundreds of studies to show that the artificial incentives of grades based on the now largely discredited behaviorism of B.F. Skinner, overlook the role of intrinsic motivation, leading to poor outcomes. Extrinsic rewards and pay-for-performance elevate obedience over learning and turns play into drudgery. However, in the Appendix B [19]: "What is Intrinsic Motivation" Kohn admits that "it is not at all obvious what is meant by the phrase intrinsic motivation. What appears at first blush an uncomplicated idea reveals itself as a tangle of possibilities, all of which have substantive implications for what we counterpose to the use of rewards." We will return to this discussion below.

Grade inflation is also consequence [20] along with an increase in associated grade anxiety contributing to a mental health crisis [21] that has broader societal implications. The Pew Research Center reported in 2019 [22] that "most teens (61%) say they personally feel a lot of pressure to get good grades, and another 27% say they feel some pressure to do so."

The National Youth Risk Behavior Survey (YRBS) compiles data every 2 years on health-risk behaviors of 9th through 12th grade students in public and private schools across the United States. YRBS data [23] provides "evidence of a significant association between academic grades and suicidal thoughts and behaviors." A report by the Worcester Polytechnic Institute to foster a campus centered on mental health and well-being notes: "Nationally, feelings of disconnection, fear about the future, hopelessness and increased anxiety are more common than ever, especially among the college-age population." [24].

A meta-analysis [25, 26] suggests that when graders have awareness about irrelevant information about students, bias may occur involving subjective and unconscious judgments. Confirmation bias, also the subject of longstanding research [27] remains a "ubiquitous phenomenon in many guises" including education. Kahneman [28] describes strategies he adopted while grading to compensate for the Halo Effect where sequence of who is graded first matters: "The Halo Effect increases the weight of first impressions." For Malouf et al. [29] anonymity in grading is prescribed. An extensive body of research, decades long and ongoing, shows that implicit bias activated by race, age, gender, sexual orientation, and other personal characteristics remains widespread [30–33] with impacts in grading practices [34, 35]. Others such as Inoue [36], recounts his own evolution in questioning grading: "I started by problematizing grades, which led me to problematize my judgment practices, which then led to problematizing the conditions of White supremacy in my classrooms as an on-going antiracist project." Inoue concluded [37] that grading standards "seek to exclude, not include, by their nature and function, by default, regardless of how we justify them or who uses them". Conventional grading privileges some over others.

Consideration should also be given to differences in intelligence, learning styles and in neurodiversity among students. In 1983, Howard Gardner [38] proposed a theory of multiple intelligences (MI) in opposition to a singular quality of intelligence. He argued that conventional testing, assessment, and measures of intelligence did not capture the full range and different proficiencies that individuals possess due to genetic, cultural, and experiential factors. Gardner introduced eight distinct kinds of intelligences: linguistic, logical/mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalist. More recently, Daniel Goleman has promoted social and emotional intelligences [39, 40] which might be added to the list.

Marenus [41] suggests the implications for learning of the theory of MI calls for individuation and pluralization: "Individuation posits that because each person differs from other another there is no logical reason to teach and assess students identically." Pluralization is "the idea that topics and skills should be taught in more than one way." In recent years technology has enabled access to alternative teaching, learning, and assessments that can suit the needs of learners. Marenus notes that there was pushback to Gardner's theory of multiple intelligence from cognitive psychologists [42] (no empirical evidence for the theory), psychometricians (conventional testing supports the idea of a singular intelligence faculty) [43] and importantly, due to lack of definitions there is no way to empirically measure these different intelligences [44]. Sternberg [45] offers his triarchic theory intelligence as another, alternative theory of multiple intelligences.

It is important to distinguish learning styles from this pluralistic concept of intelligences. Among the many models of learning, the VARK model originally proposed by Fleming and Mills [46] expands upon the earlier tripartite VAK model [47] (visualizing, auditory, kinesthetic modalities). The VARK model distinguishes four perceptual modes or preferential learning styles as follows:

1. Visual (V) for graphical and symbolic ways of representing
2. Read/Write (R) for information printed as words.
3. Aural (A) heard information
4. Kinesthetic (K) related to the use of experience and practice

The authors caution that the kinesthetic mode is multi-modal implicating "all perceptual modes-sight, touch, taste, smell and hearing" where any of these perceptual modes are engaged through "experience, example, practice, or simulation." The VARK Learning Style Inventory, among others [48], is used to help learners and teachers identify learning styles.

Students also manifest learning differences (LD) due to various physiological causes. Attention deficit disorders, autism spectrum, dyslexia, dyspraxia (a co-ordination disorder), dyscalculia and Tourette's are neurological conditions [49, 50], sometime co-occurring, that affect how individuals learn and process information. The [51] Neurodiversity Movement advocates for individuals who would normally be classified as non-neural typical "are simply normal expressions of human function rather than disorders to be diagnosed and treated." Stigmatization and labeling exacerbate the gap between what is required and what is accessible to help neurodiverse individuals succeed in higher education.

The preceding discussion is a rough sketch and certainly not a comprehensive review of various factors contributing to discussions of the pros and cons of grading and the search for alternatives. Recent trends have developed new strategies to address many of these shortcomings of grading. Perhaps these strategies share the same conviction as Goodman on the virtues of testing – aiming for mastery of the subject and skill-based competencies. Central to this discussion is the difference between intrinsic and extrinsic motivation for learning and mastery. In Punished by Rewards [19] Kohn identifies these possible candidate qualities: a desire "to feel good, an orientation toward learning and mastery, a need for competence and self-determination" and "perhaps, to relate to and be engaged with others." We will now examine some strategies that point to alternatives to conventional grading practices.

2. Ungrading

Writing in 1964, Paul Goodman begins his essay [1] with "Let half a dozen of the prestigious Universities –Chicago, Stanford, the Ivy League –abolish grading, and use testing only and entirely for pedagogic purposes as teachers see fit." He argues that the majority of college level professors would agree that "grading hinders teaching and creates a bad spirit, going as far as cheating and plagiarizing." Goodman is not alone in noting how the grading regime appears to be a necessary common sense and inevitable methodology to "know whom to accept, reward, hire."

Alfie Kohn points out that much has been written about academic assessment [52]. He points out that "We need to collect information about how students are doing, and then we need to share that information (along with our judgments, perhaps) with the students and their parents. Gather and report — that's pretty much it." Kohn reminds us that questions about the value of grading are not new. He points to the extensive literature dating back to the 1930s. Writing in 1933, A.D. Crooks [53], summarizes the perceived shortcomings of grading that to this day reflects contemporary criticisms. For example, Forman [54] that grades are "a certificate of educational veneer and an artificial stimulation which furnishes fear motivation while it lasts." Forman's solution is to provide credit for work that is complete that is original and incorporates knowledge. Crooks also cites Odell [55] who notes that grades become the primary incentive and "leading to working for ulterior rewards, cheating, self-conceit, overwork, discouragement, and jealousy." Other educators argue that grading reflects competitive human nature or the impossibility of demonstrating superior work inevitability of grades. A commonsense recommendation is to avoid the misuse of grades so that "progressive schools would simply use other tests and techniques than those now common."

Over the past decade the ungrading movement has made headway among educators. Susan D. Blum [56] describes how she encountered the secret Facebook group "Teachers Going Gradeless," and captures [57] students' fixation on grades, by summarizing the questions that faculty often hear such as: "*What do you want? What do I have to do to get an A? How can I improve my grade? "What are the criteria for grades?*" The focus is on achievement represented by a letter grade not on learning. Blum points out that rarely are students asked: "what are you learning?" rather they are more often asked (and ask each other) "wad-ja-get?" "Wad-ja-get" serves as the title for the book by Howard Kirschenbaum et al. originally published in 1971 [58]. In the subtitle of the book, authors characterized the obsession with grades as the "grading game." The book uses the device of a fictional conversation about grades to reveal the shortcomings of grading back in the mid 1960s.

In his introduction to the 50th Anniversary Edition of "Wad-ja-get," Barry J. Fishman references a comprehensive review [59] of the meaning of grades prior to the publication of "Wad-ja-get" and the 50 years following. Fishman concludes "What has changed in those fifty years? Not that much. The general finding that teacher-assigned grades are subjective and unreliable remains constant." There remains a focus on graduation rates and educational outcomes. He laments that grading continues to be considered "a useful indicator of numerous factors that matter to students, teachers, parents, schools, and communities…".

In an appendix of "Wad-ja-get" the authors discuss Alternative Grading Systems, [60]. They emphasize the need to distinguish between private and public evaluation. Private evaluation "involves the teacher and student working together, sharing information and feedback, identifying strengths and weaknesses, and planning steps toward improved performance." Public evaluation appears on the transcript and is shared among educational institutions and employers.

The authors insist that Private evaluation should always include the following for elements:

Clear statement of behavioral objectives, how these will be measured, and what levels of performance will correspond to what specific grades (if grades are used).

Meaningful written or oral communication by the teacher to the student, that considers the student's strengths, weaknesses, and possible directions for improvement, with respect to the specific course objectives.

Student self-evaluation of strengths, weaknesses, and directions for improvement, both with respect to the teacher's objectives and with respect to the student's own learning goals.

Time for the teacher and student to read each other's evaluations and engage in a dialog based on this sharing of perceptions.

They then discuss eight alternative grading strategies detailing the advantages and disadvantages of each:

Written Evaluations.
Self-Evaluation.
Give grades but do not tell the students.
The Contract System.
The Mastery Approach or Performance Curriculum (Five-Point System).
Pass/Fail Grading (P/F).
Credit/No Credit Grading (CR/NC).
Blanket Grading (do required work receive the blanket grade).

From their review of the literature on grading practices Schinske and Tanner [7] suggest that faculty would benefit from spending less time on grading thereby freeing up time to devote to exploring innovative approaches. Pressure for greater accuracy in grading may interfere with learning and demotivate students. Recognizing that students tend not to read the teacher's comment, instead focus only on the letter grade could be addressed in class discussions with a small award of points for completion. The authors pose the following questions: "What if students themselves used rubrics to examine their peers' efforts and evaluate their own work, instead of instructors spending hours and hours commenting on papers? What if students viewed their peers as resources and collaborators, as opposed to competitors in courses that employ grade curving?"

Starr Sackstein recommends the following ten "ways to go gradeless" [61]. To "change the grade mindset" she suggests communicate with the stakeholders; rebrand assignments as "learning experiences;" facilitate student partnerships; leverage digital technology to ease data collection; talk to learners inside and outside the classroom; track progress transparently, use reflection to promote metacognition; introduce self-grading and use portfolio assessments.

Susan Blum summarizes the major issues with grading [62]: uniformity of grading and lack of nuanced information about the learner and their individual circumstances; grading and college is perceived by students as a game; grading and rules for completing work is perceived to be arbitrary and inconsistent; students learn to focus on achievement, success and accomplishment not on actual learning and mistakes and risk taking are punitive often resulting in lower grades. Importantly Blum asserts that grades do not truly motivate students rather a teacher should keep in mind the distinction between extrinsic and intrinsic motivation.

Blum references the minimax strategy [63] and adds that when students only care about extrinsic reward i.e., the grade encourages the minimax strategy [63] and instrumental behavior to do the minimum amount of work to get the highest grade. The result is "Cheating, shortcuts, cramming…all those make sense if the only goal is points or winning."

Ryan and Deci [64] provide a detailed analysis and discussion of the difference between extrinsic and intrinsic motivation. Appealing to self-determination theory [65, 66] they argue that: "in order to make the critical distinction between behaviors that are volitional and accompanied by the experience of freedom and autonomy—those that emanate from one's sense of self—and those that are accompanied by the experience of pressure and control and are not representative of oneself." Self-determined behavior is based upon the psychological need for "competence, autonomy and relatedness." There is the challenge to integrate extrinsically motivated behaviors, described as "instrumental to some separable consequence" to become part of self-determined behavior.

Blum relies on this analysis to recommend the following solutions [62]: decenter grading; emphasize a portfolio as a semester long project; encourage students to develop an individual plan and self-evaluation and conduct portfolio conferences. Blum further calls for the application of Universal Design Principles. Universal Design for learning success emphasizes providing multiple paths for engagement, representation and for action and expression. The UDL guidelines [67] promote equity by offering "a set of concrete suggestions that can be applied to any discipline or domain to ensure that all learners can access and participate in meaningful, challenging learning opportunities."

Jesse Stommel a prominent voice in the ungrading movement is upfront and direct in his approach practicing a radical project: "I've foregone grades on individual assignments for 17 years, relying on qualitative feedback, peer review, and self-assessment. My goal in eschewing grades has been to more honestly engage student work rather than simply evaluate it" [68]. Stommel decries how the imposition of objective measures of performance, leads to grading practices that privileges some students over others: "Students who are female, black, brown, indigenous, disabled, neurodivergent, queer, etc. face overt and systemic oppression whether expectations are explicit or implicit." All instructors must recognize the role of implicit bias in grading regimes.

Stommel acknowledges there is no single approach to "ungrading." However, successful ungrading does requires that a faculty member can take full ownership of their pedagogical approach in the classroom. A precondition to this requires the support of administrators and the institution itself to respect and strongly support academic freedom.

Stommel encourages experimentation with the introduction of ungrading for a portion of a semester. Stommel has students "write process letters, describing their learning and how their work evolves over the term;" use minimal grading use authentic assessment; introduce self-assessment; introduce contract grading where "Students work toward the grade they want to achieve, and goal posts don't unexpectedly shift. These contracts can also be negotiated with the class." He advocates for the use of portfolios and student made rubrics. Self-reflections at the midterm and end of the semester are ways to give students ownership of their education. Stommel [69] suggests that one can start ungrading in small ways by:

Changing how you talk about assessment.
Invite students into a conversation about grades.
Grade less stuff, grade less often, grade more simply.
Ask students to reflect on their own learning.

Stommel [69] recalls Freire critique of the "banking model" of education and instead argues for "a classroom or learning environment becomes a space for asking questions -- a space of cognition not information." For Freire, education is revolutionary project empowering the learner. Stommel ties his [68] recommendations back to critical pedagogy: "We don't prepare students for a world of potential oppression by oppressing them."Alternatives to "ungrading" might include contract grading, gamification and game-based learning. The following sections will discuss each approach.

3. Contract grading

Contract Grading replaces conventional grading practices with an agreement between the instructor and the student. The student self-selects the amount of work they commit to along with the corresponding grade. Contract Grading gives students greater responsibility for and ownership of their own learning. This approach deemphasizes the instructor as evaluator and gives emphasis to the student as an autonomous learner. Kathy Davidson [70] gives this explanation of Contract Grading to students: "The advantage of contract grading is that you, the student, decide how much work you wish to do this semester; if you complete that work on time and satisfactorily, you will receive the grade for which you contracted. This means planning ahead, thinking about all your obligations and responsibilities this semester and also determining what grade you want or need in this course."

Davidson suggests that peer review is essential for the success of Contract Grading as a community building action. For Davidson, Contract Grading "is both an idealistic, student-centered way of writing one's own learning goals--and it is, quite overtly, a workaround, a better alternative to conventional grading and credentialing. By adding the peer review component, contract grading is also an act of community."

Davidson [71] recalls Paolo Freire, by offering practical advice about redesigning the classroom to be "inspired by equality, not oppression." The goal of Contract Grading is aligned with the intent of ungrading: "A pedagogy of equality aims to support and inspire the greatest possible student success, creativity, individuality, and achievement, rather than more traditional hierarchies organized around a priori standards of selectivity, credentialing, standardization, ranking, and the status quo."

Inoue [72] adds: "Thus the overarching goal of labor-based grading contract ecologies, for me, is to get students to practice a network of interlocking, noncognitive competencies (engagement, coping and resilience, and metacognition)," that he describes as a "willingness to labor." For both Inoue and Davidson contract grading is more than a transaction based on completion of a certain amount of coursework. They see Contract Grading as a way to engage students as complete human beings that are part of community of practice where learners are empowered by the noncognitive competencies described above.

On one level the concept of labor is simply the completion of the required work course work. Inoue goes much further giving a much richer meaning through what he calls "three-dimensional" labor. He draws upon Marx's concepts of labor, concepts of use-value, exchange value and Hannah Arendt's hierarchy of labor/work/action. Inoue rejects Arendt's privileging of action over the work and labor as elitist. He refashions these into a theory of value and labor that helps students understand what labor should be and what labor means in an "economy" of contract labor. Inoue pushes further in seeing an equivalence between "assessment ecologies and political economies." Three dimensional poses three questions to students to ask of themselves:

How am I laboring and what does it offer me?
How much am I laboring?
What is the nature of my labor and what do I learn from it?

Inoue continues with an analysis of labor, discussing labor-based grading contracts as "a Marxian critique of the culture of classroom assessment, its relations to the labors involved in learning and to larger capitalist modes of production."

In the Philosophical Manuscripts, Marx [73] proposed a theory of labor based on "estrangement" or "alienation." Marx asserts: "Thus, if the product of his labor, his labor objectified, is for him an alien, hostile, powerful object independent of him, then his position towards it is such that someone else is master of this object, someone who is alien, hostile, powerful, and independent of him. If he treats his own activity as an unfree activity, then he treats it as an activity performed in the service, under the dominion, the coercion, and the yoke of another man."

From one perspective, Marx's analysis is a critique of conventional grading practices. The grade is an objective "commodity" produced by the student's labor. For a student the grade is labor objectified, assigned by someone else and becomes "alien, hostile" to actual learning and diminishes the humanity of the individual. The student loses autonomy and becomes alienated or estranged from this measure of labor.

The forgoing admittedly leaves out a great deal of Marx's analysis but does provides useful ways to think about the key differences between gamification and game-based learning.

4. Gamification

In 2011, Sebastian Deterding et al. [74] proposed the following definition of gamification "as the use of game design elements in non-game contexts." The use of gamification adopts basic elements of game design that make games fun, engaging and "aim to motivate and engage end-users through the use of game elements and mechanics [75]". In principle gamification can be applied to nearly any activity. Applications include marketing; business and management; employee and customer relations; interaction and user experience design; health, fitness and lifestyle and education. The adoption of gamification across multiple sectors is paralleled by value of the gamification market [76] which has grown from 4.91 billion dollars (US) in 2016 to over 11.94 billion dollars in 2021.

Along with this growth, an extensive literature has arisen on the application of gamification to learning and education. In 2011, Raymer [77] discussed the use of game mechanics applied to eLearning. The extensive meta-analysis by Sailer and Homner [78] answers the question of whether gamification is effective for learning with a provisional yes: "the results suggest that, in general, gamification has the potential to serve as an effective instructional approach for interventions focusing on cognitive, motivational, and behavioral learning outcomes." Noting promising work with self-determination theory [64] they call for further studies to accumulate an evidence-based understanding of how gamification works and how psychological needs can be matched with high-quality learning through gamification. They identify the most promising strategies such using fictionalized worlds with avatars; use of competitive and collaborative interactions and awarding badges increases motivation. They conclude that "the question of which factors contribute most to successful gamification remains partly unresolved, at least for cognitive learning outcomes."

Gamification appropriates the formal elements of gameplay or game mechanics. These include elements such as the number of players, their roles, how they interact; the games goals and objectives; the permitted actions, procedures, and rules of play; available resources; and potential for conflict, boundaries or limits, and outcomes such as win/loss states [79]. Werbach and Hunter [80] identify generalized gamification mechanics that are also part of game design including: challenges, chance, competition, cooperation, feedback, resource acquisition, rewards, transactions, turns, and win states.

Some game mechanics commonly used in gamification to motivate and engage users [81] include:

Narrative or story to give meaning and purpose.

Points as units of measurement for tracking progress, experience, and accomplishments.

Leaderboards to rank players and to inspire competition.

Game goals, missions, quests, and challenges to motivate action and direction.

Using badges, certificates and leveling up to provide feedback to gain a sense of progression and achievement.

Creation of a community which gives meaning to achievements.

As the gamification industry matured the game mechanics that are grouped into more complex and sophisticated categories. For example, the Periodic Table of Gamification Elements [82] identifies 52 separate game mechanics that are grouped to support different user types and styles as follows:

Reward Schedule.

General.

Socializer.
Achiever.
Free Spirit.
Philanthropist.
Player.
Disruptor.

This list of player types builds upon Richard Bartle's taxonomy of player types of MUDS (multi-user dungeon/domain) and their interactions [83]. He characterized the ways that people enjoyed playing MUDS as:

1. Players are achievers who "give themselves game-related goals, and vigorously set out to achieve them."

2. Explorers are players who "try to find out as much as they can about the virtual world."

3. Socializers are players who "use the game's communicative facilities, and apply the role-playing that these engender, as a context in which to converse (and otherwise interact) with their fellow players.

4. Killers are players who "use the tools provided by the game to cause distress to (or, in rare circumstances, to help) other players."

Stewart builds upon and expands upon Bartle's original player styles [84] by synthesizing Keirsey's theory of human temperaments [85] with Bartle's player styles. Keirsey reduced the 16 personality types of the Meyers Briggs Model of personality types to what he called the Artisan, Guardian, Rational and Idealist.

These in turn were combined with Bateman's model of gameplay preferences [86]. In addition to those of Bartle and Keirsey, Stewart adds those of Roger Caillois [87] and Nicole Lazzaro's ideas on the "4 Keys to Fun" [88, 89]. Stewart also brings under his umbrella two models of game design: Ron Edwards' Gamist/Narrativist/Simulationist (GNS) classification of playing styles [90] and the Mechanics, Dynamics, Esthetics (MDA) model [91]. The result is what Stewart calls the Unified Model. Stewart designed the follow table to illustrate how the play styles of the Unified Model relate to associated gameplay features as an aid to game design (**Table 1**).

Unified play style	Associated gameplay features
Artisan/Killer/Experientialist	Action, vertigo, tool-use, vehicle use, horror, gambling, speedruns, exploits
Guardian/Achiever/Gamist	Competition, collections, manufacturing, high scores, levels, clear objectives, guild membership, min-maxing
Rational/Explorer/Simulationist	Puzzles, creative building, world-lore, systems analysis, theorizing, surprise
Idealist/Socializer/Narrativist	Chatting, role-playing, storytelling, cooperation, decorating, pets, social events

Table 1.
Stewart's unified model of play styles [84].

While Stewart acknowledges that better theories of gamers preferences and play styles may yet be develop, he concludes that "there is remarkable agreement on the basic ways in which people want to express their playfulness as a function of a general personality style." By demonstrating commonalities and overlap of these models the Unified Model provides constructive ways to think about and design for different player motivations "that will help developers create better games."

Mambo.io [92] provides gamification consultation for a range of sectors including financial services, insurance, education, government, health care, retail, travel & hospitality, telecommunications, manufacturing, and media and entertainment. Mambo.io identifies 108 gamification mechanics and breaks down users into similar categories as above: socializers, explorers, killers and achievers. A further component of gamification is to build in motivational core drives. Yu-kai Chou [93], has developed the Octalysis Gamification Framework that identifies the following eight core drives that motivate people to act:

1. Epic Meaning.

2. Accomplishment.

3. Empowerment.

4. Ownership.

5. Social Influence.

6. Scarcity.

7. Unpredictability.

8. Avoidance.

Chou gives a different twist and emphasis to the meaning and intention behind gamification: "Gamification is the craft of deriving all the fun and engaging elements found in games and applying them to real-world or productive activities." Chou distinguishes between what he calls "Human-Focused Design," as opposed to "Function-Focused Design." Human-Focused Design optimizes for feelings, motivations, and engagement as a design principle in opposition to simple functionality and efficiency. Mechanics appeal to certain motivators as part the player's motivational profile.

The Reese Motivation Profile assesses [94] 16 basic desires that "determine our values, predict our behavior, influence the development of our personality traits, and create harmony or conflict in our interpersonal relationships." These empirically derived traits are acceptance, beauty, curiosity, eating, family, honor, idealism, independence, order, physical activity, power, saving social contact, status, tranquility and vengeance.

Others [95] haven taken a deeper dive into understanding motivational studies to further examine the theories of the growth mindset and intrinsic motivation, to develop a program of research to further the neuroscientific research in education. Cook and Artino [96] articulate intersections, commonalities, and differences between five theories of motivation noting "recurrent themes of competence, value, attributions, and interactions between individuals and the learning context."

These five theories include expectancy-value theory, where. Motivation is interpreted as a "function of the expectation of success and perceived value." Attribution theory looks at the "causal attributions" learners use to "explain the results of an activity... in terms of their locus, stability, and controllability." Social- cognitive theory focuses on self-efficacy and self-regulated learning. Goal orientation theory "suggests that learners tend to engage in tasks with concerns about mastering the content (mastery goal, arising from a 'growth' mindset regarding intelligence and learning) or about doing better than others or avoiding failure (performance goals, arising from a 'fixed' mindset)." Self-determination theory proposes that actions can be "motivated by intrinsic interests or by extrinsic values that have become integrated and internalized." While there is not space to examine these five theories in detail, it is worth noting that a deeper understanding of theories of motivation and the impact on education requires additional research.

These distinctions lead to the reconsideration of the long-standing critique of gamification which hinges on extrinsic versus intrinsic motivation. Dahlstrøm [97] underscores that gamification increases user engagement, through game like experiences "that afford intrinsic motivation in users." Citing research [75, 98] the gamification trend initially focused on "implementing reward systems commonly found in games through elements such as points, badges and leaderboards." Dahlstrøm concludes that gamification is not necessarily a "solution to a general lack of user motivation." Games should be not only a reward system but rather "about goals, challenges, stories and the experiences" as part of the gameful experience. Dahlstrøm advocates for a meaningful experience that employs mechanics like points and badges to confer "a sense of competence and autonomy in users". More recently, [99] critics point to uncertain and inconclusive results of gamification systems used in education settings.

5. Game-based learning

James Paul Gee [100] opened the door to the consideration of games as a sophisticated learning system. Learners willingly adopt roles and take on quests, missions, and goals in such a way that the game itself becomes an environment for learning. For Gee, learning is a core game mechanic and sees video gameplay as an inherently social activity that is contrary to common understandings of video gameplay as an isolating activity. Drawing upon his background in fields such as psycholinguistics and new literacy studies [101] he conceptualizes the activity of video gameplay as participating in a discourse community [102, 103]. He describes his own direct observation [104] of game playing as a prosocial activity in observing game play with his own children.

Gee listed [100] the following learning principles that are activated by well-designed video games:

Identity–Players explore new roles for interacting in virtual worlds.

Interaction–Players engage in content-rich discourse with non-playing and real characters.

Production–Players help determine the direction and outcomes.

of the game world through their decisions, players create representations or play to communicate in-game learning to external audiences.

Risk Taking–Learning results from experiencing failure, receiving feedback, and trying again. Games allow for repeated failure and customized feedback for learning.

Customization–Game worlds adapt to player preferences and playstyles.

Agency–Players react to the challenge of game play to achieve a sense of control over their actions.

Well-Ordered Problems–The game environment scaffolds challenges to support the development of player ability levels.

Just-in-Time in learning–Information in games is provided just as failure happens and just when players need guidance to correct their practices.

Situated Meanings–Play is integrated into a meaningful context.

Pleasantly Frustrating–Games guide players through failure from which they can learn.

Systems Thinking–Play involves navigation and sense making of layered, complex interconnected worlds.

Cross-Functional Teams–Players adopt roles coordinated through organized social groups.

Video games were celebrated as powerful learning environments in part due to how they engage players both individually and socially. The traditional classroom learning environment focuses on learning outcomes resulting in "teaching to the test" and less on authentic learning. Kurt Squire [105] proposed the concept of games as "designed experiences." Through gameplay, students enact new identities within the classroom community of gamers. Through multiple performances of the adopted identity, the student player internalizes and instantiates theories of how the game world works leading to a richer understanding than merely focusing on outcomes.

Homer, Plass and Kinzer [106] indicate that game-based learning emphasizes play in the pursuit of well-defined learning outcomes [107], where a balance is sought between play game play and the need to deliver educational subject matter [108]. Homer et al. also distinguishes gamification from game-based learning, in that the former "involves the use of game elements, such as incentive systems, to motivate players to engage in a task they otherwise would not find attractive." While acknowledging the ongoing debate over the definition of what makes a game, they shift to argue that play as "the essential activity in games—has long been thought of as a critical element in human development."

Plass et al. [109] also argue for a comprehensive approach to game-based learning. Rather proceeding from a single perspective, they advocate for integrating "viewpoints of cognitive, motivational, affective, and sociocultural perspectives" that are essential for both game design itself and for game research.

Multiple perspectives inform the creation of learning environments based on games that foster actual engagement and achieve learning goals. Designing learning experiences from the cognitive perspective "can enhance learner engagement, make tasks meaningful and relevant, and adaptively respond to learner's specific needs and conditions." Understanding the motivational factors to rationalize the use of games for learning emerges from how games for entertainment engage players for extended periods of time and commitment. Affective foundations include the elements of narrative, esthetics, game mechanics, sound, and music. These elements can induce emotional responses to heighten learning. Other researchers, notably Gee [100, 104] point to the rich social interactions that emerge within communities of players both in collaborative or competitive play "may be one of the most important aspects of game-based learning."

Homer et al. further advocate for the concept of "playful learning" which they define "as an activity by the learner, aimed at the construction of a mental model (a coherent representation of the information in memory), that is designed to include one or more elements of games for the purpose of enhancing the learning process." Game designers, taking into consideration the learning goals, can implement playful learning environments that either fully games or are playful activities, having some game play elements. They distinguish playful learning as incorporating playful tasks where-as gamification adds "game elements to an existing task that may be unengaging, tedious, or boring." Playful learning requires actual play!

Prensky has identified the generations who have grown up with digital technology and playing video games as Digital Natives [110]. Prensky suggests [111] that video games may be creating "people with special skills in discovering rules and patterns by and active and interactive process of trial error." Prensky quotes Greenfield [112], who recognized that playing video games encourages "the process of making observations, formulating hypotheses and figuring out the rules governing the behavior of a dynamic representation is basically the cognitive process of inductive discovery…the thought process behind scientific thinking."

Digital Natives who grew up playing video games do not read manuals. Rather they simply start learning the game by trial and error. In this "fearless environment" they assume the "software is supposed to teach" them how to use it. As gamers, they learn that failure is necessary for success. A well-designed game allows the player to learn through trial and error. Players know that a game can be beat and therefore continue playing [113] despite temporary failure. Players are resilient because they know their persistence will pay off. Mark Rober calls this the Super Mario Effect [114]. The player focuses on the end goal to save the princess rather than on the mistakes and failures. Gee [115] among many others [116, 117] hypothesizes that well designed games incorporate failure as part of learning. Games "allow players to take risks that might be too costly elsewhere, like classrooms, where failure is often seen as an end result [118]".

Jane McGonigal [119], argues that games, unlike the real world, make it safe to fail. Instead, games offer a positive experience "We normally think of games as being fun, kind of trivial, maybe something to pass the time, but what if we thought about them as a platform for inventing the future of higher education?" McGonigal argued that playing games leads to a constellation of positive emotional effects that are essentially the opposite of depression. She advanced games as a cure for lack of engagement and for the potential to transform education citing the following positive effects:

(In descending order)
Joy
Relief.
Love.
Surprise.
Pride.
Curiosity.
Excitement.
Awe and wonder.
Contentment.
Creativity.

A key element of game play is the activation of what Csíkszentmihályi [120] identified as the state of flow which is induced by pursuing a goal, confronting obstacles, increasing challenges and voluntary participation that characterizes the experience of playing a game. McGonigal points out that games quickly give immediate feedback [119]: "The result was a much faster cycle of learning and reward, and ultimately a sense of perfect and powerful control over a 'microworld' on the screen." Prensky [111] describes this as one of the "pay off vs. patience" lessons learned by the Games Generation "if you put in the hours and master the game, you will be rewarded—with the next level, with a win, with a place on the high scorers' list." This is one among ten different cognitive styles that Prensky identifies that educators should take account of when teaching:

1. Twitch speed vs. conventional speed.
2. Parallel processing vs. linear processing.
3. Graphics first vs. text first.
4. Random access vs. step-by-step.
5. Connected vs. standalone.
6. Active vs. passive.
7. Play vs. work.
8. Payoff vs. patience.
9. Fantasy vs. reality.
10. Technology-as-friend vs. technology-as-foe.

Students in Prensky's Game Generation are presumably more receptive to game-based learning as they are more accustomed to fast paced game play; tracking multiple game-play elements in parallel; rapidly switch focus in non-sequential ways; playing networked games and engaging in communities like Discord or Twitch; see the game world, characters and the esthetics before reading; actively engaging in play; grinding in a game is part of play; expecting rewards as the reward for persistence; grew up on a diet of pop-culture fantasy and because of their extensive experience playing games, are comfortable with technology and see it as a source of fun, entertainment and social connectivity.

Game-based learning affords the opportunity to do detailed assessments and track the progress of players-as-learners. Halverson and Steinkuehler [121] suggested that games can be a powerful research tool to generate and collect data on learning. They call for a "game ecology" that affords researchers "opportunities to assess the gameplay skill of players, the degree to which players mastered declarative and procedural content, and the play experience." However, writing in 2014, the authors note the current limitations of the commercial game industry "which include compelling game worlds and interaction spaces, but without clear models of learning assessment, and in academic game spaces, which are developing reliable learning tools, but without compelling game environments."

The challenge for game-based learning remains how to make educational games that are engaging and are actually fun to play. Some efforts are made in defining what games are and then applying such definitions to game development.

The ambition of the Handbook of Game Based Learning [122] is to "help establish a solid empirical and theoretical foundation for the discipline of game-based learning that synthesizes and organizes existing research and sets a research agenda for years to come." This is a comprehensive overview by leading practitioners, scholars, and researchers of what is now a mature field. Divided into four major parts, the handbook provides a three-chapter introduction to game-based learning; an overview of the theoretical underpinnings with four chapters discussing the cognitive, affective, motivational and the socio-cultural foundations of game-based learning. The third part offers eight chapters on practical guides to implementing instructional support with feedback and coaching; guides to providing self-regulation and reflection; adaptivity and personalization, use of narrative and multi-media; strategies of collaboration and cooperation along with emerging design principles for game-based design The fourth part features chapters that discuss gamed-based learning examples in science, math, engineering, technology, language learning, cognitive skill training and workforce learning. The final two chapters cover games for assessment and learning analytics which reflects Halverson's and Steinkuehler's earlier call [121] for a "game ecology" that affords researchers "opportunities to assess." Indeed, popular contemporary game engines such as Unity or Unreal now offer sophisticated analytics which foster tracking and assessments of players in great detail.

The editors are in fact declaring that game-based learning is well-established on a firm theoretical foundation that is further supported by extensive empirical research, having well-established design principles and an ever-expanding library of use cases and successful implementations. The Handbook continues to advocate for, as discussed earlier in [106], a consensus regarding the complementary domains of inquiry–namely the cognitive, affective, motivational, and socio-political as important lens through which to view and understand game-based learning.

6. Discussion

Vygotsky's [123] zone of proximal development (ZPD) is a road map for cognitive development and learning which provides a powerful way to conceptualize scaffolding. Playing a game and game development also mirror similar zones of proximal development. A gamer initially discovers "what I can do." A game developer, especially when using the discipline of agile development [124] begins with identifying and listing doable tasks (e.g., programming) that they already have had experience solving such as using the arrow keys to control the playable character.

One of James Paul Gee's observation is that playing video is often a social activity. Gamers exchange information on forums like Discord and elsewhere, on how to gain experience points, where to discover Easter eggs, beat level bosses and level up. Similarly, game development is more often done in teams. Agile development formalizes asking the question "what I can do next with help (if I need it)? ".

Both gamers and developers also confront the question of "What I can't do or don't know how to do." Game play and game development also share a methodology of test and iterate. Failure and do overs are part of the process. Gamers must repeatedly lose before they figure out how to beat the level boss. Game Developers make mistakes in programming or even are forced to abandon what appeared to be promising avenues of development or game mechanics.

But designing and building games is hard and time consuming. It takes time and money which are rare commodities for teachers and faculty. Games must be playtested and usability tested. For game-based learning there must be longitudinal assessments of large populations to reveal promising, statistically significant results.

Game development becomes the responsibility of professionals. Where does that lead teachers and faculty? Given limited resources, one option is to gamify the classroom to engage for meaningful learning and shift students from the obsession with grades.

Games are notable for their immersive engagement, fun, play and depending on the game design and genre competitiveness. The key element of fun is often elusive and is not always found in "serious" learning games.

Playfulness is also key ingredient. In Homo Ludens [125], Johan Huizinga defined play as "Play is a free activity standing quite consciously outside 'ordinary' life as being 'not serious,' but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner."

Vygotsky [123] gave a different emphasis to aspects of play as an activity that is "desired" and "always involves an imaginary situation." Play is governed by rules which are shared and understood by the players during or even in advance of the activity of play. For Huizinga [125], this activity forms what he called the magic circle:

All play moves and has its being within a playground marked off beforehand either materially or ideally, deliberately or as a matter of course. Just as there is no formal difference between play and ritual, so the "consecrated spot" cannot be formally distinguished from the playground. The arena, the card-table, the magic circle, the temple, the stage, the screen, the tennis court, the court of justice, etc., are all in form and function playgrounds, i.e., forbidden spots, isolated, hedged round, hallowed, within which special rules obtain. All are temporary worlds within the ordinary world, dedicated to the performance of an act apart.

Huizinga articulated five key elements of play:

Play is free.
Play is not "ordinary" or "real" life.
Play is distinct from "ordinary" life both as to locality and duration.
Play creates order, is order. Play demands order absolute and supreme.
Play is connected with no material interest, and no profit can be gained from it.

Salen and Zimmerman [126] took Huizinga's analysis further by discussing Gregory Bateson's notion [127] of how "play occurs within a delimited psychological frame, a spatial and temporal bounding of a set of interactive messages." A key element of play for Bateson is metacommunication between the players which lead Salen and Zimmerman to define that activity of play "as not just to follow the rules and rituals of play, but also to continually communicate the idea that the play-actions are just play and not something else." This is a kind of double-consciousness (after Bateson) frames the simulation of the play activity. This is captured by Brian Sutton-Smith [128]: "Children know that they are manipulating their thoughts about reality, not reality itself; and they know that their play self is not the same as their everyday self." This double-consciousness of the individual player through continual "metacommunication" with other players brings to life and sustains the magic circle during play.

The holy grail and rationale for gamification was to tap into the magic of gaming and play. Zichermann and Cunningham [129] define gamification as "The use of game thinking and game mechanics to engage users and solve problems."

This definition of gamification does not reference play or fun or any of the elements discussed in the preceding paragraphs. Use of the term gamification served to capture the trend to introduce playful activities and game mechanics in marketing campaigns, product promotion, health and fitness, lifestyle and weight loss applications, political organizing, incentivizing customer loyalty, education and in serious games.

Sententia Gamification [130] is leader in gamification strategy design providing learning solutions for corporate trainers, human resource professionals, educational institutions, and independent consultants. Sententia offers a gamification certification program that introduces a variety of game mechanics (e.g., points, levels, challenges, rewards, chance, collaboration, scarcity, time limits, and leaderboards) where the "goal is to increase learning and engagement through key concepts found in game design and behavioral psychology." By adding game mechanics to training, gamification presumably increases interest, but it also makes training 'fun.' A well-designed and well-implemented gamification program promotes engagement, meaning, mastery, and autonomy."

Both gamification and game-based learning aspire toward fun through "serious" play. Both draw upon an extensive body of research and studies from a range of disciplines to provide theoretical underpinnings and give an evidence-based validity to their outcomes. An important distinction between game-based learning and gamification is revealed by the definition provided by Sebastian Deterding et al. [74] "as *the use of game design elements in non-game contexts*." Game design elements are an add on where-as with game-based learning, the content and learning objectives are intimately bound to the game mechanics and game play.

A common criticism of gamification is that it relies primarily on extrinsic motivation where-as game-based learning incorporates intrinsic motivation sometimes in concert with the use of extrinsically motivating mechanics (e.g., experience points, leaderboards etc.). Hsieh [131] puts it this way: "Intrinsic motivation is triggered by human needs for mastery, curiosity, and overcoming challenges. Extrinsic motivation is relevant to elements not related to the task value, such as rewards, grades "performance and competition or evaluation by others."

The distinction between intrinsic and extrinsic motivation follows from self-determination theory. By reviewing self-determination theory, Ryan and Deci [64] make the following distinction "between behaviors that are volitional and accompanied by the experience of freedom and autonomy—those that emanate from one's sense of self—and those that are accompanied by the experience of pressure and control and are not representative of oneself." Thus, intrinsically motivated behaviors "satisfy the innate psychological needs for competence and autonomy." Extrinsically motivated behaviors "are instrumental to some separable consequence." Ryan and Deci acknowledge that extrinsic motivations can be aligned with self-determination through internalization and integration as: "the processes through which extrinsically motivated behaviors become more self-determined." Some mechanics can function as triggers and others as rewards. Mechanics appeal to certain motivators and core desires as part the player's motivational profile. An argument in defense of gamification is that a well-crafted, gamified experience aligns the operational mechanics to core desires. This in turn, is sufficient to induce fun.

Both gamification and game-based learning understand play as essential. To ensure playful learning, Homer et al. [132] point to the following key principles:

Playful learning is intrinsically motivating.
Playful learning depends on a break from reality.
Playful learning requires a polytheoretical approach.
New technologies provide new opportunities for playful learning.
Playful learning requires an integration of play and learning.

As noted earlier in this chapter, the Handbook of Game-Based Learning Plass et al. [109] propose a polytheoretical approach which includes research into the cognitive, affective, motivational, and sociocultural domains: "For game designers, our approach suggest that the integration of multiple perspectives of learning is required if games for learning are to reach their full potential."

Schwartz and Plass [133] outline a research agenda to collect empirical evidence from each of these domains. They propose a full spectrum understanding "taking into account learner differences, types of engagement, identifying patterns and processes of engagement and the relationship to learning outcomes." By doing so they seek to redefine engagement as "the active and focused investment of effort in a game environment."

Pushing the boundaries of research beyond the boundaries prescribed by the polytheoretical approach that addresses the cognitive, affective, motivational, and sociocultural domains for game-based learning, the National Institute for Play (NIFP) identifies the three broad areas of research into the nature of play [134]:

Neuroscience.
Behavioral Science.
Ethology (animal behavior).

A deeper dive into the area of neuroscience, as listed above can further distinguished the disciplines examine play, yielding further research are listed below:

Affective neuroscience (how emotions function in the brain).
Behavioral neuroscience (the connections between brain function and behavior).
Biology.
Developmental neuroscience (how our brains develop).
Evolutionary biology.
Neuroanatomy.

From these different disciplines, this research compiled by NIFP provides and very different lens through which we can begin to understand and appreciate the importance of true play. This is seen in this assertion:

When the play circuits in the midbrain are triggered, the related neurons create a cascade of activity in our higher brain functions. The more often this happens—the more often we play—the more those neurons connect and the stronger those pathways get. The neural connections created when we play are the brain wiring patterns that give us better control over our movement, our thoughts, and our emotions.

NIFP simply asserts that "play is central to leading healthy, productive human lives." As researchers explore the neurocorrelates of play and their impacts on affective, behavioral, biological developmental and evolutionary factors and results are published, these results will deepen our understandings that build upon the research agenda as outlined in the Handbook of Game-Based Learning.

7. Conclusion

This chapter does not attempt to define or appeal to any one definition of what constitutes a game. That is a topic beyond the scope of this one. This chapter, on the other hand, started with a review of some of the criticisms concerning grading and some of the current trending alternatives, such as ungrading and grading contracts. Conventional grading practices are a blunt instrument that obscures different learning styles and needs. Student focus on grades distorts and undermines true learning and should be replaced by a range of assessment strategies that incorporate Universal Design. The goal is to remove the stress, fears and obsession with grades that conventional assessment practices engender and at the same time motivate and engage the learner. Sometimes referred as "ungrading," the adoption of these strategies prioritizes the progress of each individual student and re-envisions learning as a series of achievements that students complete and level-up to take on a series of successive challenges based on previous accomplishments not unlike the playing of a video game. Grading contracts can shift the responsibility and engagement to the learner. Scholarship and research into motivation and theories of engagement yield insights into the efficacy of gamification and game-based learning strategies. A multi-theoretical approach through the lenses of the cognitive, affective, motivational, and socio-political domains is needed to address the full spectrum of the needs and learning styles of learners for engagement and motivation.

This chapter also briefly, revisited core themes of play, through a brief discussion of Vygotsky, Huizinga, and others' critical framing of how we perceive and experience games and play. Both gamification and game-based learning seek to harness the power of play to engage to motivate learning and skill acquisition.

Gamification can suffer from a reliance on extrinsic motivation that risks the some of the same drawbacks as conventional grading. Game-based learning in some respects is a better solution but is at times impractical especially for the busy teacher without the resources to build games and therefore must rely on the entertainment and educational industries to offer solutions in the marketplace.

The challenges presented by neurodiversity, gender, racial bias, both implicit and explicit in the classroom, remain persistent. This calls for a multifaceted approach requiring flexibility, resources and commitment informed by continuing research. Both gamification and game-based learning seek to tap into players voluntary commitment to play and are rewarded by the sense of mastery of new skills and achievement. The motivation for this approach to ensure equity and inclusion in the classroom by creating a compassionate environment to enhance student engagement and learning.

Successful gamification and game-based learning experiences aspire to induce intrinsic motivation that is based upon the psychological need for "competence, autonomy and relatedness" while engaging with others. These are features of core desires and motivations intimately bounded to learning styles and play styles that foster a sense of freedom, autonomy and self-determined behavior that is aligned with the player's sense of self and identity.

Acknowledgements

I acknowledge the support of Quinnipiac University and the College of Arts and Sciences, 2022–2023 Scholarship and Grants Committee.

Thanks

I am grateful for the insights provided by the one-day online workshop and post conference Gamification Certificate program conducted by Sententia Gamification (www.SententiaGamification.com) as part Serious Play 2022 (https://www.seriousplayconf.com/).

Nomenclature

Agile Development [124]: Most agile development methods break product development work into small increments that minimize the amount of up-front planning and design. Iterations, or sprints, are short time frames (timeboxes) that typically last from 1 to 4 weeks. This minimizes overall risk and allows the product to adapt to changes quickly.

Author details

Gregory Garvey
Quinnipiac University, Hamden, Connecticut, United States

*Address all correspondence to: gregory.garvey@quinnipiac.edu

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Goodman P. Proposal to abolish grading. In: Compulsory Miseducation. New York: Horizon Press; 1964. [Internet] Available from: https://arvindguptatoys.com/arvindgupta/goodman.pdf [Accessed: April 24, 2022]

[2] Goodman P. Growing up Absurd: Problems of Youth In the Organized System. New York: Vintage Books; 1962

[3] Illich I. Deschooling Society. London, New York: Marion Boyars; 1971

[4] Kirschenbaum H, Napier R, Simon S. Wad-Ja-Get? The Grading Game in American Education. New York: Hart Publishing Company; 1971

[5] Kirschenbaum H, Napier R, Simon S. Wad-ja-get? The Grading Game in American Education. 50th Anniversary ed. Ann Arbor: Maize Books; 2021. DOI: 10.3998/mpub.11900733

[6] Bloom BS. Mastery learning. In: Block JH, editor. Mastery Learning: Theory and Practice. New York: Holt, Rinehart & Winston; 1971. pp. 47-63

[7] Schinske J, Tanner K. Teaching more by grading less (or differently). CBE Life Science Education. 2014;**13**(2):159-166. DOI: 10.1187/cbe.CBE-14-03-0054 [Internet] Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4041495/ [Accessed: May 10, 2022]

[8] Brookhart SM, Guskey TR, Bowers AJ, McMillan JH, Smith JK, Smith LF, et al. A century of grading research: Meaning and value in the most common educational measure. Review of Educational Research American Educational Research Association. 2016;**86**(4):803-848. [Internet]. Available from: https://www.jstor.org/stable/44668237 [Accessed: April 28, 2022]

[9] Freire P. Education for Critical Consciousness. United Kingdom: Seabury Press; 1973

[10] Freire P. Pedagogy of the Oppressed. 30th Anniversary ed. United Kingdom: Bloomsbury Publishing; 2014

[11] Giroux H, Utopian thinking in dangerous times: Critical pedagogy and the project of educated hope. In: Cote M, Day RJF, de Peuter G, editors. Utopian Pedagogy: Radical Experiments against Neoliberal Globalization. Toronto: University of Toronto Press; 2019. 25-42. doi: 10.3138/9781442685093-004

[12] McLaren P. Life in Schools: An Introduction to Critical Pedagogy in the Foundation of Education. Boston, MA: Allyn & Bacon; 2003

[13] Hooks B. Teaching to Transgress: Education as the Practice of Freedom. New York: Routledge; 1994

[14] Shor I. When Students Have Power: Negotiating Authority in a Critical Pedagogy. Chicago: University of Chicago Press; 1996

[15] Schinske J, Tanner K. Teaching more by grading less (or differently). CBE life. Science Education. 2014;**13**(2):159-166. DOI: 10.1187/cbe.CBE-14-03-0054

[16] Purpel DE. The Moral and Spiritual Crisis in Education. Granby Mass: Bergin & Garvey; 1989

[17] Thomas J. Factors relating to student grade obsession: a quantitative correlational study [dissertation]. Phoenix: University of Phoenix; 2011

[18] Romanowski MH. Student obsession with grades and achievement. Kappa Delta Pi Record. 2004;**40**(4):149-151. DOI: 10.1080/00228958.2004.10516425

[19] Kohn A. Punished by Rewards: The Trouble with Gold Stars, Incentive Plans, A's, Praise, and Other Bribes. Boston: Houghton Mifflin; 1993/1999/2018

[20] Newlon C. College grade inflation: Does 'A' stand for 'average'? USA TODAY College. 2013. [Internet] Available from: https://www.usatoday.com/story/news/nation/2013/11/21/college-grade-inflation-what-does-an-mean/3662003/ [Accessed: May 2, 2022]

[21] Eyler J. Grades are at the center of the student mental health crisis. Inside Higher Ed. 2022. [Internet] Available from: https://www.insidehighered.com/blogs/just-visiting/grades-are-center-student-mental-health-crisis [Accessed: May 2, 2022]

[22] Horowitz JM, Graf N. Most U.S. Teens See Anxiety and Depression as a Major Problem Among Their Peers. Washington, DC: Pew Research Center; 2019. [Internet] Available from: https://www.pewresearch.org/social-trends/2019/02/20/most-u-s-teens-see-anxiety-and-depression-as-a-major-problem-among-their-peers/ [Accessed: May 4, 2022]

[23] CDC.Gov. Making the Connection: Suicidal Thoughts and Behaviors and Academic Grades. 2015. [Internet] Available from: https://www.cdc.gov/healthyyouth/health_and_academics/pdf/DASHfactsheetSui [Accessed: May 2, 2022]

[24] Worcester Polytechnic Institute. Initial Findings and Recommendations of The Mental Health And Well-Being Task Force. 2022. [Internet] Available from: https://www.wpi.edu/sites/default/files/2022/01/19/WPI_MHWB_FindingsAndRecommendations_Phase1_2022.pdf [Accessed: May 2, 2022]

[25] Malouf JM, Thorsteinsson EB. Bias in grading: A meta-analysis of experimental research findings. Australian Journal of Education. 2016;**60**(3):1-12. DOI: 10.1177/0004944116664618

[26] Malouff J. Bias in grading. College Teaching. 2008;**56**(3):192-191

[27] Nickerson RS. Confirmation Bias: A ubiquitous phenomenon in many guises. Review of General Psychology. 1998;**2**(2):175-220

[28] Kahneman D. Thinking, Fast and Slow. New York: Farrar, Strauss, and Giroux; 2011

[29] Malouff JM, Emmerton AJ, Schutte NS. The risk of halo Bias as a reason to keep students anonymous during grading. Teaching of Psychology. 2013;**40**(3):233-237

[30] Greenwald AG, Krieger LH. Implicit bias: Scientific foundations. California Law Review. 2006;**94**(4):945-967

[31] The Kirwan Institute. Milestone: Annual State of The Science: Implicit Bias Review. 2014. [Internet] Available from: https://www.issuelab.org/resources/21634/21634.pdf [Accessed: May 6, 2022]

[32] Ratliff KA, Smith CT. Lessons from two decades of project implicit. In: Krosnick JA, Stark TH, Scott AL, editors. The Cambridge Handbook of Implicit bias and Racism. Cambridge, England: Cambridge University Press; 2021

[33] Charlesworth T, Navon M, Rabinovich Y, Lofaro N, Kurdi B. The project implicit international dataset: Measuring implicit and explicit social group attitudes and stereotypes across 34

countries (2009-2019). PsyArXiv. 1-66. 2021. [Internet] Available from: https://psyarxiv.com/sr5qv/ [Accessed: May 4, 2022] DOI: 10.31234/osf.io/sr5qv

[34] Irizarry Y. Selling students short: Racial differences in teachers' evaluations of high, average, and low performing students. Social Science Research. 2015;**52**:522-538

[35] Bygren M. Biased grades? Changes in grading after a blinding of examinations reform. Assessment & Evaluation in Higher Education. 2020;**45**(2):292-303. DOI 10.1080/02602938.2019.1638885.

[36] Inoue AB. Labor-Based Grading Contracts: Building Equity and Inclusion in the Compassionate Writing Classroom. Boulder: University Press of Colorado; 2019. p. 22. DOI: 10.37514/PER-B.2019.0216.0

[37] Inoue AB. Labor-Based Grading Contracts: Building Equity and Inclusion in the Compassionate Writing Classroom. Boulder: University Press of Colorado; 2019. p. 11. DOI: 10.37514/PER-B.2019.0216.0

[38] Gardner H. Frames of Mind: The Theory of Multiple Intelligences. New York: Basic Books; 2011

[39] Goleman D. Emotional Intelligence. New York: Bantam Books; 1995

[40] Goleman D. Social Intelligence: The New Science of Human Relationships. New York: Bantam Books; 2006

[41] Marenus M. Gardner's theory of multiple intelligences. Simply Psychology. 2020. [Internet] Available from: https:www.simplypsychology.org/multiple-intelligences.html [Accessed: May 5, 2022]

[42] Waterhouse L. Inadequate evidence for multiple intelligences, Mozart effect, and emotional intelligence theories. Educational Psychologist. 2006;*41*(4):247-255

[43] Gottfredson LS. Schools and the g factor. The Wilson Quarterly. 2004;**28**(3):35-45

[44] Davis K, Christodoulou J, Seider S. In: Sternberg RJ, Kaufman SB, editors. Cambridge Handbook of Intelligence. Cambridge: Cambridge University Press; 2011. pp. 485-503

[45] Sternberg RJ. Beyond IQ: A Triarchic Theory of Human Intelligence. New York, NY: Cambridge University Press; 1985

[46] Fleming ND, Mills C. Not Another Inventory, Rather a Catalyst for Reflection. To Improve the Academy. 1992;**11**:137-155. DOI: 10.1002/j.2334-4822.1992.tb00213.x

[47] Barbe WB, Milone MNJ. What we know about modality strengths. Educational Leadership, Association for Supervision and Curriculum Development. 1981;**38**:378-380

[48] Learning-styles-online.com. Free learning styles inventory, including graphical results. [Internet]. 2011. Advanogy.com. Available from: https://www.learning-styles-online.com/inventory/ [Accessed: 2022-05-18]

[49] Bewley H, George A. Neurodiversity at Work. National Institute of Economic and Social Research (NIESR); 2016. [Internet] Available from: https://www.tourettes-action.org.uk/storage/downloads/1482243777_Neurodiversity_at_work_0916-(1).pdf [Accessed: May 18, 2022]

[50] AppliedBehaviorAnalysisEdu.org. What Is The Neurodiversity Movement and Autism Rights? [Internet]. 2022. AppliedBehaviorAnalysisEdu.

org Available from: https://www.appliedbehavioranalysisedu.org/what-is-the-neurodiversity-movement-and-autism-rights/ [Accessed: May 18, 2022]

[51] Clouder L, Karakus M, Cinotti A, Ferreyra MV, Amador G, Rojo P. Neurodiversity in higher education: A narrative synthesis. High Education. 2020;**80**:757-778. DOI: 10.1007/s10734-020-00513-6

[52] Kohn A. The Case Against Grades. 2011. [Internet] Available from: https://www.alfiekohn.org/article/case-grades/ [Accessed: May 25, 2022]

[53] Crooks AD. Marks, and marking systems: A digest. The Journal of Educational Research. 1933;**27**(4): 259-272. DOI: 10.1080/00220671.1933

[54] Forman WO. The gradeless era in high school. Journal of Education, CXI. 1930;**111**(18):501-502

[55] Odell CW. Educational Measurement in High Schools. New York: The Century Company; 1930

[56] Blum SD, editor. UNgrading: Why Rating Students Undermines Learning (and What to Do Instead). Morgantown: West Virginia University Press; 2020. p. 245

[57] Blum SD. The significant learning benefits of getting rid of grades. 2017. [Internet] Available from: https://www.insidehighered.com/advice/2017/11/14/significant-learning-benefits-getting-rid-grades-essay?width=775&height=500&iframe=true [Accessed: May 15, 2022]

[58] Kirschenbaum H, Napier R, Simon SB. Wad-ja-get? The Grading Game in America. 50th Anniversary ed. Ann Arbor: Maize Books; 2021. p. 242. DOI: 10.3998/mpub.11900733

[59] Fishman BJ. In: Kirschenbaum H, Napier R, Simon S, editors. Wad-ja-get? The Grading Game in American Education. 50th Anniversary ed. Ann Arbor: Maize Books; 2021. pp. xiv-xvi. DOI: 10.3998/mpub.11900733

[60] Kirschenbaum H, Napier R, Simon S. Wad-ja-get? The Grading Game in American Education. 50th Anniversary ed. Ann Arbor: Maize Books; 2021. p. 214. DOI: 10.3998/mpub.11900733

[61] Sackstein S. Hacking assessment: 10 ways to go gradeless in a traditional grades school. Cleveland: X10 Publications. 2015. p. 149

[62] Blum SD. Ungrading. Inside Higher Ed. 2017. [Internet] Available from: https://www.insidehighered.com/advice/2017/11/14/significant-learning-benefits-getting-rid-grades-essay?width=775&height=500&iframe=true Accessed May 8, 2022

[63] Kruglanski AW, Stein C, Riter A. Contingencies of exogenous reward and task performance: On the "minimax" strategy in instrumental behavior. Journal of Applied Psychology. 1977;**7**(2):141-148. DOI: 10.1111/j.1559-1816.1977.tb01335.x

[64] Ryan RM, Deci EL. Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary Educational Psychology. 2000;**25**(1):54-67. DOI: 10.1006/ceps.1999.1020 Available from: https://selfdeterminationtheory.org/SDT/documents/2000_RyanDeci_IntExtDefs.pdf [Accessed: June 12, 2022]

[65] Deci EL, Eghrari H, Patrick BC, Leone DR. Facilitating internalization: The self-determination theory perspective. Journal of Personality. 1994;**62**:119-142

[66] Deci EL, Ryan RM. Intrinsic Motivation and Self-Determination in

Human Behavior. New York: Plenum; 1985

[67] CAST. The UDL Guidelines. [Internet]. 2022. CAST. Available from: https://udlguidelines.cast.org/ [Accessed: May 10, 2022]

[68] Stommel J. How to Ungrade. 2018. [Internet] Available from: https://www.jessestommel.com/how-to-ungrade/ [Accessed: May 25, 2022]

[69] Stommel J. Ungrading: An Introduction. 2021. [Internet] Available from: https://www.jessestommel.com/ungrading-an-introduction/ [Accessed: May 30, 2022]

[70] Davidson C. Getting Started 6: Contract Grading and Peer Review. 2015. [Internet] Available from: https://www.hastac.org/blogs/cathy-davidson/2015/08/16/getting-started-6-contract-grading-and-peer-review [Accessed: May 30, 2022]

[71] Davidson C. Why student-centered learning needs an alternative credentialing mechanism. In: Buck D, editor. Crowd Sourcing Ungrading. #UNgrading Virtual Book Club; [Internet]. 2021. Pressbooks. Available from: https://pressbooks.howardcc.edu/ungrading/ [Accessed: June 2, 2022]

[72] Inoue AB. Labor-Based Grading Contracts: Building Equity and Inclusion in the Compassionate Writing Classroom. [Internet]. 2019. The WAC Clearing House. Boulder: University Press of Colorado; Available from: https://wac.colostate.edu/docs/books/labor/contracts.pdf [Accessed: June 2, 2022]

[73] Marx K. Economic and Philosophical Manuscripts of 1844. [Internet]. 2009. Marx-Engels Internet Archive. Moscow: Progress Publishers; 1959. Available from: https://www.marxists.org/archive/marx/works/1844/manuscripts/labour.htm [Accessed: June 4, 2022]

[74] Deterding S, Dixon D, Khaled R, Nacke L. MindTrek '11. In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments. 2011. pp. 9-15. DOI: 10.1145/2181037.2181040

[75] Seaborn K, Fels DI. Gamification in theory and action: A survey. International Journal of Human-Computer Studies. 2015;**74**:14-31. DOI: 10.1016/j.ijhcs.2014.09.006

[76] Statistica, Value of the Gamification Market Worldwide in 2016 and 2021. 2021. [Internet] Available from: https://www.statista.com/statistics/608824/gamification-market-value-worldwide/ [Accessed: June 4, 2022]

[77] Raymer R. Gamification: Using game mechanics to enhance elearning. eLearn. 2011 Article No: 3;**2011**(9). DOI: 10.1145/2025356.2031772

[78] Sailer M, Homner L. The gamification of learning: A Meta-analysis. Educational Psychology Review. 2020;**32**:77-112. DOI: 10.1007/s10648-019-09498-w

[79] Fullerton T. Game Design Workshop: A Playcentric Approach to Creating Innovative Games. 3rd ed. Boca Raton: CRC Press; 2014. p. 495

[80] Werbach K, Hunter D. How Game Thinking Can Revolutionize your Business. Philadelphia: Wharton Digital Press; 2012. p. 148

[81] Denton M. Gamify: What Game Mechanics are used in Gamification? [Internet]. 2022. Gamify. Available from: https://www.gamify.com/gamification-blog/what-are-game-mechanics. [Accessed: June 8, 2022]

[82] Gamified UK. Periodic Table of Gamification Elements. [Internet]. 2022. Gamified.uk. Available from: https://www.gamified.uk/user-types/gamification-mechanics-elements/ [Accessed: June 9, 2022]

[83] Bartle R. Hearts, Clubs, Diamonds, Spades: Players Who Suit MUDS. 1996. [Internet] Available from: https://mud.co.uk/richard/hcds.htm#Bartle,%201985 [Accessed: June 15, 2022].

[84] Stewart B. Personality and Play Styles: A Unified Model. 2022. [Internet] Available from: https://www.gamasutra.com/view/feature/6474/personality_and_play_styles_a_.php?print=1 [Accessed: June 15, 2022]

[85] Keirsey D. Please Understand Me II. 1998. [Internet] Available from: http://www.keirsey.com/ [Accessed: June 12, 2022]

[86] Bateman C. 21st Century Game Design. Boston: Cengage Learning; 2005. p. 332

[87] Caillois R. Man, Play, and Games. Urbana and Chicago: University of Illinois Press; 1961 224 p

[88] Lazzaro, N. The Four Keys to Fun. [Internet]. 2004-2010. Oakland, CA: XEODesign, Inc; Available from: https://www.xeodesign.com/research/ [Accessed: June 14, 2022]

[89] Bateman C. 21st Century Game Design 2005. DGD1: What Play Style Do You Prefer?

[90] Edwards R. GNS and other matters of role-playing theory, Chapter 2. In: The Forge. 2001. [Internet] Available from: http://www.indie-rpgs.com/articles/3/ [Accessed: June 15, 2022]

[91] Hunicke R, LeBlanc M, Zubek R. MDA: A Formal Approach to Game Design and Game Research. 2004. [Internet] Available from: https://users.cs.northwestern.edu/~hunicke/MDA.pdf [Accessed: June 15, 2022]

[92] Kanazawa M. 108 Gamification Elements and Mechanics to Encourage Engagement. 2022. [Internet] Available from: https://mambo.io/blog/gamification-elements-and-mechanics [Accessed: June 9, 2022]

[93] Chou Y. The Octalysis Framework for Gamification & Behavioral Design. [Internet]. 2022. yukaichou.com. Available from: https://yukaichou.com/gamification-examples/octalysis-complete-gamification-framework/ [Accessed: June 10, 2022]

[94] The Science of Motivation. [Internet]. 2022. Mclean, Virginia: IDS Publishing Corporation; Available from: https://www.reissmotivationprofile.com/ [Accessed: June 15, 2022]

[95] Ng B. The neuroscience of growth mindset and intrinsic motivation. Brain Science. 2018;**8**(2):20. DOI: 10.3390/brainsci8020020 PMID: 29373496; PMCID: PMC5836039

[96] Cook DA, Artino AR Jr. Motivation to learn: An overview of contemporary theories. Medical Education. 2016;**50**(10):997-1014. DOI: 10.1111/medu.13074 PMID: 27628718; PMCID: PMC5113774

[97] Dahlstrøm C. Impacts of Gamification on Intrinsic Motivation. [Internet]. Trondheim, Norway: NTNU.edu; 2017. Available from: https://www.ntnu.edu/documents/139799/1279149990/04+Article+Final_camildah_forsøk_2017-12-06-13-53-55_TPD4505.Camilla.Dahlstrøm.pdf [Accessed: June 10, 2022]

[98] Hamari J, Koivisto J, Sarsa H. Does Gamification Work? A Literature Review of Empirical Studies on Gamification. In: 2014 47th Hawaii International Conference on System Sciences, 2014. p. 3025-3034. DOI: 10.1109/HICSS.2014.377.

[99] Huang R, Ritzhaupt AD, Sommer M, Zhu J, Stephen A, Valle N, et al. The impact of gamification in educational settings on student learning outcomes: A meta-analysis. Education Technical Research Devevelopment. 2020;**68**:1875-1901. DOI: 10.1007/s11423-020-09807-z

[100] Gee JP. Learning by design: Good video games as learning machines. E-Learning and Digital Media. 2005;**2**(1):5-16. DOI: 10.2304/elea.2005.2.1.5

[101] Lankshear C, Knobel M. New Literacies: Changing Knowledge and Classroom Learning. 2nd ed. Philadelphia: Open University Press; 2006

[102] Gee JP. Social Linguistics and Literacies: Ideology in Discourses. London: Falmer Press; 1990

[103] Gee JP. An Introduction to Discourse Analysis: Theory and Method. London and New York: Routledge; 1999

[104] Gee JP. What Video Games Have to Teach us about Learning and Literacy. New York, NY: Palgrave Macmillan; 2006

[105] Squire K. From content to context: Videogames as designed experience. Educational Researcher. 2006;**35**(8):19-29

[106] Homer B, Plass JL, Kinzer CK. Foundations of game-based learning. Educational Psychologist. 2015, 2015. [Internet] Available from: https://www.academia.edu/21879101/Foundations_of_Game_Based_Learning;**50**(4):258-283 Accessed: June 10, 2022

[107] Shaffer DW, Halverson R, Squire KR, Gee JP. Video Games and the Future of Learning. (WCER Working Paper No. 2005-4. Madison: University of Wisconsin–Madison, Wisconsin Center for Education Research (NJ1); 2005

[108] Plass JL, Perlin K, Nordlinger J. The games for learning institute: Research on design patterns for effective educational games. In: Game Developers Conference (GDC) March 2010. San Francisco, CA; 2010. [Internet] Available from: https://www.gdcvault.com/play/1012682/The-Games-for-Learning-Institute [Accessed: June 8, 2022]

[109] Plass J, Homer B, Mayer R, Kinzer C. Theoretical foundations of game-based and playful learning. In: Plass JL, Mayer RE, Homer BD, editors. Handbook of Game-Based Learning. Cambridge, MA: The MIT Press; 2019

[110] Prensky M. Digital Natives, Digital Immigrants. On the Horizon. MCB University Press. October 2001;**9**:3-6. http://dx.doi.org/10.1108/10748120110424816 [Internet]. 2001. markprensky.com Available from: https://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf [Accessed: June 9, 2022]

[111] Prensky M. Digital Game-Based Learning. New York: McGraw-Hill; 2001

[112] Greenfield PM. Mind and Media: The Effects of Television, Video Games, and Computers. Cambridge, MA: Harvard University Press; 1984

[113] Becker K. Video game pedagogy: good games = good pedagogy. In: Miller CT, editor. Games: Purpose and

Potential in Education. Calgary: Springer Publishing; 2008. pp. 73-125

[114] Rober M. The Super Mario Effect—Tricking Your Brain into Learning More. TEDx Penn. [Internet]. May 31, 2018. Available from: https://www.youtube.com/watch?v=9vJRopau0g0 [Accessed: June 10, 2022]

[115] Gee JP. Are video games good for learning? Curriculum & Leadership Journal. 2006;**5**(1) [Internet] Available from: http://www.curriculum.edu.au/leader/are_video_games_good_for_learning,16866.html?issueID=10696 [Accessed: June 5, 2022]

[116] Juul J. Fear of failing? The many meanings of difficulty in video games. In: In: Perron B, Wolf. JP., editor. The Video Game Theory Reader. 1st ed. New York: Routledge; 2009: p. 456. DOI: 10.4324/9780203887660

[117] Justice LJ. Learning to lose: Using gaming concepts to teach failure as part of the learning process. In: 38th Annual Proceedings of the Annual Convention of the Association for Educational Communications and Technology (AECT). Indianapolis, IN; 2015. pp. 238-241

[118] Gee JP. Learning and games. The Ecology of Games: Connecting Youth Games, and Learning. 2008;**3**:21-40

[119] McGonigal J. Reality Is Broken. New York: Penguin Books; 2011

[120] Csikszentmihalyi M. Flow: The Psychology of Optimal Experience. New York: Harper & Row; 1990

[121] Halverson R, Steinkuehler C. Games and learning. In: Sawyer KR, editor. Handbook of the Learning Sciences. 2nd ed. Cambridge: Cambridge University Press; 2014. [Internet] Available from: https://www.cambridge.org/core/books/the-cambridge-handbook-of-the-learning-sciences/2E4224681267E61DBCE9B27630ED17BA 10.1017/CBO9781139519526 [Accessed: June 5, 2022]

[122] Plass JL, Mayer RE, Homer BD, editors. Handbook of Game-Based Learning. Cambridge, MA: The MIT Press; 2019

[123] Vygotsky LS. The Role of Play in Development. In: Cole M, John-Steiner V, Scribner S, Souberman E, editors. Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press; 1978. 174 p. pp. 92-104 10.2307/j.ctvjf9vz4

[124] Moran A. Agile risk management. In: Agile Risk Management. Springer Briefs in Computer Science. Cham: Springer; 2014. pp. 33-60. DOI: 10.1007/978-3-319-05008-9_3

[125] Huizinga J. Homo Ludens: A Study of the Play-Element in Culture. Boston: Beacon Press; 1955

[126] Salen K, Zimmerman E. Rules of Play: Game Design Fundamentals. Cambridge, MA: MIT Press; 2004

[127] Bateson G. A theory of play and fantasy. In: Steps to an Ecology of Mind. Chicago: University of Chicago Press; 1972

[128] Sutton-Smith B. The Ambiguity of Play. Cambridge, MA: Harvard University Press; 2001

[129] Zichermann G, Cunningham C. Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps. Sebastopol, CA: O'Reilly Media; 2011

[130] Sententia Gamification. n.d. [Internet] Available from: https://www.

sententiagamification.com/ [Accessed: June 12, 2022]

[131] Hsieh TL. Motivation matters? The relationship among different types of learning motivation, engagement behaviors and learning outcomes of undergraduate students in Taiwan. Higher Education. 2014;**68**(3):417-433. DOI: 10.1007/S10734-014-9720-6

[132] Homer B, Raffaele C, Henderson H. Games as playful learning. In: Plass JL, Mayer RE, Homer BD, editors. Handbook of Game-Based Learning. Cambridge, MA: The MIT Press; 2019

[133] Schwartz RN, Plass JL. Types of engagement in learning with games. In: Plass JL, Mayer RE, Homer BD, editors. Handbook of Game-Based Learning. Cambridge, MA: The MIT Press; 2019

[134] National Institute for Play. [Internet] 2014-2021. National Institute for Play. Available from: https://www.nifplay.org/play-science/scientific-disciplines-researching-play/ [Accessed June 12, 2022]

Chapter 12

Learning by Doing Active Social Learning

Anat Raviv

Abstract

Project-based learning and future-based pedagogy are important and effective tools for teaching and learning in the twenty-first century. They are especially suited to instilling social activism among students, which is extremely valuable in today's multicultural society. This study examined the impact of such learning among Arab and Jewish students and teachers in Israel. Following a collaborative program on social activism, in which students from different sectors worked together via digital platforms and face-to-face encounters, the impact of the program and its pedagogical tools were examined. The program, called Living in a Multicultural Society, reflects the mosaic of different people and communities, living side by side yet separated by religion, culture, and language. Through this program, students who may not have otherwise met worked together to learn, research, and create. This study was conducted using the mixed-method approach, whereby the qualitative data were gathered via interviews, and the quantitative data were collected through questionnaires. The findings show that this project-based learning program led to significant encounters, understandings, and co-operations between different sectors, and to meaningful end-products relating to social activism. This study enhances the concept that significant pedagogical processes increase students' motivation, in-depth learning, and outcomes.

Keywords: deep learning, social activism, future-based learning, STEEP learning, project-based learning, globalism

1. Introduction

This chapter discusses the unique project-based learning (PBL) program called Living in a Multicultural Society, in which both Jewish and Arab elementary school students in Israel participate and cooperate. With a focus on social activism, the project strives to develop and instill the twenty-first-century learning skills in students – i.e., future-based learning skills that incorporate social, technological, environmental, economic, and political (STEEP) aspects [1–3]. After presenting this special project, this paper evaluates the project's contribution to social activism, i.e., the social and moral call-for action, and reflects on learning concepts that stem from the assumption that the key to deep learning is practical experience, also known as learning by doing. To the best of our knowledge, previous research has not examined the impact of project-based learning or future-based pedagogy on the social activism of learners.

IntechOpen

2. Learning in the twenty-first century

In light of the significant social and technological changes and developments that have occurred worldwide, learning today requires skills that were not previously needed. On a global level, we face unprecedented social, economic, and environmental challenges that are driven by accelerated globalization processes and fast technological developments. By 2030, students who entered the education system, 2018–2020, will be young adults. As such, schools need to prepare them for life in an era of uncertainty and an unclear future; the labor market will require skills and tools that have not yet been created, as well as solution to problems that have not yet been predicted. To successfully navigate through such uncertainty, today's students must develop curiosity, imagination, mental resilience, and self-control; they must learn to evaluate different concepts and perspectives for dealing with interdisciplinary issues. These students also need to be motivated, possess tools for self-learning, and be able to manage their time and resources. In other words, the twenty-first century learner must acquire both humane and technological know-how, with an emphasis on differential-personal development, technology-based tools, and higher-order thinking capabilities [4–6].

The education system must, therefore, teach students to become initiating agents – a term that refers to their ability to act independently, out of interest and curiosity. It is this concept that underlies today's education systems in the west, as seen in the Future of Education and Skills 2030 Project[1] presented by the Organization for Economic Co-operation and Development (OECD). The project seeks answers to two far-fetched questions: (1) Which skills, knowledge, attitudes, and values do today's students need to thrive and shape their world? and (2) How can learning systems effectively develop these skills, knowledge, attitudes, and values? Education systems around the world must therefore embark on interdisciplinary teaching that is based on research and problem solving while instilling self-learning skills among the students.

Furthermore, in order to be both effective and relevant, learning programs in today's multicultural societies must combine both social activism and future-based learning [7]. Harpaz [8] states that "teaching should be an inspiring practice, a life-giving activity that can exist only in light of excellence, morality, and involvement" (52). In line with this statement, teaching today should be based on three Es: *excellence*, *engagement*, and *ethics* [9]. Moreover, the main dimensions underlying today's learning process include learning by doing, curiosity-stimulating learning, and glocalism – a blend of global and local [2]. In other words, it is the imparting of social and learning skills that shape the profile of the desired learner in the twenty-first century [2].

For lifelong learning to take place, learners must acquire skills with a technological/digital orientation, develop the ability to identify and evaluate learning possibilities, learn independently, and manage their learning – while developing the meta-cognitive ability for analyzing the given learning method. To achieve such a learning process, teachers must assist learners in identifying and choosing the most suitable learning options to suit their learning styles and objectives, monitor their progress, and assist them when problems arise. As such, schools must function as a learning-oriented center that provides learners with guidance and support in identifying learning possibilities and choosing learning services that suit the specific time and place [10]. Studies show that in the near future, teachers will use more than one medium in their lessons (e.g., [6, 11, 12]). Incorporating technology in teaching

[1] https://www.oecd.org/education/2030-project/

enables multi-modal teaching, new and updated curricula, and rich online research and collaborations; moreover, it allows students to become much more engaged in constructing their own knowledge, and cognitive studies [13].

3. The desired learner and meaningful learning

In today's post-modern era, education systems should aspire to create a graduate who incorporates three main components: the socialized graduate, the civilized graduate, and the realized graduate. The first refers to graduates who possess the ability to fulfill social functions; the second relates to graduates whose values, qualities, and attitudes are similar to those in the culture in which they study; and the third component relates to people who have acquired the necessary skills and capabilities for learning and working in the twenty-first century ([14]; Amzalag & Masry-Herzallah 2021).

The major twenty-first century skills that the student must require during his/her school study are the following: nurturing social relationships, leadership, creativity, critical thinking (Ghafar, 2020), problem-solving [15], self-managed learning, teamwork, interpersonal communication and reflection [16], computational perspectives, cognitive skills, collaborative skills, and creative problem-solving skills [17]. We also argue that these skills can be transferred from a learning context to a real-world context [18]. Moreover, learners, today should be curious people who have a strong desire to know, understand, and influence others; students who are aware of their own perceptions and attitudes, and are able to define and realize their goals. Learners must acquire skills and strategies for finding and processing information, asking questions, combining different information sources, presenting arguments, critically evaluating information, and learning through the media channels of the twenty-first century. These learners will then acquire a sense of self-efficacy and the desire to realize their capabilities and express themselves creatively. There will be learners who are able to create social relationships, conduct respectful discourse, and work as part of a team while interacting with the environment [2].

Data, from around the world, indicate that students achieve meaningful deep learning when they are able to transfer knowledge from the classroom to solving authentic problems, and when they participate in projects that require continuous involvement and cooperation with their classmates and with others. The ability to transfer these skills from a learning context to a real-world context, and to implement them successfully is one of the main twenty-first century skills. Nakakoji & Wilson [18] investigated the process of skill transfer in problem-solving, via students' "think-aloud" processes. Think-aloud processes show recursive use of interpretation, integration, and planning and execution of thinking processes, and highlight the meta-cognitive strategies used in the transfer. They argued that the perspective of academics and students on skill transfer is important to optimize twenty-first century learning and that more attention to the concept of skill transfer is needed. A collaborative learning project enhances such skills in the student learning process.

Active learning (i.e., learning by doing) impacts learners' outcomes far more than any other variable, including their background and previous achievements. Students' achievements are better when they are taught how and what to learn. In their review of the research, Barron and Darling-Hammond [19] write that decades of research around the world show that inquiry-based and cooperative learning contribute to developing the knowledge and skills that are needed for students to succeed in our constantly changing world. Such learning is an inseparable part of learners' training process in the twenty-first century (Sulam, Syakur & Musyarofah, 2019; [5]).

4. Social activism and STEEP learning

Social activism relates to the development of students' self-esteem and identity in areas such as human rights and responsibility [20]. In the 21st century, changes in society are accompanied by changes in values, at both a local and global level [2]. New values may include individualism and individual empowerment, rather than collectivism which was an important value in the past. Moreover, values such as social responsibility, ethics, transparency, accountability, human and civil rights, and fairness are the basis of fruitful contributions to the community [21].

In education systems, integrating these values into the learning process has been found to be directly linked to social activism and to the development of learners' abilities to thrive in a multicultural society [22]. Through the mutual collaboration of both students and teachers, social initiatives can be created to reflect their personal and civic responsibility, respectfulness, and fairness within the school-community relationship. This type of learning is one of the main STEEP milestones, which enables life-wide learning [6, 10, 23]. STEEP-oriented learning refers to the use of a range of computerized tools for teaching and learning purposes combined with the students' ability to identify and utilize these during the learning process. This provides students with an opportunity to research and learn a subject from a variety of viewpoints, based on each student's own learning characteristics, including trial and error, feasibility, collaborations, and facilitating knowledge [2, 24].

Social activism projects provide an educational experience that incorporates future-based pedagogy, such as the STEEP method and PBL, and implements them in the learning processes and end results. Social activism can become a learning topic through solving problems and executing initiatives that pose significant and authentic challenges for students, derived from our ever-changing environment. Learners can participate in social and community projects, on a local or global level, and then present their participation and outcomes to colleagues, fellow students, students, and other interested parties [25].

5. Leveraging social activism through future-based learning

Future-based learning (such as STEEP) is both individual and social oriented, develops day-to-day skills and teaching-learning methods, expands learning resources, encourages involvement in the community, and entails the use of innovative technologies [26]. Moreover, future-based learning moves the focus of education from the students' compliance with strict curricula to their active contribution to their studying, learning how to learn, and accessing necessary information [27]. In pluralistic societies, such active learning processes emphasize acceptance and diversity. One key aspect of creating a fruitful platform for multicultural learning is using innovative teaching and learning strategies [28]. In general, innovation in teaching is expressed through various learning methods that encourage the students' self-direction toward active and meaningful learning. Teachers using such methods tend to involve students as partners in the learning and knowledge self-construction processes. The learning process is based on teamwork, significant assignments, time planning, and practical experience related to multicultural subjects. Moreover, PBL develops and enhances students' independence and self-efficacy [29].

With regards to social activism projects, future-based learning encourages diversity and enables students to express their own personal opinions and attitudes. This flexibility is also reflected in the teacher's willingness to give each student an opportunity to express and emphasize their own interest and uniqueness [30]. Teachers who maintain the learners' involvement throughout the study process (using the PBL method) and use thought-provoking questions promote speculation and doubts. The outcome is an integration of knowledge, new information, and higher-order thinking skills among the learner (Lohman 2002; [31]). In addition, future-based learning methods provide students with the freedom and opportunity to present various options for solving problems and encourage the development of critical and diversified attitudes among students [29, 32].

Nowadays, students are expected to be able to combine social learning, technology, and higher-order thinking skills. To do so, they must be exposed to twenty-first-century skills, including information and communication literacy, critical thinking and problem-solving capabilities, and creative and innovative thinking [33, 34]. Digital platforms enable multidimensional communications, collaborations, and teamwork. These socially oriented aspects require students to be able to share information and knowledge with their peers [35] and develop interpersonal functioning, whereby they are able to conduct interpersonal communications with respect, sensitivity, tolerance, and consideration [6, 23, 36].

The education system in Israel, led by the Ministry of Education, designed structured frameworks based on STEEP skills and research concepts (2008)[2]. These frameworks aim at ensuring graduates become curious, critical, independent learners who can make educated decisions and have the skills to be team players. Research-based learning will be an element in the school culture, encompassed in the teaching, learning, and evaluation processes. Students will acquire research skills while practicing a range of research processes throughout their school. These research skills will be included in a range of topics and each student must conduct at least two research studies each year.

6. Living in a multicultural society PBL learning project

The aim of PBL is to provide students with a meaningful experience through active learning. While this concept is far from new, it is invaluable in today's fast-paced and advanced world. This type of learning requires students to investigate and make decisions based on collaboration and end products [37]. In this paper, the PBL examined is the Living in a Multicultural Society Project in which Jewish and Arab students from elementary schools participated. This project integrated STEEP future-based learning methods for promoting social activism, enhancing teamwork skills, and creating social initiatives, while increasing personal and civic responsibility, mutual respect, and fairness among its participants. In other words, this PBL provided a platform for significant and valuable learning combined with practical experience, i.e., learning by doing.

[2] Implementing Research Learning in the Israeli Education System, Ministry of Education, Pedagogical Secretary, August 2008: https://cms.education.gov.il/NR/rdonlyres/8C17EFF7-3DC9-4DC0-BD96-B74630598D38/146467/resource_1811190036.pdf

In the multicultural and multi-identity society that is typical of Israel, this project provided a unique opportunity for students from different sectors to meet and become acquainted with one another. Schools from different sectors were paired up, such as a Jewish school and an Arab one, or a Jewish school and a Druze one. Every few weeks, the students from the paired school either met in person or talked via a digital platform such as Skype, to work on joint activity. The sessions dealt with issues such as friendship, accepting others, pluralism, and multiculturalism. Moreover, each pair of schools collaborated to prepare an artifact relating to social activism at the end of the project, such as a poster, talk, or presentation.

Integrating PBL learning activities onto digital platforms, as with this project, enables a meaningful dialog between students, teachers, communities, and cultures. It encourages creative thinking, strong leadership, and effective learning methods. Throughout the project, collaborative team learning was used to encourage meaningful dialogs and cooperation between the participants. Moreover, the product of each team enabled the students to reflect on their work and cooperation and on the attitudes and outlooks of others – in both a verbal and non-verbal means of communication.

The purpose of this study, therefore, was to examine the contribution of this PBL project, which incorporated future-based and STEEP learning methods, to the developing and enhancing of social activism among the participating students and teachers. In the project, which was based on *Curriculum for Changing the World* [38], the concept of future-based learning was applied through online platforms and the social involvement of young school students.

7. The research

Research Questions.

The study examined two central research questions:

1. To what extent do future-based learning and pedagogy contribute to:

    a. The development of social awareness and social activism among students in a multicultural society.

    b. Building a network of cooperation between students from different sectors.

    c. Building a network of cooperation between teachers from different sectors.

2. Are there differences in the contribution of these future-based learning and pedagogy between the various populations who participated in the study?

8. Methodology

8.1 Participants

Living in a Multicultural Society Project was conducted throughout the 2017–2018 academic year. A non-probabilistic sampling process was performed, the sampling was constructed from all project participants, 73% of the students answered the questionnaire, and 100% of the teachers participated in the project.

About 856 elementary school students and 32 teachers from 32 different schools took part in the project. At the end of the project, 622 students and all 32 teachers took part in an evaluation process, to assess the impact of the project on social activism.

The 32 teachers included 16 Arab teachers and 16 Jewish teachers. The Arab teachers included four Druze teachers, three Christian teachers, and nine Muslim teachers. Each teacher was from a different school across Israel: 16 from the center of the country, 10 from the northern region, and six schools from the south. On average, the participating teachers had been teaching for 14.3 years.

In addition to the teachers, 622 students participated in the study: 264 Jewish students (42%) and 358 Arab students (58%). The Arab population included 19 students from a Druze school and 17 students from a Circassian one. All students were from grades four–six. The Jewish students were from eight Jewish schools, and the Arab students were from six Arab schools, one Druze school, and one Circassian school.

8.2 Research tools

The study included a closed questionnaire for students and teachers, that was validated by two inspectors in the Ministry of Education and two school principals who were partners in the planning of the project. Students filled out a questionnaire composed of 29 items from six indices, as detailed in **Table 1**. Items were rated on an agreement scale from 1 = (does not agree at all) to 5 = (agrees to a great extent), and scale scores were computed with mean of the items. The teachers were presented with

dices and examples of items from students' questionnaire (N = 622)Indices	**No. of Items**	**Sample Item**	**Cronbach's α**
Studying social activism via PBL in a mixed multicultural student team.	7	Introducing PBL methods in studying human rights/social activism with students from other schools.	0.69
The impact of the project on raising awareness of social activism.	5	The digital environment helps promote interest and diversifies learning about social activism.	0.81
The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).	6	Please write which communication tools you used during the program (e.g., WhatsApp, email, Skype).	0.72
Cross-cultural cooperation through learning teams.	6	Which activities would you like to do with students from the other group (e.g., design a digital project together, take a virtual tour of their school, meet via video conferencing to learn together)?	0.84
Entrepreneurship and social activism; end products of the project.	5	Which activities were most meaningful to you during the program (e.g., participating in a forum about multicultural acceptance, school meetings with students from another school, working together on a digital platform)?	0.73
Program evaluation (i.e., average of all indices)	3	What are the benefits of the project to your learning skills?	0.68

Table 1.
Questionnaire indices, sample items, and internal consistency (N = 622).

Index	No. of Items	Sample Item	Cronbach's α
Teaching social activism via PBL in a mixed multicultural student team.	4	To what extent did the project contribute to developing strategies for processing information among the learners?	0.95
The impact of the project on raising awareness of social activism.	4	To what extent can your students apply values relating to the acceptance of others learned and acquired during the program?	0.50
The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).	12	Throughout the project, a range of technological tools were used for creating a range of end products (e.g., computerized terminology maps, computerized poster designs, collaborative tools).	0.84
Cross-cultural cooperation through learning teams.	2	To what extent did your students acquire skills for conducting discourse and discussions in mixed groups, following their participation in the project?	0.53
Entrepreneurship and social activism; end products of the project.	3	To what extent does the joint end product reflect the attitudes and perception of innovative learning (e.g., glocal, personal, conducting research, combining technology)?	0.63
The impact and value of the project regarding interactions between teachers from different sectors.	5	To what extent did the project provide a platform for getting to know the "other" beside what was required from the project (e.g., personal get-togethers)?	0.95
Changes in the teachers' teaching methods following their experience and participation in the project.	6	To what extent did you change your perception of the role of the learner as an active participant rather than a passive one?	0.48
Added value for other members of staff who did not participate in the program.	3	To what extent where the project contents principles explained and distributed to other teachers in the school who did not participate in the project?	0.90
Program evaluation (i.e., average of all indices)	3	What are the benefits of the project to student learning skills?	0.76

Table 2.
Indices and examples of items from teachers' questionnaire (N = 32).

42 items from 9 indices as shown in **Table 2**. The teachers were asked to rate each item on a 1–5 scale (1 = Not at all, 5 = To a great extent).

The questionnaire has analyzed the findings, which shows that some of the internal traces are normal, but some were low. Considering the low internal consistency findings in some of the indices, it was necessary to update some of the statements in the questionnaire for the evaluation of the program. In all cases, the index score was composed of the average of the items. See **Tables 1** and **2**.

In-depth interviews with students focus groups and interviews with accompanying teachers were done between 1–2 weeks after the project ended. All the interviews were validated by two inspectors in the Ministry of Education and two school principals.

8.3 Research procedure

The research was conducted using the mixed-method approach, combining both quantitative and qualitative measures. The data was collected from the participants via a questionnaire during each group's final meeting of the project. Moreover, in-depth semi-structured interviews were conducted through six focus groups, each including six students (N = 36), and one-on-one interviews with school principals, teachers, and students during the last week of the project and a week after it ended.

8.4 Data analysis

The mixed-method research approach was used in this study, combining both qualitative and quantitative methods for answering the research questions. To analyze the findings descriptive statistics, T-Test, and multiple regression analysis was applied, MANOVA and ANOVA test were used.

Using skewness (SK < [2.0]) and kurtosis (K < 7.00) procedures, each teacher index was examined. Moreover, multiple analysis of variance (MANOVA) was performed, using the different sectors as a variable, followed by ANOVA for each index separately.

Sabra Ben Yehoshua [39], Shelsky and Arieli [40], noted the significance of the qualitative approach to understand the impact of the project on the perception of students and teachers. The reasons for integrating the qualitative paradigm in the study lie in the desire to understand in-depth the effects of the project on the participants in a deductive way. To create a diverse sample with maximum variation (Variation Maximum), the sample included participants from different schools with different religions, gender, and place of residence. Deductive thematic analysis was conducted based on categorical repeating patterns of the content. The process was carried out by organizing the various parts of the text by coding into categories, locating common meanings, and repeating patterns in the analyzed texts.

9. Results

The survey evaluated the contribution of 21st learning skills, including PBL and STEEP methods, for enhancing pluralism and collaborative learning, and social activism among students from a range of groups in Israel. **Table 3** presents the mean scores for each index on the students' questionnaire (N = 622) and on the teachers' (N = 32). The students' input is presented for all participants in general, and according to each sector in particular. The results show high evaluations for the first index, *Teaching/Learning social activism via PBL in a mixed multicultural team*, with an average score of 4.65 out of 5 among students and 4.70 among teachers. These high scores indicate that the experience was both successful and meaningful, for students and teachers alike.

The second index, relating to *The impact of the project on raising awareness of social activism*, was also highly evaluated by both teachers (M = 4.51) and students (M = 4.50). One teacher from a Jewish school stated that: "The students were exposed to the issue of children's rights in Israel and around the world as part of their PBL research, including the International Children's Rights Day." Participating in the project greatly contributed to enhancing the students' learning and know-how; meeting the Druze students was also fascinating for them, and the collaborative end-products reflect significant learning and cooperation between the two groups of students.

Index	Total Student Sample *M* (*SD*)	Jewish Students *M* (*SD*)	Arab Students *M* (*SD*)	Total Teacher Sample *M* (*SD*)
Teaching/studying social activism via PBL in a mixed multi-cultural student team.	4.65 (0.32)	4.53 (0.55)	4.78 (0.46)	4.70 (1.05)
The impact of the project on raising awareness of social activism.	4.50 (0.63)	4.38 (0.72)	4.67 (0.43)	4.51 (1.01)
The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).	3.40 (0.93)	2.90 (0.85)	3.9 (0.71)	4.55 (1.22)
Cross-cultural cooperation through learning teams.	4.02 (1.01)	3.45 (0.83)	4.60 (0.81)	4.61 (1.03)
Entrepreneurship and social activism; end products of the project.	4.32 (0.90)	3.83 (1.00)	4.80 (0.39)	4.45 (1.23)
The impact and value of the project regarding interactions between teachers from different sectors.	—	—	—	4.54 (1.08)
Added value for other members of staff who did not participate in the program.	—	—	—	4.31 (1.27)
Changes in the teachers' teaching methods following their experience and participation in the project	--	--	--	4.72 (0.96)
Program evaluation (i.e., average of all indices)	4.17 (0.63)			4.52 (1.06)

Table 3.
Mean scores for eight indices presented to teachers and students.

The third index, *The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms)* scored higher among teachers (M = 4.55) than among students (M = 3.40) yet is still an above mid-scale score. The fourth index, regarding *Cross-cultural cooperation through learning teams*, also achieved high scores by both teachers (M = 4.61) and students (M = 4.02). Finally, both teachers (M = 4.45) and students ((M = 4.32) highly ranked the fifth index, *Entrepreneurship, and social activism; end products of the project*.

The findings presented in **Table 4** show that in-depth learning and internalization of social activism did take place via the PBL project, which entailed collaborative learning in mixed multicultural student teams using future-based tools. A sixth-grade student from a Druze school said: "We explained to the sixth-graders in another school [a Jewish school] what social activism is and how it is expressed through the acceptance of others in a multicultural and pluralistic society. We used a digitally shared presentation on social activism and the acceptance of others that we had prepared as a part of our PBL project. We then held discussions via Skype with those students and devised a plan for researching our mutual subject. In another session, we conducted a joint activity that included preparing a digital poster about friendship from an intersectoral perspective. For us, it was very interesting and empowering to collaborate on digital platforms with students from a different school as a joint research team."

A teacher in an Arab school summarized the learning and implementation process using digital platforms and multicultural teams: "Following a theoretical introduction

	2.	3.	4.	5.
Studying social activism via PBL in a mixed multicultural student team.	.39***	.21*	.23*	.20*
The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).		.11	.31***	.10
The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).			.44***	.61***
Cross-cultural cooperation through learning teams.				.48***
Entrepreneurship and social activism; end products of the project.				

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 4.
Intercorrelations between students' evaluation of the program (N = 622).

to the main concepts of social activism, acceptance of the other, equality, and students' rights, students' work teams were formed in the classroom and were then paired up with students from our associated school. The teams from both schools (Arab and Jewish) collaborated via a digital platform and talked via Skype. Their main topic was the value of accepting others in a multicultural society. As a PBL project, the students chose to prepare a digital poster as a tool for disseminating information among all their school students. The students prepared a poster that was presented in the school corridors of both schools. The poster was written in both Hebrew and Arabic. It was fascinating to see the collaboration between the students, despite the language gaps between them." At the beginning of the following school year, the principal provided each student with a school diary with a copy of this poster appearing on the front page of each diary.

In addition to the quantitative data gathered via questionnaires, qualitative data were obtained through interviews with students and teachers from the various schools. A student from an Arab school said, "The idea of working with children that we do not know via the computer is a good idea, but there were language difficulties, and we did not always understand each other; our teacher helped us at the beginning of the project and translated some of our ideas. After several sessions of joint work, we managed to build a joint PBL product in Hebrew and in Arabic." One of the Arab students reflected on the learning process, explaining: "We produced a short video clip in Arabic and in Hebrew, illustrating the common points of interest among young students in the twenty-first century." In addition, a teacher from a Jewish school remarked that: "The project via the computer was a new experience for our students, who worked as a collaborative team on a global online project called *Cultural Mosaic – the acceptance of others* on an online project. It was complicated but very interesting. It took the students a few sessions to decide what their subject of interest is and what to create for their final product."

With regards to the overall evaluation of the program, both teachers and students evaluated the program positively (students M = 4.17; teachers M = 4.52). One student from a Jewish school said: "We conducted an activity in a mixed cultural group from the two schools. Our PBL product was an advertisement that was exhibited on the school corridors. We prepared the advertisement in Hebrew and Arabic on social activism, friendship, rights, and the acceptance of others." Another student from a Jewish school said: "As a result of our activities, students from other schools (Arab and Druze schools) visited us, and together we conducted activities on social activism and on the acceptance of others in a pluralistic and multicultural society."

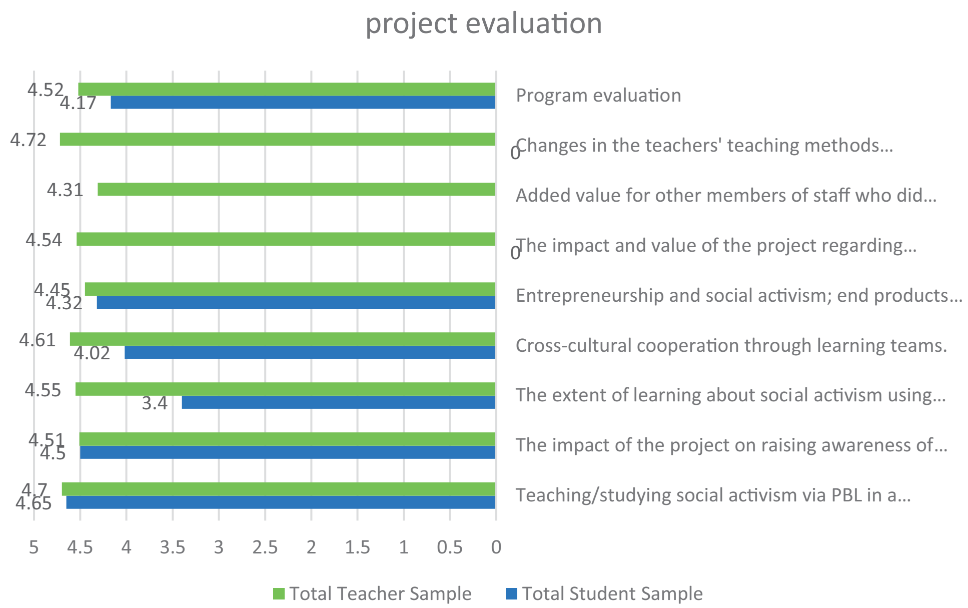


Figure 1.
Students' and teachers' evaluation of the STEEP/PBL project.

To examine possible differences between students and teachers, additional statistics were conducted. With regards to students, T-tests were run on their evaluation of the program, as shown in **Figure 1**. Significant differences were found for four of the five indices, all except for the first index, *Studying social activism via PBL in a mixed multi-cultural student team*. For all five indices, the average scores among Arab students (ranging from 3.90 to 4.80) were higher than the average scores for Jewish students (ranging from 2.90 to 4.53).

Using skewness (SK < [2.0]) and kurtosis (K < 7.00) procedures, each teacher index was examined. Moreover, multiple analysis of variance (MANOVA) was performed, using the different sectors as a variable, followed by ANOVA for each index separately. Significant differences (p < 0.05) are presented as Cohen's standardized values.

The MANOVA revealed a significant grouping effect [Wilks' $\lambda = 0.51$, $F_{(9, 22)} = 2.30$, $p = 0.05$, $\eta^2 = 0.458$.] Follow-up ANOVAs performed for each index revealed significant mean differences between the Arab and Jewish teachers for only two indices: *The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms)* and *The impact and value of the project regarding interactions between teachers from different sectors* (**Table 5**). Finally, comparing means revealed the following significant effects ($p < 0.01$): Arab students had higher values for using digital tools ($d = 1.1$) and for inter-sector relationships ($d = 1.25$). **Table 6** presents the mean values and SDs for the five index variables.

The impact of future-based learning (i.e., STEEP and PBL) on the collaborative work between students from different schools and between teachers from different schools was examined through interviews and questionnaires. Students noted that learning through PBL and digital tools was effective for building a relationship and communicating with students from the paired school; while there were certain language gaps at the beginning of the process, requiring teachers' intervention and

DOI: http://dx.doi.org/10.5772/intechopen.105523

	The impact of the program on raising awareness of social activism.	**Teaching social activism via PBL in a mixed multicultural student team.**	**Cross-cultural cooperation through learning teams**	**Changes in the teachers' teaching methods following their experience and participation in the project.**	**The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).**	**Entrepreneurship and social activism; end products of the project.**	**Added value of the project for connecting between teachers from other sectors.**
The impact of the program on raising awareness of social activism.	1.00	0.67	0.61	0.71	0.76	0.48	0.56
Teaching social activism via PBL in a mixed multicultural student team.		1.00	0.30	0.39	0.57	0.29	0.40
Cross-cultural cooperation through learning teams.			1.00	0.48	0.42	0.07	0.29
Changes in the teachers' teaching methods following their experience and participation in the project.				1.00	0.45	0.37	0.24
The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).					1.00	0.22	0.81

	The impact of the program on raising awareness of social activism.	Teaching social activism via PBL in a mixed multicultural student team.	Cross-cultural cooperation through learning teams	Changes in the teachers' teaching methods following their experience and participation in the project.	The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).	Entrepreneurship and social activism; end products of the project.	Added value of the project for connecting between teachers from other sectors.
Entrepreneurship and social activism; end products of the project					0.76	1.00	0.39
Added value of the project for connecting between teachers from other sectors.							1.00

Table 5.
Multiple regression of indices for impact of program on social awareness.

	B	β	t	Accumulated R^2
The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms)	0.27	0.07	0.36	57.2%
Changes in the teachers' teaching methods following their experience and participation in the project.	0.24	0.09	0.26	74.6%
Studying social activism via PBL in a mixed multicultural student team.	0.20	0.08	0.22	79.2%
Cross-cultural cooperation through learning teams.	0.22	0.07	0.25	82.6%
Entrepreneurship and social activism; end products of the project.	0.12	0.04	0.23	86.9%

Table 6.
Regression coefficients for impact of program on social awareness.

assistance; students overcame the language barrier and managed to work in mixed groups via digital platforms – creating meaningful opportunities for mutual learning and for creating a significant end product. One-sixth-grader from a Jewish school explained: "Through the computer activities, we managed to get to know each other and corporate in an effective manner, in order to produce a significant PBL end product that was introduced to other students in our schools." A fifth-grader from an Arab school noted: "In the beginning, it was hard to get to know our team members for the other school via the virtual world, but through our weekly mutual sessions, we got to know each other and collaborated very well."

Intercorrelations between the **students'** evaluation of the program reveal that most are positive and significant. The index *Studying social activism via PBL in a mixed multicultural student team* is positively and significantly related to all other indices. Indices *The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms)* and *Entrepreneurship and social activism; end products of the project* are also positively interrelated. In addition, *The extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platform)* is positively related to *Cross-cultural cooperation through learning teams.*"

The participating teachers were asked whether networking between teachers from different sectors had been achieved. This index scored 4.31 out of 5 points, with most teachers agreeing with this (63%) to a great extent. Moreover, they stated that most interactions were conducted during the mutual activities and when developing the learning materials.

Intercorrelations between the teachers' evaluation of the program were analyzed by performing Pearson's tests. A medium-to-strong relationship ($r = 0.67$, ($P \leq 0.001$) was found between *Teaching social activism via PBL in a mixed multicultural team* and *The impact of the project on raising awareness of social activism*.

One main issue that hindered collaboration was the language barrier. More than half the teachers mentioned that there were some communication difficulties among the students – especially at the beginning of the project. Despite this difficulty, the students did not give up, and relationships were formed via digital channels, with the help of their teachers. (It should be noted that not all paired teams had different mother tongues. For example, students from a secular Jewish school and their paired students from an orthodox Jewish school are all Hebrew speakers.) The teachers stated that most connections were formed during the face-to-face encounters, that were both exciting and meaningful for the students and teachers and enabled the continuation of the project via the digital platform. One teacher from a Jewish school wrote: "The research work was very interesting because the students did not speak a common language. We [the teachers] had to translate for the students, thereby making our role more dominant. By the end of the project, however, the students had managed to produce a joint product, which was in both Hebrew and Arabic." A teacher from an Arab school said: "The language was not an obstacle but rather a challenge; the children from the Arab school improved their Hebrew and the Jewish children were patient and spoke more slowly."

Significant collaboration occurred through the teachers working together to develop the study program and the joint project. Pearson tests showed a medium relationship between *studying social activism via PBL in a mixed multicultural student team* and *added value of the project for connecting teachers from other sectors* ($r = 0.40$, $P \leq 0.05$).

In order to examine the indices that predict the impact of the program on increasing awareness about social activism, a multiple regression analysis was performed on the indices, as shown in **Table 5**.

The regression model is significant ($F_{(5,26)} = 34.44, p < 0.001$). The predicting factors explain 86.9% of the variance in the degree of awareness of social activism. The strongest predictor is *the extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms).* The correlations between the variables in the model show that additional indices also have a strong positive correlation with social activism. Moreover, the *added value of the project for connecting teachers from other sectors* was strongly correlated with the dependent variable, yet this index was not included in the model as it has a strong but insignificant correlation with *the extent of learning about social activism using STEEP methods (digital tools, Skype, mind maps, digital platforms)*. **Table 6** presents the regression coefficients of the model.

The qualitative data gathered from the students shows that the pedagogical methods used in the PBL project enhanced the students' learning and cooperation. First, the program enabled the students to become *learners and thinkers*. Asking open-ended questions requires skills of inquiry, especially when dealing with inter-sectoral connections, i.e., the acceptance of the different others in a pluralistic and multicultural society. One student from a Druze school relates: "As part of the program of social activism, we explored our rights using different questions. In our PBL team project, we explored a few rights and understood their significance in a pluralistic society. In a joint meeting with students from the Jewish school via Skype, we decided to create a mask together for our final product. We decided to write on the masks the rights that we think are most important to be preserved in a pluralistic society."

Next, the program encouraged students to *be independent and take responsibility*, as the teachers in the program allowed the students' freedom of choice and challenges that would enhance their independence and skills. One teacher from an Arab school said: "One of the subjects of the program was social activism from a cross-sectoral perspective. We discussed the issues of acceptance and of the different other in a pluralistic and multicultural society." Dealing with such issues in relation to solving authentic problems enables learners to use different learning sources and engage them in problem-solving and active research. The teachers in the program also allowed great flexibility and shifting of the focus throughout the activities, in response to the student's interests and questions. One-sixth-grader from a Jewish school said: "During a mutual activity, we were talking [the students from the paired schools] about our rights, friendship, rejection, and central values of a pluralistic society. As a final joint activity, we created a graffiti project that formulated a convention dealing with accepting the different other in a pluralistic and multicultural society."

An additional theme reflected in the project relates to the *use of diverse sources of information*, as the learned materials are accessible to students in both Hebrew and Arabic – through digital platforms, posters, pictures, videos, hard copies, and more. With PBL projects, this type of learning exposes students to new experiences, enabling them to create new structures for integrating the information. A Jewish teacher said: "The students in the Arab school researched the subject of accepting the other in a multicultural society and then created a poster. My group of students researched the subject and prepared a presentation. During the sessions via the Skype digital platform, the students decided to create a joint final product of a presentation in both Hebrew and Arabic about the values and principles they had researched. They presented their work in the form of a digital poster about the acceptance of the different other. The presentation was then used to disseminate the subject among the other students in both schools."

A fourth theme seen in the study refers to *creating connections between theoretical and practical issues that relate to the learner's life and global issues (i.e., glocalism).* The learning process created links to the real world outside the school walls, relating to everyday situations. For example, students from different schools jointly created shared thinking maps using a common digital platform. Teachers from an Arab and Jewish pair of schools explained that: "During the program, the students were introduced to the different values that characterize a pluralistic society. Each group chose a value and researched it. During the research process, the students built a concept map of the values that were studied. At the end of the research process, they created a large concept map and held a debate with other groups that participated in the program."

Finally, actively learning in groups provides a *significant emotional experience* involving the development of intrapersonal and interpersonal communications, empathy, and tolerance toward the other, increasing the learner's personal involvement, intrinsic motivation, and enjoyment. A student from a Jewish school recalled: "Learning on the program contributed to me and to the other students. As well as learning, we were also engaged in the dissemination of the subject to other students in our school and in the Arab and Druze schools, and this was a huge contribution to me because introducing the material to other students boosted my self-confidence."

Analysis of the findings reveals that with regards to learning and assimilation of the program, the subject of acceptance of others in a multicultural society was significantly implemented among students, through a variety of future-based teaching strategies such as PBL, STEEP, and digital tools. The end products presented by the students and teachers indicate a significant level of assimilation and learning, creativity, and active learning achieved through digital platforms, debates, group training, and joint creations. A sixth-grader from an Arab school shared his impressions: "Working with computers helps create activities regarding social activism. The project's 'acceptance of others – social activism' was based on teamwork within the school and with peers from the other school. We constructed a mutual research process, accompanied by creating joint products." A Jewish student from the paired school added: "After building the joint products, we shared them with students from the paired school and from our school."

As shown in the findings, the index of the *extent of learning about social activism using STEEP methods (digital tools skype, mind maps, digital platforms)* was positively related to all other items. A fifth-grader studying in a Circassian school related: "We talked about the right to equality in a pluralistic society. The product that we created was done in cooperation with the students from the Jewish paired school. We were corresponding via the forum and shared ideas via Skype. We worked in full cooperation (despite the language difficulties) on a digital platform and created a joint product in Hebrew and Arabic. It was very important for us to meet our colleagues and get to know each other." A sixth-grade student from a Jewish school also said: "What we acquired was another type of friendship, with more knowledge and experience in the field of friendship, discourse, and acceptance of the different other in a multicultural and pluralistic society. I now understand what social activism is in the context of accepting the other and rules for conducting fair discourse."

10. Discussion and conclusion

Enhancing social activism among students requires innovative, future-based learning methods. The teachers and students who participated in the Living in a Multicultural Society PBL project reported significant and meaningful learning among the paired teams, combined with the planning and execution of collaborative initiatives between students from different sectors. The findings reinforce the concept of teaching/learning using new pedagogical approaches for enabling multi-dimensional learning – in order to develop learners' research skills and produce diversified products. One possible explanation for the significant differences in the evaluation of the program between students in the Jewish and Arab sectors could be that PBL, STEEP, and future-based learning methods may not be use as widely in the Arab schools as in the Jewish schools. If these methods were new to some students but not to others, this could have led to differences in the levels of appreciation and evaluation of the students.

Moreover, the final project products were displayed and explained to additional students from the schools who did not participate in the project. This social activism initiative provided teachers with the opportunity to experience innovative pedagogical methods based on digital tools that enable learning, innovation, creative thinking, curiosity, and research methodologies – all of which are highly all relevant to the students' day-to-day. In other words, this learning provided a new platform for developing thinking, creativity, work ties, and teamwork between class students and students from different sectors.

The moral international issue of social pluralism and accepting others is the core issue of most western societies that accept immigrants from around the globe. Therefore, this topic is of the utmost importance when educating students to become good and meaningful citizens. Moreover, providing students with a range of pedagogical tools, twenty-first century skill is of great educational value [18]. As such, the contribution of the Living in a Multicultural Society program is significant. First, from a social point-of-view, active group learning develops interpersonal communications and helps achieve a balance between group and individual learning. In the twenty-first century, being able to work in a team and internalize social intelligence is invaluable [6, 32]. Furthermore, from a language point-of-view, this type of project develops and enhances communication capabilities and dialogs with people from other cultures, nationalities, and religion, as well as enriching the participants' vocabulary. Finally, from a cognitive point-of-view, this type of active learning contributes to acquiring existing knowledge and creating new knowledge [41].

The program presented in this study encompasses future-based pedagogy for dealing with glocalism [2, 18], i.e., the nurturing of the global citizen. By implementing this concept in the educational initiative of social activism, the students had to act outside their comfort zone, creating learning partnerships with students who do not belong to the same cultural background. This was meaningful, as opportunities for such intercultural encounters build and strengthen the local and global perceptions within the learner's personal development.

With globalization becoming more and more widespread in recent years, a range of populations has begun migrating to western countries, turning the issue of multiculturalism and acceptance of the different others into a major topic. This social activism project creates a platform for educating the students toward tolerance and acceptance of others. Educating students and youth from an early age toward tolerance and recognizing others as having equal rights and worth will make human society more tolerant and less discriminative toward minorities. In addition, the acceptance of others will also lead to the assimilation and integration of cultures, thereby creating a more egalitarian and pluralistic society. Social activism in a multicultural society is necessary in all schools in the Western world.

The findings of this study strongly indicate that such projects are effective in educating the younger generation toward tolerance and inclusion of others. Moreover, they indicate that using a varied range of future-based learning processes based on PBL and STEEP contributes to the assimilation of social activism and basic values of a pluralistic society.

11. Limitations

This study on social activism was conducted among elementary and junior high school students in a number of sectors in Israel. Future studies could benefit from expanding the research and conducting a joint study with schools from different countries, such as Germany, France, and Italy – in order to examine the impact of the program for raising social activism awareness on a large international scale. In turn, the assimilation of this program on an international scale, among young students, could leverage the understanding of how social activism impacts acceptance and tolerance among all sectors of the population.

Author details

Anat Raviv
Tel Hai Academic College, Israel

*Address all correspondence to: anatraviv34@gmail.com

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Lavi R, Tal M, Dori YJ. Perceptions of STEM alumni and students on developing 21st century skills through methods of teaching and learning. Studies in Educational Evaluation. 2021;**70**:101002

[2] Morgenshtern O, Pinto I, Vegerhof A, Hoffman T, Lotati S. *Pedagogiya Mutat Atid 2: Megamot, Ekronot, Hashlachot Veyesumim* [Future-Based Pedagogy 2: Trends, Principles, Consequences, and Applications]. Jerusalem, Israel: Ministry of Education; 2019 Available from: http://meyda.education.gov.il/files/Nisuyim/pama2018taktsir.pdf

[3] Passig D. *Forcognito – The Future Mind* [Forcognito – HaMoach HaAtidi]. Tel-Aviv: Yediot Press; 2013. pp. 189-221

[4] Allan CN, Green DM. Griffith Sciences Blended Learning Model. School of Information and Communication Technology Zhe Wang. 2019. Available from: https://app.secure.griffith.edu.au/exlnt/entry/6405/view

[5] Kelly, K. COVID-19 Planning for Spring 2021: What We Learned About Hybrid Flexible Courses in Fall 2020 [blog post]. 2021. Available from: https://philonedtech.com/covid-19-planning-for-spring-2021-what-we-learned/

[6] Raviv A. Teachers experiment learning based on future-oriented pedagogies. International Journal of Current Research. 2017;**9**(7):54189-24200

[7] Beetham H. Designing for active learning in technology-rich contexts. In: Beetham H, Sharpe R, editors. *Rethinking Pedagogy for a Digital Age: Designing for 21st Century Learning*. 2nd ed. New York: Routledge; 2013. pp. 31-48

[8] Harpaz Y. Hora'a Meoreret Hashraa [inspirational teaching]. *Hed HaChinuch* [Echo of Education]. 2016;**6**:55-52

[9] Gardner H, Csikszentmihalyi M, Damon W. Good Work When Excellence and Ethics Meet. New York: Basic Books; 2001

[10] Lifewide Education UK. Lifewide Learning. Available from: http://www.lifewideeducation.uk/

[11] Kim H, Dong-Hyun C. The development and application of a STEAM program based on traditional Korean culture. Eurasia Journal of Mathematics, Science & Technology. 2016;**12**(7):1925-1936

[12] Tao Y, Oliver M, Venville G. A comparison of approaches to the teaching and learning of science in Chinese and Australian elementary classrooms: Cultural and socioeconomic complexities. Journal of Research in Science Teaching. 2013;**50**(1):33-61

[13] Stefania B, Kampylis P, Punie Y. "Innovating learning: Key elements for developing creative classrooms." JRC Scientific and Policy Reports, European Commission. OECD Future of Education and Skills 2030. 2012. Available online: http://www.oecd.org/education/2030/

[14] Harpaz Y. HaBogrim HaRetsuyi: Likrat Hagdara Chadasha [the desired graduates: Towards a redefinition]. Hed HaChinuch [Echo of Education vol. 1 pp 22-35]. 2013

[15] Sari R, Sumarmi S, Astina I, Utomo D, Ridhwan R. Increasing students critical thinking skills and learning motivation using inquiry mind map. International Journal of Emerging Technology in Learning. 2021;**16**(3):1863-0383

[16] Konstantinou I, Elizabeth M. Self-managed and work-based learning:

Problematising the work place classroom skills gap. Journal of Work-Applied Management. 2021;**13**(1):6-18

[17] Nouri J, Zhang L, Mannila L, Norén E. Development of computational thinking, digital competence and 21st century skills when learning programming in K-9. Education Inquiry. 2020;**11**(1):1-17

[18] Nakakoji Y, Wilson R. Interdisciplinary learning in mathematics and science: Transfer of learning for 21st century problem solving at university. Journal of Intelligence. 2020;**8**(3):32. DOI: 10.3390/jintelligence8030032

[19] Brigid B, Darling-Hammond L. "Teaching for Meaningful Learning: A Review of Research or Inquiry-Based and Cooperative Learning." Edutopia – The George Lucas Educational Foundation George Lucas Educational Foundation. P.O. Box 3494, San Rafael, CA 94912; 2008

[20] Nam BH, Hong D, Marshall RC, Hong JH. Rethinking social activism regarding human rights for student-athletes in South Korea. Sport in Society. 2018;**21**(11):1831-1849

[21] Edmundo G. "Children of the Sleeping Giant: Social Activism among Latino Youth in the United States," (MS thesis, Texas A&M University, 2013). Texas A & M University

[22] Ferrari A, Cachia R, Punie Y. Innovation and Creativity in Education and Training in the EU Member States: Fostering Creative Learning and Supporting Innovative Teaching Literature Review on Innovation and Creativity in E&T in the EU Member States (ICEAC), JRC Technical Notes. Institute for Prospective Technological Studies, Directorate-General Joint Research Center European Community; 2009. Available from: http:// ftp.jrc.es/EURdoc/JRC52374_TN.pdf

[23] Redecker C, Leis M, Leendertse M, Punie Y, Gijsbers G, Kirschner P, et al. *The Future of Learning: Preparing for Change.* Joint Research Center, Scientific and Technical Reports. European Commission; 2011. Available from: http://dspace.ou.nl/bitstream/1820/4196/1/The%20Future%20of%20Learning%20-%20Preparing%20for%20Change.pdf

[24] Darling-Hammond, Linda, Lisa Flook, Channa Cook-Harvey, Brigid Barron, and David Osher. 2017. Implications for educational practice of the science of learning and development. Applied Developmental Science. 24(2), 97-140. Available from: https://www.tandfonline.com/doi/full/10.1080/10888691.2018.1537791

[25] Future Problem Solving Program International (FPSPI). 2019. Available from: http://www.fpspi.org/index.html

[26] Vidislavski M, Peled B, Pevsner O. "Hatamat Beit HaSefer LaMeah Ha-21 Vepedagogia Chadshanit" [adapting schools to the 21st century]. *Aureka* [Eureka]. 2010;**30**:1-6

[27] Jean A, Anna B, Wootton M, Burton R. "Facilitated Networks of Learning." Seminar Series 237. Centre for Strategic Education, East Melbourne Victoria 3002. 2014. Available online: https://static1.squarespace.com/static/5dd1b5c9da15f732723fe4c6/t/5e576c28c2a34a5be86f4531/1582787628964/8+Facilitated-Networks-of-Learning-Seminar.pdf

[28] Heller E. "Sicha Im Dr. Ricky Tessler al Aktivism Bechinuch" [Talking to Dr. Ricky Tessler about Activism in Education]. Vol. 12. *Kolot*: *Ktav Et Leinyanei Chinuch*

Vechevra [Voices: Journal of Education and Society]; 2016. pp. 6-9

[29] Cremin T. Creativity, uncertainty and discomfort: Teachers as writers. Cambridge Journal of Education. 2009;**36**(3):415-433

[30] Department for Education and Skills UK. Aiming High: Raising the Achievement of Minority Ethnic Pupils. Department for Education and Skills UK; 2003 Available from: https://dera.ioe.ac.uk/16362/7/DfES%20-%20Aiming%20high%20consultation_Redacted.pdf

[31] Treffinger DJ, Young G, Selby EC, Shepardson C. *Assessing Creativity: A Guide for Educators*. USA: National Research Center on the Gifted and Talented; 2002

[32] Ladegaard H, Phipps A. Intercultural research and social activism. Language and Intercultural Communication. 2020;**20**(2):67-80

[33] Yaari M. "Ani Veata Neshane et Haolam – Aktivism, Irgunim Leshinuyi Chevraty Vehamimshakim Benehem" [You and I will Change the World – Activism, Organizations for Social Change, and their Mutual Interface]. *Shatil*: *Hakeren Hachadasha LaIsrael* [The New Israel Fund Initiative for Social Change]; 2015

[34] Yu-Sien L. Fostering creativity through education: A conceptual framework of creative pedagogy. Creative Education. 2011;**2**(3):149-155

[35] Melton GB. Treating children like people: A framework for research and advocacy. Journal of Clinical Child and Adolescent Psychology. 2005;**34**:646-657

[36] Krish C, Liu Q, Wenwei L, Josie J, Gcora N, Shenglin B. "Bridging the Digital Divide: Measuring Digital Literacy." G20-Insights.org. Germany. 2017. Available online: https://goo.gl/5WVMCe

[37] Handrianto C, Arinal Rahman M. P roject based learning: A review of literature on its outcomes and implementation issues. Linguistics, Literature and English Teaching Journal. 2018;**8**(2):110-129. Available from: https://jurnal.uin-antasari.ac.id/index.php/let/article/viewFile/2394/1704

[38] Doyle HB. "A Curriculum for Changing the World: Preparing Students for an Interconnected, Global Society — Starting in Kindergarten." Harvard Graduate School of Education U.K; 2017. Available from: https://www.gse.harvard.edu/news/uk/17/05/curriculum-changing-world

[39] Sabar Ben Yehoshua N. Traditions and Currents in Qualitative Research: Strategic Concepts and Advanced Tools. Tel Aviv: Mofet Institute; 2016

[40] Shelsky S, Arieli M. From the interpretive approach to the post-modernist approaches in the study of education. In: Tzabar-Ben Yehoshua N, editor. Traditions and Currents in Qualitative Research. Lod: Dvir; 2001. pp. 31-76

[41] Ministry of Education in Israel. *Netivim Lehora'a Mashmautit: Menifat Modelim Yesumiim Lehora'a Mashmautit* [Paths to Significant Teaching: A Variety of Applicable Models for Meaningful Teaching]. Jerusalem: Pedagogical Secretariat; 2015

Chapter 13

Agoraphobic Dispositions towards Action Research: Teacher Education Students' Perceptions and Experiences

Davison Zireva

Abstract

One of the contemporary global education thrusts in teacher education is the generation of context-based theory through engagement in action research. While practicing in the classroom, the teacher education student is essentially in the laboratory creating procedural knowledge. Action research in the classroom involves reflective practice, which is indispensable to praxis. Despite the efficacy of action research in facilitating *mathetics* (learning how to learn), there are some militating situations that are fuelled by diehard traditional perceptions and practices. An exploration of teacher education students' perceptions and experiences with action research was done with 16 informants who were selected purposively and exposed to in-depth interviews. The data were thematically analyzed and the findings were that some students develop agoraphobic dispositions toward action research due to some miseducative experiences that are largely attributed to traditional educational practices. The teacher education students are exposed to vices like technical rationality instead they should be oriented toward epistemic and pragmatic rationalities that are the linchpins of professional development. The experiences that precipitate agoraphobic dispositions in action research should be known and subsequently obliterated.

Keywords: action research, reflective practice, agoraphobic dispositions, mathetics, perceptions

1. Introduction

There seems to be a dearth in the generation of theories in the education phenomenon despite the large volumes of educational research that scholars have produced [1, 2]. The "intellectuals" generally take recourse to technicist education, which is characterized by the overreliance on technical rationality. The practitioners consider what was discovered by renowned academics to be the effective panacea to all academic ills even in situations that are apparently diverse. There is a tendency to apply the all-size-fits-all approach. The education practitioners are thus involved in miseducative practices which make the learners unaware pawns in written theories [3]. The teacher, education practitioners, both lecturers, and mentors lack knowledge about action research to the extent that they eschew it. Consequently, they adversely affect the life-long professional development of the teacher education students. The student should learn how to acquire procedural knowledge through action research.

This chapter aims at providing insights into the precipitation of agoraphobic dispositions when teacher education students are exposed to action research. The chapter is hinged on an empirical study with some teacher education students. For the clarification of issues that are in the discourse, firstly there are explications of critical concepts. The informants' (teacher education students') verbatim responses are then used to substantiate some viewpoints in the discourse.

2. Background

At Columbia University in the United States of America, action research was formally introduced by Stephen Cory in teacher education in the 1950s [4]. Cory as a staunch advocate of action research postulated;

We are convinced that the disposition to study ... the consequences of our own teaching is more likely to change and improve our practices than is reading about what someone else has discovered of his teaching.

Cory was emphasizing on the essence of action research as far as theories can be generated by the practitioners themselves. He was encouraging the education practitioners to embrace action research as it could liberate them from the academic slavery of technical rationality and systematicity. When action research was introduced in the United States of America, it was branded to be riddled with more vices than virtues [4]. In the 1970s, there was a revival of action research and educators questioned the applicability of conventional research that was grounded in positivism in generating solutions to educational problems. Some critical education practitioners postulated that conventional research was too theoretical and too general and thus not grounded on practice [5].

The renaissance of action research in the USA came with so much vigor that it was considered to be synonymous with professional development. The importance of action research was explained;

> *Action research emphasizes the involvement of teachers in problems in their own classrooms and has as its primary goal the in-service training and development of the teacher rather than the acquisition of general knowledge in the field of education [4].*

Action research is considered a requisite for professional development. The practitioner who embarks on action research is actively involved in the creation of knowledge about how to improve practice.

3. Agoraphobic dispositions

Agoraphobia is an anxiety disorder that is manifested by a person in situations that are perceived to be unsafe for the well-being of that person. It develops when one thinks that the immanent situation is potentially prone to causing feelings of entrapment, helplessness, or embarrassment. In other words, agoraphobia is the fear of situations that are suspected to cause estrangement or embarrassment. The person affected will go to great lengths to avoid these situations [6, 7]. Agoraphobia is often, but not always, compounded by a fear of social embarrassment. In most cases, the person who experiences agoraphobia avoids the situations and stays in the comfort of his/her safe haven [8]. Due to agoraphobic dispositions, some people refuse to leave their old practices even when the old practices are no longer valuable because the fear of being outside of their comfort areas is too great.

Agoraphobic dispositions are habits of the mind or tendencies to be apprehensive of some situations [9]. Being habits of the mind, agoraphobic dispositions are precipitated by some experiences. Experience is the conscious involvement of a person in a situation or event which requires that one thinks, feels, does, and concludes at the time or immediately thereafter [10]. It is given meaning and value when one does some reflections, that is when one recaptures his or her experience, thinks about it, mulls it over, and evaluates. Thus an experience shapes one's perceptions. The definition of perception is given as;

> *… the process by which people translate sensory impressions into a coherent and unified view of the world around them. Though necessarily based on incomplete and verified (or unreliable) information, perception is equated with reality for most practical purposes and guides human behavior in general [11].*

Thus, perception is the viewpoint of an individual that was developed through interaction with the environment in particular situations. Through perception, the respondent gains information about properties and elements of the situation, which are critical to his or her survival [12]. The nexus between conception and experiences conjures up praxis.

4. Praxis

Praxis is about action informed by theory and the construction of theory from practice. The contemporary conception of praxis was developed from the conception of the ancient Greek philosophers who considered it as human action in the natural and social world [13]. Aristotle, the ancient Greek philosopher, considered praxis as transformative and emphasized on the prominence of action over thought [14, 15]. Thus, according to him, praxis is a goal-directed action. The conception has since been developed to refer to the enactment or embodiment of theory. The worthiness of the theory was determined by the extent to which it could be put into practice for the transformation of the natural and social terrain.

In the education realm, praxis is realized through the cyclical process of experiential learning that was propounded by David Kolb [16]. In other words, praxis is also considered as reflection and action focused on critical consciousness of the oppressive structures [17]. The philosophy of praxis is emancipatory since it is antithetical to one-sided counterfeit venerations of reasoning that are rampant in spheres of life like religion and intellectualism [18].

Praxis is about philosophical discourses that consider the close intertwinement of empiricism and rationalism. In other words, praxis involves knowing, acting, and reasoning [19]. In praxis, reflection is the nodal point between theory and action. Reflection makes theory valuable by enabling its contextual embodiment. On the other hand, reflection provides rationality for action. Thus in praxis, the reality is interacted with consciously with the express purpose of transforming it for the improvement of the natural and social world [20, 21].

5. Action research

Action research is a mode of research in the quest for the requisite attitudes, knowledge, and skills about how to improve one's practice. The educator-researcher embarks on research to improve the self in terms of teaching skills, techniques, and strategies. The value of action research is in the change that occurs in everyday classroom practice. Action research can be viewed as a tool for classroom practice reforms [4].

Action research is defined as;

> *… a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social and educational practices and the situations in which these practices are carried out [22].*

Thus action research is a requisite research strategy that should be employed by educators when they are learning to solve contextual problems in their working environments [23]. The educator develops introspection and is not susceptible to externalization of teaching-learning problems. Thus the essence of action research is to improve on own practice which is tantamount to sustainable professional development [24]. Action to improve on practice is connected to research. Thus research and action are done simultaneously [25].

6. Research methodology

The teacher education learners' perceptions and experiences were empirically explored by employing the qualitative research approach. The focus was on the generation of verbal data, which were about the descriptions of the learners'

Informant	Male	Female
Informant 1	X	
Informant 2		X
Informant 3		X
Informant 4		X
Informant 5		X
Informant 6		X
Informant 7	X	
Informant 8	X	
Informant 9		X
Informant 10	X	
Informant 11		X
Informant 12		X
Informant 13	X	
Informant 14	X	
Informant 15		X
Informant 16		X

Table 1.
Informants' bio-data.

perceptions of and meanings that they gave to experiences with action research. Thus the paradigm that guided the empirical part of the chapter is hermeneutical phenomenology. The essence of hermeneutical phenomenology is to interpret the lived experiences of the informants [26–29]. The data were generated through in-depth interviews which were carried out one-on-one with 16 teacher education learners. The informants were purposively selected after they had abandoned the action research, which they had initially chosen. The interview questions were pilot-tested on four teacher education learners who had attributes similar to the sampled learners. The data generated from the pilot test were judged to be trustworthy and then the interview questions were presented to the informants whose gender data are presented in the **Table 1**.

The interviews carried out were audio-taped so as not to miss any data that were generated. The data were then transcribed and analyzed by employing the thematic approach. The data were coded according to themes that were identified and scrutinized for intra-coder consistency through reflexive, critical, and rigorous thinking guided by the Johnson-Christensen method. Thus the teacher education learners' verbatim perceptions and experiences were categorized into themes that gave meaning to the prevailing situation [30–32].

7. Manifestations of agoraphobic dispositions

Agoraphobia is the condition where sufferers become anxious in unfamiliar situations or when they perceive that they have little knowledge about a situation is precipitated by some experiences [33]. Informant 1 met with experiences that precipitate agoraphobic dispositions. He posited:

> *"My research supervisor hinted that I could be putting my studies in jeopardy by embarking on action research since I was not intellectually gifted to do reflections that could contribute meaningfully to the stock of didactic procedural knowledge."*

Similar experiences were met with by informant 2 who stated:

> *"I was told by fellow students that I was becoming overzealous doing action research which is as of now hazy - and that in the end, I was going to meet with humiliation when I fail. Thus I decided to stop doing action research."*

8. Denigration of action research

Action research is denigrated by some education practitioners. The denigration is miseducative and causes agoraphobic dispositions toward action research. In formant 3 postulated,

> *"My mentor bluntly attacked me saying that action research was good for nothing. I then had to do the traditional fundamental research."*

The condemnation of action research was corroborated by informant 4 who posited:

"Though I had embraced action research, I could not pursue it during my teaching practice. The mentors belittled it as amateur research which could yield nothing more than opinions that could not be generalized."

Further corroborative remarks were given by informant 5 who claimed:

"Lecturers do not mince their words when it comes to their preferences concerning the research type. They are blunt that they prefer that their supervisees do the traditional fundamental research which they appraise as being more organised than action research [17, 34]."

The stage of action research non-acceptance in education that was explained by the teacher education learners was once experienced in the USA in the 1950s. Action research was attacked as being unscientific, a bit more than common sense, and an amateur's work [4]. The attack was exacerbated by the increased interest in positivist inquiry during that era. The academics exalted positivism to utopian levels of objectivity and verifiability. To some extent the situation experienced by the teacher education, students could be worse off since some influential education practitioners are skeptical about the essence of action research.

Action research is surrounded by skepticism since most of the teacher educators did not formally study action research but the traditional conventional research. Informant 6 explained how she developed agoraphobic dispositions towards action research;

"My research supervisor told me that action research is a new type of research as such very few lecturers are well versed in it. If the supervisor professes lack of adequate knowledge who am I to venture onto the academic slippery ground."

Further remarks were given by informant 7 who asserted:

"My research supervisor advised me that action research is hardly done at higher degree level and is thus potentially difficult. Thus I was afraid to do action research since I am simply a mediocre student."

In the same line of experiences, informant 8 gave the remarks;

"The mentors do not offer adequate support on action research. When asked about research, they readily produce the researches that they did at university or college and encourage students to plagiarize. I was left with no option but to stop doing action research."

Some teacher educators are not well versed in both declarative and procedural knowledge about action research. Such a situation leads them to the conservatism of their traditional research orientations and vilifications of action research. Lack of adequate knowledge of academic issues evokes some agoraphobic dispositions towards that issue. The dispositions are latent in some teacher educators when they insidiously discourage teacher education students to undertake action research. Thus the action research supervisors have an influence on the perceptions and experiences of students in action research.

9. Agoraphobia from lack of praxis

In academia the separation of theory from practice makes the practitioners of education lose touch with reality. Detachment from reality begets alienation which according to Marx is the estrangement of learners from their experiential realities [35] which could subsequently cause the development of agoraphobic dispositions. The panacea to alienation is praxis which is conceptualized as the action and reflection upon the world in order to transform it [17]. Thus, the theory is used in studying the word and action uses the studied 'word' to interact meaningfully with the world. On the other hand, interaction with the world begets the generation of the meaningful 'word'. Thus the word-world gulf is closed by the philosophy of praxis.

Informant 9 explained some experiences that lacked praxis and were causing agoraphobic dispositions;

> *"I identified a problem in teaching learners and I decided to carry out action research on the problem but my supervisor discouraged me when I was generating baseline data. She said that the whole research was going to be a fiasco. She said that the theory I learnt at college was not supported by my practicing findings."*

Praxis is regarded as the only philosophy that is based on practice [36]. It is concerned with practical reasoning which is reasoning about what should be rather than what is there in real- life experiences.

10. Agoraphobia enhancement due to lack of mathetics (learning how to learn)

The teacher should forever be a student [17]. There should never be a time of complacency and feelings of omnipotence in education since society is never at stasis. The teacher education student should always be learning how to learn in order to be an effective educator. Learning how to learn is *mathetics* [2].

Learning is a pedagogical activity that focuses on the acquisition of requisite skills, knowledge, and attitudes for sustainable interaction with the environment. Learning cannot take place without a bearing on the contextual realities of life. If there was an instrument that measures the extent of learning (learnometer) it was supposed to focus on how the acquired attributes can be put into practice. The teacher education learner shows that learning would have taken place if he or she is in a position to embody the learned theories and discover their contextual virtues and vices. This can be shown when one embarks on participatory action research, which has an emphasis on reflection-in-action and reflection-on-action.

In pedagogical situations, there are some pseudo-learning activities which among others are; memorizing, cramming, mimicking, plagiarizing, and reciting. These activities lack reflection but are often confused with the learning activity by most education practitioners and learners. Informant 10 exposed how he developed agoraphobic dispositions from colleagues who had not been exposed to *mathetics*;

> *"I was ridiculed at by fellow students when they were through with their traditional fundamental researches which they had plagiarised. They teased me that I was*

expending time and energy on research which could make me fail other disciplines as well as the research. I then thought otherwise to circumvent the imminent embarrassment."

Situation bereft of context-based learning.

Context-based learning lies within the framework of the theory of change (ToC) [36]. The theory of change when reflected upon culminates in the action of change (AoC). The action of change is realized in action research. The practitioner is challenged to critically reflect on his or her own practices thus becoming introspective. If one is poised for the action of change, then agoraphobic tendencies should be done away with.

Agoraphobic tendencies could be precipitated when pedagogical situations are bereft of context-based learning (CBL) scenarios. The CBL scenarios are efficacious since they make references to the use of real-life examples in teaching-learning situations. Thus the learners hinge learning on their practical experiences. The efficacy of the theories that are exposed to the learners should be tested against their lived experiences. Furthermore, practical experiences should help in the development of theories [37].

Informant 11 described a situation that was bereft of contextual learning, which precipitated an agoraphobic disposition in action research;

"I was told by my lecturer that during external examination, some external examiners are hyper-critical about the processes and the findings from action research. It was stressed that findings at diploma level should be biased towards theories established already. Thus I perceived action research to be scary since my realities were not a carbon copy of theories that I learnt."

11. Lack of awareness of conception of the laboratory school

In 1896 John Dewey, the American pedagogue philosopher experimented on the efficacy of the first laboratory school [38]. The school was the first embodiment of praxis. Dewey wanted to show the intertwinement of empiricism and rationalism in the creation of knowledge. It was Dewey's conviction that all ideas about education should be tested empirically in the laboratory (the classroom) and reflected upon to create contextual knowledge. Dewey's praxis orientation can be considered contemporary action research [39]. Lack of proper awareness of the essence of action research exacerbated the development of agoraphobic dispositions towards action research. Informant 12 postulated;

"I was advised by my research supervisor that if I choose to do action research, I could it to my own peril. He emphasized that nothing sensible was going to come out of my teaching experiments. I found the advice quite forbidding."

The laboratory school was characterized by the experimentation of teaching-learning ideas and practices. The other issue focused on by the laboratory school was the relevance of the curriculum content in solving the problems experienced by the learners and society at large [40]. Taking from Dewey's laboratory school, contemporary teacher education should discourage the practice of traditional education that is characterized by the regurgitation of facts given by the 'educator' or found in textbooks or the internet. The teacher education students should be encouraged to be creators of knowledge in the 'laboratory' which is the classroom.

The students who were exposed to monological teaching techniques are apprehensive of challenging the status quo in the acquisition of knowledge. Researching in teacher education has become confirmatory of the hunches of the renowned "educators." Informant 13 exclaimed:

> *"I later on realized that I was supposed to get some anchoring of my teaching on what I was taught and how I was taught. Grappling with action research was something else. My lecturer wanted me to be his education image!"*

The informant had acquired the traits of a traditional teacher. When encountered by a problem, the traditional education-oriented learner 'researches' from the textbooks, or the internet when instead he or she is supposed to research with the learners focusing on the context of the learners he is teaching.

The other strategy that is followed by the traditional teacher education student is absolution. The student abstains from intervening in the problem and thinks that providential intervention would bring the solution. Informant 14 postulated:

> *"I was once worried when I failed to teach my grade five learners a certain concept and I wanted to research on my practice. After some time I dropped the concern and I know with time all will be fine."*

12. Inadequacy of declarative knowledge for action research

The teacher education learner in a traditional education setup is by and large exposed to the acquisition of declarative knowledge which can also be referred to as descriptive knowledge, propositional knowledge, or "know that" knowledge. This type of knowledge focuses on specific facts [41]. It is content-based and could be associated with pseudo- learning activities such as cramming and memorization. Informant 15 described an agoraphobic situation derived from considering declarative knowledge on its own;

> *"I had to stop action research when the knowledge I had about theories of learning could not augur well with what I was experiencing with my class."*

The implication is that declarative knowledge is not adequate for teacher education which requires the learner to be an effective facilitator of learning. The worthiness of declarative knowledge is realized when it provides insights into the contextual practicing of teaching. There should be a strong bond between declarative knowledge and procedural knowledge. The dearth of knowledge from experiences or practicing begets technical rationality [42].

13. Technical rationality

One who succumbs to technical rationality relies on declarative knowledge which is acquired from external and secondary sources which are among others; teachers, textbooks, or the internet. The technical rationalist learner memorizes theories that he or she can hardly actualize or authenticate their efficacy in contextual situations. Informant 16 proclaimed;

> *"I don't think that action research is for the mediocre learner. There is a lot to be done in trying to put theory into practice. One cannot profess to have concrete truth from action research. I wouldn't want to dice with failure in my research studies."*

Technical rationality is embedded in logical positivism since its adherents have the view that social reality is objective, measurable, explained in rational terms, and reflected upon in professionalization to enrich scientific problem-solving abilities [43]. The approach of technical rationality to problem-solving is linear since it purports that there is a systematic application of tried and tested solutions to some professional problems [44]. Thus technical rationality is employed by established professions in solving problems by considering concrete technical knowledge [45].

Technical rationality forecloses reflection-in-action for the creation of procedural knowledge. It also pertains more to the scientific and objectifiable manner in which knowledge should be obtained while reflection-in-action correlates more to the application of action that practitioners employ within their given professions to attain knowledge [43].

14. Procedural knowledge

Procedural knowledge is concerned with the knowledge of how to perform a specific skill. It is also known as; practical knowledge, imperative knowledge, performative knowledge, or "knowing-how" knowledge [46]. The prime activity is practicing a skill that is focused on problem-solving in particular situations. Practicing and experiencing with reflection enhance the development of effective teaching skills [47]. In the context of the teacher education student, procedural knowledge about the skill of teaching is best developed when the student is oriented in action research which promotes practical and pragmatic rationality.

15. Practical and pragmatic rationality

The teacher education learner as a practitioner should develop both practical and pragmatic rationality. Practical rationality is the substantiation of one's knowledge anchored on one's reflections on own experiences. In other words, practical rationality is the intellectual capacity for resolving a problem through reflection on the actions performed [48].

Practical rationality is closely related to pragmatic rationality which is now a contemporary educational value. This rationality is antithetical to the systematicity that is inherent in traditional education [48]. It makes reference to the results that are produced out of conscious action. Pragmatic rationality requires the practitioner to actively participate in making interventions to solve a problem. Subsequently, there should be reflections on the process adopted to come up with the desired results. Pragmatic rationality is realized by reflecting in action.

16. Reflection-in-action

Schon is credited for integrating the role of science into professional practice and education through reflection-in-action [49]. Reflection-in-action entails active, persistent, and careful consideration of any belief or supposed form of knowledge in light of the grounds that support it and the further consequences to which it leads [1].

The employment of reflection-in-action in professional practice is characterized by the practitioner's actions that show his/her desire to learn, obtain knowledge, and understand the situation that he/she works in [44]. Thus the practitioner reflects on phenomena and considers prior interpretations of knowledge that are understood and then employs this knowledge in the operation of generating new knowledge [50]. The theoretical framework in which reflection-in-action is found is reflective practice.

17. Mitigation of agoraphobia through reflective practice

Reflective practice provides the anchorage for reflecting in- and on-action when being engaged in the process of continuous learning. Thus, the continuous reflection that the practitioner does on his or her own practice promotes lifelong learning. Reflective practice involves paying critical attention to the practical values and theories which inform everyday actions, by examining practice reflectively and reflexively [51]. From the definitions above, the prime rationale for reflective practice is that experience alone does not necessarily lead to professional development but the reflection on experience. Professional development does not come about with experience but is influenced by how one reflects on experience [52].

Reflective practice can be an important tool in practice-based professional learning settings where people learn from their own professional experiences, rather than from formal learning or knowledge transfer [53]. Reflective practice is one of the most important sources of personal professional development and improvement. It is also an important way to bring together theory and practice. Through reflection a practitioner is able to see and label forms of thought and theory within the context of his or her work [54]. A practitioner who reflects throughout his or her practice does not merely review the past actions and events but makes conscious scrutiny of his or her emotions, experiences, actions, and responses to gain insights into his or her existing knowledge base so as to develop professionally [55].

The concept of reflective practice is now widely employed in the field of teacher education and teacher professional development and is the basis for many programs of initial teacher education [56]. The practitioner in education is expected to embrace reflective practice since it entails the process by which the practitioner studies his or her own teaching methods to discover the best practice of learning facilitation. It involves the consideration of the ethical consequences of classroom procedures on students [56, 57]. Reflective practice in education can be described as teacher metacognition [58].

The term reflective practice is complex since it incorporates a wide range of the practitioner's metacognition of activities in teaching-learning situations. Teaching and learning are complex concepts, and there is no universally right approach since their effectiveness is contextual rather than global. Reflecting on different approaches to teaching, and reshaping the understanding of past and current experiences, will lead to improvement in teaching practices in particular contexts [53].

The practitioners can gain insights from Schon's reflection-in-action since they can develop professional knowledge from their experiences in the classroom.

Reflection can be regarded as learning from experience and is paramount to the educator's practice since it evokes awareness of being accountable. Without reflection, educators are not able to look objectively at their actions or take into account the emotions, experiences, or consequences of actions to improve their practice [59]. Through reflective practice, educators get engaged in continuous professional learning. The educators are conscientized on the essence of retrospection in their practices and reflect on how they support learners to achieve optimal learning outcomes.

Reflective practice moves teachers from their knowledge base of distinct skills to a stage in their careers where they are able to modify their skills to suit specific contexts and situations, and eventually invent new strategies [60]. Thus through reflective practice educators are able to develop themselves beyond existing theories in practice and become responsive to the dynamic environments of their day-to-day practices.

18. Conclusion

Agoraphobic dispositions in action research of the teacher education learners are precipitated by the miseducative experiences of the learners. The teacher education practitioners, the lecturers, and the mentors are the perpetrators of the miseducative experiences. They have a proclivity to traditional education, which in research emphasizes the traditional fundamental research at the expense of action research. The educators explicitly vilify action research. The learners though in the laboratory (classroom) are not encouraged to be creators of procedural knowledge. The learners are credited for exhibiting technical rationality which focuses only on the use of declarative knowledge. Instead, the learners should be encouraged to focus on practical and pragmatic rationality, which uses procedural knowledge created by them. The agoraphobic dispositions could easily be warded off when learners are exposed to *mathetics* (learning how to learn) in particular contexts.

Author details

Davison Zireva
Morgenster College of Education, Zimbabwe

*Address all correspondence to: dzireva63@yahoo.co.uk

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Dewey J. How we Think: A Restatement of the Relation of Reflective Thinking to the Educative Process. Boston: Houghton Mifflin; 1933

[2] Brookfield SD. Understanding Facilitating Adult Learning. London: Penguin; 1991

[3] Higgs P, Smith J. Rethinking our World. Cape Town: Juta; 2015

[4] Ferrance E. Action Research. New York: LAB; 2000

[5] Borg WR. Educational Research: An Introduction. New York: David McKay; 2007

[6] Bracha HS. Human brain evolution and the "neuroevolutionary time-depth principle" implications for the reclassification of fear-circuitry-related traits in DSM-V and for studying resilience to warzone-related posttraumatic stress disorder. Progress in Neuro-Psychopharmacology and Biological Psychiatry. 2006;**30**(5):827-853

[7] Fava GA, Rafanelli C, Grandi S, Conti S, Ruini C, Mangelli L, et al. Long-term outcome of panic disorder with agoraphobia treated by exposure. Psychological Medicine. 2001;**31**(5):891-898

[8] Sanchez M, Rosa A, Marin M, Gomez C. Psychological treatment of panic disorder with or without agoraphobia: A meta-analysis. Clinical Psychology Review. 2008;**30**:37-50

[9] Brookhart SM, Nitko AJ. Educational Assessment of Students. New Jersey: Merrill Prentice-Hall; 2019

[10] Boud D, Keogh R, Walker D. Promoting Reflection in Learning. London: Penguin; 2005

[11] University of St. Mark and St. John. Business Dictionary – perception. n.d.. Available from: www.businessdictionary.com/definition/perception.hmtl. [Accessed: 14, April 2022]

[12] Cherry, K. "Perception and the Perceptual Experience". 2014. About.com Psychology in http://psychology.about.com/od/sensationandperception/ss/perceptproc.htm. [Accessed: 14, April 2022]

[13] Scott J, Marshall G. A Dictionary of Sociology. Oxford: Oxford University Press; 2009

[14] Feenberg A. The Philosophy of Praxis: Marx, Lukács, and the Frankfurt School. London: Verso; 2014

[15] Smith MK. What is praxis? In: The Encyclopedia of Informal Education. 2011. Available from: https://infed.org/mobi/what is praxis/ [Accessed: 15 April, 2022]

[16] Breunig M. Turning experiential education and critical pedagogy theory into praxis. The Journal of Experimental Education. 2005;**28**(2):106-122

[17] Freire P. Pedagogy of the Oppressed. New York: Continuum; 2018

[18] Glass RD. On Paulo Freire's philosophy of praxis and the foundations of liberation education. Educational Researcher. 2001;**30**(2):15-25

[19] Song H. Action research as a praxis for transformative teaching practice in ELT classroom. Contact Magazine. 2019. Available from: https://contact.teslontario.org>action-research-as-a-praxis-for-transformative-teaching-practice-in-elt-classroom/ [Accessed: 13 April, 2022]

[20] Burke PJ, Lumb M. Research and evaluation equity and widening participation: Praxis-based frameworks. In: Burke PJ, Hayton A, Stevenson J, editors. Evaluating Equity and Widening Participation in Higher Education. London: Institute of Education Press; 2018

[21] Zuber-Skerritt O. Action learning and action research: Paradigm, praxis and programs. In: Sankara S, Dick B, Passfield R, editors. Effective Change Management through Action Research and Action Learning: Concepts, Perspectives, Processes and Applications. Lismore: Southern Cross University Press; 2001. pp. 1-20

[22] Kemmis S, McTaggart R, editors. The Action Research Planner. 3rd ed. Victoria: Deakin University; 2014

[23] Hoberg SM. Research Methodology: Research Methodology: Education Management Study Guide 2. Pretoria: UNISA; 2001

[24] Hendricks C. Improving Schools through Action Research. Boston: Pearson; 2017

[25] Bencze LJ. Action research support for educators. 2005. http://leo.oise.utoronto.ca/-lbencze/action_research_help.html

[26] De Vos AS, Strydom H, Fouche CB, Delport CLS. Research at Grassroots; for the Social Sciences and Human Service Professions. Pretoria: Schaik; 2011

[27] Mouton J. How to Succeed in your Masters and Doctoral Studies. Pretoria: Van Schaick; 2011

[28] O'Leary Z. The essential guide to doing your research project. South African Public Law. 2010;**24**:297-327

[29] Cresswell JW, Cresswell JD. Research Design: Qualitative, Quantitative and Mixed Methods Approaches. Los Angeles: SAGE; 2018

[30] Johnson B, Christensen L. Educational: Quantitative, Qualitative and Mixed Approaches. Los Angeles: Sage; 2019

[31] Slavin RE. Educational Research: In Age of Accountability. Los Angeles: Sage; 2007

[32] Steyn GM, McDonald MEW, Van der Horst HR, Loubser CD, Niekerk LJ, Kamper GD, et al. Portfolio: Med-Tutorial Letter 101. Pretoria: UNISA; 2004

[33] Raffaello S, Alessandra SM, Alessandra S. [Primary agoraphobia specific symptoms: From natural information to mental representations] (PDF). Italian Journal of Psychopathology. 2011;**17**(3):265-276

[34] Greene DE. Marxism: The philosophy of praxis. Links International Journal of Socialist Renewal. 2017. Available from: https://links.org.au/marxism-philosophy-of-praxis

[35] Honderich T, editor. Oxford Companion to Philosophy. Oxford: Oxford University Press; 2005

[36] Chung M, Gouleta E. Context-based approaches to developing theories of change in basic education. Global Education Review. 2020;**7**(1):1-5

[37] Trimmer W, Hawes P. In: Blessinger P, Carfora J, editors. Inquiry-Based Learning for Science, Technology, Engineering, and Math (STEM) Programs: A Conceptual and Practical Resource for Educators. United Kingdom: Emerald; 2015

[38] Flanagan FM. Minerva—An internet journal of philosophy. 2010. http://www.ul.ie/~philos/vol1/dewey.html. [Accessed: 30, March 2022]

[39] Rud AG, Attwood A. Dewey lab School at the University of Chicago. In: Peters M, editor. Encyclopedia of Educational Philosophy and Theory. Singapore: Springer; 2016

[40] Spring J. The American School from Puritans to No Child Left behind. 7th ed. New York: McGraw Hill; 2008

[41] Burgin MS. Theory of Knowledge : Structures and Processes. New Jersey: Prentice Hall; 2017

[42] Kinsella EA. Technical rationality in Schon's reflective practice: Dichotomous or non-dualistic epistemological position. Nursing Philosophy. 2007;**8**(20):102-113

[43] Kelly T. Epistemic rationality as instrumental rationality: A critique. Philosophy and Phenomenological Research. 2003;**66**(3):612-640

[44] Schön DA. The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books; 2017

[45] Kelly T. The rationality of belief and some other propositional attitudes. Philosophical Studies. 2002;**110**:163-196

[46] Stanley J, Williamson T. Knowing how. The Journal of Philosophy. 2001;**98**(8):411-444

[47] Patel R. What is Procedural Knowledge and How to Use It? 2021. Available from: www.thecloudtutorial.com/procedural-knowledge. [Accessed: 6, May 2022]

[48] McHugh C, Way J. What is good reasoning? Philosophy and Phenomenological Research. 2018;**96**: 153-174

[49] Loughran JJ. Effective reflective practice: In search of meaning in learning about teaching (PDF). Journal of Teacher Education. 2002;**53**(1):33-43

[50] Bolton G. Reflective Practice: Writing and Professional Development. 3rd ed. Los Angeles: Sage Publications; 2018

[51] Shapiro H. John Dewey's reception in 'Schönian' reflective practice. Philosophy of Education Archive. 2010:311-319

[52] Huxley A. Experience and reflection. 2013. http://www.goodreads.com…/92753. [Accessed: 22, March 2022]

[53] Johns C, Burnie S. Becoming a Reflective Practitioner. Chichester, UK; Ames, Iowa: Wiley-Blackwell; 2022

[54] Leitch R, Day C. Action research and reflective practice: towards a holistic view. Educational Action Research. 2000;**8**(1):179-193

[55] Jones JL, Jones KA. Teaching reflective practice: Implementation in the teacher-education setting. The Teacher Educator. 2013;**48**(1):73-85

[56] Davies S. Embracing reflective practice. Education for Primary Care. 2012;**23**(1):9-12

[57] Johns C, editor. Guided Reflection: A Narrative Approach to Advancing Professional Practice. 2nd ed. Chichester, UK; Ames, Iowa: Blackwell; 2010

[58] Hartman HJ. Teaching metacognitively. In: Hartman I, Hope J, editors. Metacognition in Learning and Instruction: Theory, Research, and Practice. Dordrecht; Boston: Kluwer Academic Publishers; 2001. pp. 149-172

[59] Paterson C, Chapman J. Enhancing skills of critical reflection to evidence learning in professional practice

(PDF). Physical Therapy in Sport. 2013;**14**(3):133-138

[60] Larrivee B. Transforming teaching practice: Becoming the critically reflective teacher (PDF). Reflective Practice: International and Multidisciplinary Perspectives. 2000;**1**(3):293-307

Chapter 14

Educational Paradigm with Ubuntu Mindset: Implications for Sustainable Development Goals in Education

George Frempong and Raavee Kadam

Abstract

The COVID-19 pandemic has exposed the fragility of our development systems and drawn attention to the implementation of the Sustainable Development Goals (SDGs). In this chapter, we acknowledge the critical role of education in supporting sustainable development. We argue for inclusive education for the Sustainable Development approach and offer the African philosophy of Ubuntu (I am because we are) as a mindset that should drive the transformative change required. We contend that this mindset serving as a theoretical and methodological model offers unique potential possibilities of bringing learners close to their social realities and helping them learn together better, the Africentric way. We expect this model to help better understand the intervention and transformative changes required for sustainable education that works for all learners.

Keywords: Ubuntu, Africentric, education, sustainable development, transdisciplinarity

1. Introduction

1.1 Impact of Covid-19 on educational systems

The March of 2020 was the start of the most significant pandemic that the world has ever seen and unleashed a crisis of gigantic proportions. We never imagined that the so advanced human race would be defeated by a virus, impacting different aspects of human development such as education, health, income, well-being, etc. As news of the Covid-19 virus traveled from the Wuhan province of China to the rest of the world, national borders were closed overnight, flights suspended, and lockdowns imposed globally in the first attempt to contain the spread of the virus. The Covid-19 virus brought the entire world to a standstill. With many lost lives and livelihoods, we continue to fight the virus tooth and nail. The virus had a devastating impact on people, businesses, and economic systems, with the entire world, turned upside down. To ensure continuity in how we worked, learned, and lived, the world embraced

IntechOpen

digital transformation, overhauling systems over the next few months. Lockdown measure shifted many activities online. However, this adoption of technology brought the digital divide globally to the front. The World Economic Forum indicated that more than 4 billion people, mostly in developing countries, still do not have access to the Internet [1]. That is almost half of the world's population. And, as expected, the impact was severe for people without Internet access. Even with technological advances, Internet access and availability are issues in several countries globally. Many rural and low-income communities worldwide, including those in large urban areas, lack reliable, affordable access. So, when schools and other educational institutions adopted online schooling to ensure learning continued, that was a start to one of the most prolific challenges and changes in the history of educational systems.

The pandemic brought about the most extensive disruption of education systems ever. The United Nations estimates that approximately 1.6 billion students in more than 190 countries were out of classrooms due to the lockdowns imposed by governments across many countries. Schools and other educational institutions closed overnight to contain the spread of the virus, impacting 94 percent of the world's student population and up to 99 percent in low and lower-middle-income countries [2]. However, education systems worldwide were swift to react and digitally transform themselves. The crisis stimulated innovation within the education sector, with solutions previously thought difficult or impossible to implement were seamlessly adopted within the educational landscape. Educational stakeholders quickly developed distance learning solutions, with online learning becoming the new way of acquiring education from home. Though this shift to online learning mitigated the pandemic's adverse effects on education, the entire experience also caused many students' trauma and loss of knowledge, particularly in disadvantaged and vulnerable communities. For these students, the crisis exacerbated the already existing educational inequities globally. Without access to or availability of the Internet, electronic devices for learning or a home environment conducive to learning, students lose learning times. A lot of schools also lacked the infrastructure to help such students. According to the United Nations, the economic impact of the pandemic coupled with school closures could turn the learning crisis into a generational catastrophe impacting the future of many students. Nevertheless, the pandemic has taught us that while technology is here to stay, creating sustainable and resilient systems is required to overcome the challenges and avoid this crisis turning into a generational catastrophe.

1.2 Impact of Covid—19 on disadvantaged students

According to UNESCO, millions of children do not go to school each day due to emergencies and ongoing humanitarian crises. Schools protect children from the physical dangers around them, provide food, water, health care and hygiene supplies, and ensure their physical and emotional well-being [3]. Education attainment is a significant factor in reducing poverty and increasing a student's ability to lead a healthy life and participate in society. Despite the enormous benefits of education to children and communities, the United Nations points out that education is often the first service suspended and the last to be restored during a crisis. And this scenario is what we experienced during the Covid-19 pandemic. Though most students experienced the negative impact of the pandemic on their learning, the vulnerable ones before the pandemic were disproportionately affected widening the pre-existing opportunity and achievement gaps.

Schools are a source of daily meals and provide a safe and comforting environment for many students globally, alleviating the difficulties at home. While school closures led to the quick adoption of alternate learning modes, the prominent rise of online learning as a delivery model impacted students from different walks of life. The hardest hit were those from vulnerable and marginalized communities. Students from privileged backgrounds could find a way to work around the new learning systems with access to all or most of the resources required. However, many students from disadvantaged backgrounds lost access to education and other facilities when schools shut down. Students lost access to their meals, health facilities and other benefits apart from learning that schools provide. The Covid-19 pandemic exposed many shortcomings and inequities, such as; limited access to the internet and devices for learning, supportive home learning environment, putting many students at a further disadvantage. Furthermore, other students faced mental and emotional health issues due to social isolation from their friends and peers.

In the United States, the McKinsey & Company [4], analysis of schools showed that the impact of the pandemic on K–12 student learning was significant. Their research indicates that students, on average, were five months behind in mathematics and four months behind in reading by the end of the 2020–2021 school year. In math, students in most Black schools ended the year with six months of unfinished learning, and for students in low-income schools, the deficit was seven months. High schoolers have become more likely to drop out of school, and high school seniors, especially those from low-income families, are less likely to go on to postsecondary education. And the crisis had an impact on not just academics but also on the broader health and well-being of students. Students of color and low-income students suffered the most. Long-standing inequities such as disproportionate levels of punishment, suspensions, assignment to special education programs, inherent racism, stereotyping and social labeling have further compounded other pandemic-related factors such as social isolation and family economic losses. These challenges reiterate the urgent need to build educational systems that are resilient and sustainable and where every child can succeed, irrespective of their background.

1.3 Building sustainable education systems with an "Ubuntu" mindset

Extant research since 2020 in the context of K-12 education examined the impact of Covid-19 on learning loss for students across different parts of the world. Several studies have brought to light the inequities and injustices faced by marginalized groups. Research has also revealed that systems and structures in educational institutions were under immense stress during this crisis. This time of global upheaval and uncertainty allows us to question the design of educational systems that perpetuate and aggravate historical barriers to equitable education. With several kinds of inequities within the educational systems brought to the front during the pandemic, we believe in the need to broaden the notions of academic resilience and bring about a remarkable transformation in the education landscape.

An important lesson from the pandemic is the realization that we as individuals do not exist in isolation, and we are all interconnected. The lesson that we argue can serve as a systematic transformation required to overhaul education systems and redesign them based on strong partnerships and collaborations among its stakeholders. We contend that such sustainable educational systems are required so that all students from every walk of life succeed at school and in life. We argue that creating such sustainable systems would require a mindset that we as a human race are connected, and in order to progress, we must do so together. We characterized this concept as "Ubuntu" mindset that is critical to understanding our interconnection with each other required to build strong partnerships to transform learning environments. Educational leadership and management can benefit from developing an Ubuntu mindset to bring about a transformation where every stakeholder works collaboratively to ensure that every student succeeds. This idea fulfills one of the fundamental principles of 'transdisciplinary education,' which scholars highly recommend as one way to accomplish sustainability goals.

2. Education for sustainable development

The United Nations adopted the Sustainable Development Goals (SDGs), also known as the Global Goals, as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity [5]. The movement serves as the blueprint to achieve a better and more sustainable future for all and address the global challenges we face: poverty, climate change, and educational inequity. The 17 SDGs aim to ensure that development must balance social, economic and environmental sustainability, given their interconnectedness. SDG 4 – Quality Education focuses on '*ensuring inclusive and quality education for all and promoting lifelong learning*'[6]. According to the United Nations, education enables socioeconomic mobility upward and is a key to escaping poverty. Education also helps reduce gender or socioeconomic inequalities and is crucial to fostering tolerance and creating more peaceful societies. Education for Sustainable Development (ESD) was born from the need for education to address the growing sustainability challenges and posit education as the most critical factor for ensuring holistic development [7]. ESD, an integral part of SDG 4, recognizes education as a means of societal transformation and is posited as the critical factor in accelerating progress across all the other SDGs.

'ESD for 2030'is the global framework for the implementation of Education for Sustainable Development from 2020 to 2030. The framework emphasizes education's contribution to the achievement of the SDGs. It aims to review the "*purposes and values that underpin education and reorient all levels of education and learning to contribute to sustainable development*" [8]. The framework takes a 'whole institution approach emphasizing that "*to encourage learners to become change agents who have the knowledge, means, willingness and courage to take transformative action for sustainable development, learning institutions need, themselves, to be transformed*" [9]. This whole-institution approach to ESD calls for learning environments where learners learn what they live and live what they learn. An expert review of literature on processes of learning for Education for Sustainable Development by Prof. Tilbury [10] identified certain key processes that underpin ESD frameworks and practices, including processes that engage the 'whole system'. ESD seeks to challenge existing educational systems, structures and/or practices and adopt a systematic approach to change. The process supports the attainment of – as well as the education of – sustainable development, which brings to life not only in the curriculum but also in other educational systems such as teaching practices, pedagogy, data systems, and processes [10]. And to successfully foster these transformative and sustainable changes will ultimately depend on effective leadership and management within the educational system. The pandemic highlighted the interdependence amongst students, teachers, families, school leadership, government and the community as a whole. Educational leadership and management (EDLM) played a critical role in the pandemic. They will now again play a vital role in reorienting the whole institution towards an innovative, democratic environment that is responsive to social and community needs. EDLM will be a significant factor in bringing about the transformation by adopting the Ubuntu philosophy to build back a shaken system.

3. What is Ubuntu?

Ubuntu is a philosophy that inspires the beliefs, values, norms and practices of different African societies [11] and is one of the "inspiring dimensions of life in Africa" [12]. Ramose [13] states that "Ubuntu is simultaneously the foundation and the edifice of African philosophy" (p. 49). The notion of Ubuntu has its roots in the sub-Saharan African culture and focuses on the interconnectedness and relationality amongst the human race [14]. The concept is indigenous to the African continent and one of the foundations of the different cultures across Africa. Ubuntu is one of the foundational tenets of African communal cultural life [15], and its meaning is often explained with the phrase "umuntu ngumuntu ngabantu", which means "a person is a person through other people" [16]. Similarly, Mbigi [17] also stated that Ubuntu literally means "I am because you are – I can only be a person through others" (p. 6). According to Lutz [18], Ubuntu signifies the notion of one being truly human only as a part of the community rather than in isolation. This means that "people are not individuals, living in a state of independence, but part of a community, living in relationships and interdependence" ([19] p. 36). The basic concept is that our social and economic development evolves through relationships with the larger group. Malunga [20] describes Ubuntu as a cultural worldview that captures the essence of being human and humanity. According to Woermann and Engelbrecht [21], Ubuntu "addresses our interconnectedness, our common humanity and the responsibility to each other that flows from our deeply felt connection."

Describing the core values of Ubuntu, Mangaliso et al. [11] stated vales that include harmony and solidarity, reciprocity, respect for elders, collaboration, mutual concern, compassion, consultation, and consensus". Similarly, Horwitz [22] points out the significance of collective solidarity and interrelationships, stating that "values such as adherence to social obligations, collective trust, deference to rank and seniority, sanctity of reciprocity and good social and personal relations are relevant" (p. 2943). Ubuntu "addresses our interconnectedness, our common humanity and the responsibility to each other that flows from our deeply felt connection" ([12], p. 1). Oviawe [23] describes Ubuntu as "a philosophy of being that locates identity and meaning-making within a collective approach as opposed to an individualistic one" (p. 3).

Relationality and interconnectedness are central to the concept of Ubuntu. According to Nussbaum ([12], p. 1), "one of the ontological assumptions of Ubuntu is the communal or relational nature of being" The entire idea of Ubuntu is opposite to that of individualism, which characterizes many Western cultures. According to Hofstede [24], individualism can be defined as "a preference for a loosely-knit social framework in which individuals are expected to take care of only themselves and their immediate families" (p. 1). Contrarily, the central belief of Ubuntu is the fact that we are humans only because of the connection that we share with other human beings. Explaining the same, Mbigi ([17], p. 69) stated that, "I cannot separate my humanity from the humanity of those around me". Pérezts et al. [14] reiterated the fact that "such a relational approach to morality and ethics grounded in harmony, and brings a different ethos to Western approaches, which prioritize utility, autonomy and capability" (p. 736). Ubuntu stresses "an I/we relationship as opposed to the Western I/you relationship with its emphasis on the individual" ([25], p. 21). An individual is bound by others and a sense of community and does not exist independently. Luthans et al. [26] stated, "under Ubuntu there is an individual existence of the self and the simultaneous existence for others" (p. 515).

In his book titled "Ubuntu: Shaping the Current Workplace with (African) Wisdom", the author Vuyisile Msila [27] demystified the concept of Ubuntu and explained its meaning for everyday corporate life and organizations. He talks about the "five P's in Ubuntu philosophy:

- People-centeredness: Ubuntu emphasizes the role of the people within the organization. Without an interest in people, Ubuntu cannot be realized.

- Permeable walls: communication in the organization is not restricted, and the walls are not opaque. All the members can communicate with one another without fear.

- Partisanship: one of the most positive factors of the Ubuntu philosophy is loyalty. People communicate freely, making them feel closer to the organization.

- Progeny: Ubuntu leadership promotes collective decision-making. However, effective leadership is respected, and the leader is respected.

- Production: when the above characterizes the organization, production is guaranteed. The organization prospers when its members enjoy respect, loyalty and good leadership" (p. 15).

According to Mangaliso et al. [11] "a great deal of research on Ubuntu has offered positive vantage points for revaluing African philosophies and translating them into management practices, most notably in the field of human relations" (p. 4). Msila [28] stated that Ubuntu is a very crucial concept for many institutions in the society, including the understanding of leadership and management in varied organizations. Though Ubuntu might be an African philosophy, its basic ideas and ethos have a global appeal for leading and managing people and organizations effectively. According to Lutz [18], the first step in developing a leadership and management style based on upon the philosophy of Ubuntu, is to recognize the organization or institution as a community, where every individual is critical to the success of the community. According to Karsten and Illa [29] "Ubuntu provides a strong philosophical base for the community concept of management" (p. 6). Similarly, McFarlin et al. [30] state that the African management philosophy that "views the corporation as a community and can be summed up in one word – Ubuntu" (p. 71). The idea here is not about maximizing the value for only the owners or shareholders of the organization, but for the entire community and its members who are important stakeholders of the organization. The central idea of Ubuntu is interconnection between individuals. Ubuntu espouses the idea of the collective achievement of the goals of the organization. It does not relegate an individual's own goal as secondary, but confirms to the idea of achievement of individual goals and the achievement of group goals are equally critical and go hand-in-hand. Ubuntu is about pursuing your own good through the common good [18].

3.1 Ubuntu for educational leadership and management

To ensure that we overcome the barriers faced and become more resilient to such drastic effects on schooling systems, a systematic transformation is required. Scholars have indicated that traditional top-down hierarchical structures in school are rigid and not agile to change and adaption. Such hierarchical styles have resulted in dysfunctional schools and researchers call for the need to adopt newer and contemporary leadership and management styles in educational institutions. The pandemic brought to light the interdependence amongst educational stakeholders including children to overcome the difficulties faced during the pandemic. Collaboration, co-operation and partnerships were some of the basic qualities that helped schools overcome the challenges and ensured that there were no interruptions to learning. As we navigate an uncertain future, leading with such a people-centered and collaborative mindset is critical to developing resilience and sustainable education systems. And this is where an Ubuntu mindset comes into the picture. Msila [31] contends Ubuntu as a classic model for educational leadership and management. The communal nature of Ubuntu can help the success of any institution including educational leadership and management. He states that leading with an Ubuntu mindset would enable school leaders to lead school effectively with the resources at their disposal.

Extant research has established the benefits of leading with an Ubuntu mindset for educational leadership and management. The basic fundamental principles of Ubuntu, namely interconnectedness and relationality are important to cater to the diverse stakeholders in educational institutions. Schools have students with different nationalities, cultures, social class, language, values and belief systems. Ubuntu brings together people from different walks of life, to work and live harmoniously. Mbigi and Maree [32] explain that Ubuntu enables one to move towards a common goal based on the belief of collective shared values and solidarity with the group. Similarly, Ubuntu style of leading an organization involves "a departure from hierarchically structured management relations and rather introduces a cooperative and supportive form of leadership in which collective solidarity of the group is employed and respected" ([31], p. 149). Here the leader seeks co-operation and interdependence amongst members of the organization to achieve its goals. Collective solidarity amongst team members can enable the effective achievement of goals. Rather than a top-down management approach, Ubuntu is about shared decision-making, participation, collaboration, cooperation and a shared vision. It is about fostering a culture of collectivism among the organization and progressing the entire system with a 'whole institution' approach. Mboyo [33] reiterated how leadership and management of educational systems can benefit from the unique Ubuntu operational patterns such as understanding others' needs, negotiating and prioritizing needs, assessing available resources, attending to others' needs, and raised expectations and commitment to organizational goals.

3.2 Ubuntu for teaching and learning

Ubuntu as a philosophy not only helps leading and managing educational institutions, but also can be adopted as a teaching philosophy by teachers to reconstruct their behavior and effectiveness in schools [34]. Today's culturally diverse societies are reflected in classrooms, where we have students from different walks of life. Ensuring the learning of diverse students requires teachers to adopt strategies that ensure inclusive education processes that help every learner succeed. Ubuntu as a philosophy that can assist teachers to manage classrooms effectively, as it encourages working together amongst people in various settings [35]. Broodryk [36] stated that underlying values of Ubuntu include that of humanness, trust, empathy, respect, tolerance and compassion. Embodying such values would help teachers connect better with their diverse students and this would make a significant difference in the school and student outcomes [37]. With students from marginalized and vulnerable communities facing racism within schools, educators with an Ubuntu mindset would help us address the systematic barriers within the school system. Given the benefits of adopting Ubuntu, Mutanga [38] called for teacher education premised on the indigenous Unhu/Ubuntu philosophy. Pather [39] contended that Ubuntu as a concept, encourages inclusion and cohesion in education, where there is a continued focus on a segregated approach to supporting children. According to Elder et al. [40], Ubuntu can help us with defining and understanding newer interpretations of inclusive education, where every child feels included and an important part of the classroom. Beets [41] recommended "infusing the principles of Ubuntu in the way teachers act, opens new possibilities for deepening the morality of their teaching practice - of how they, for example, use assessment to enhance both teaching and learning in the interests of each learner and ultimately society" (p. 70). Furthermore, Brock-Utne [42] calls for the need of an Ubuntu paradigm in curriculum work, language of instruction and assessment to redesign school systems based on the basic principle of humanity. Similarly, Nxumalo and Mncube [43] recommend the inclusion of Ubuntu philosophy in the school curriculum using indigenous games for teaching a decolonized curriculum content and instilling moral principles and cultural beliefs such as the value of communal identity.

4. Transdisciplinary education with an Ubuntu mindset

In order to prepare students to cope with the challenges of an uncertain, volatile, ever-changing and a complex world, an approach to teaching needs to meet the ideals of ESD. Only academic or discipline knowledge is inadequate to prepare students to tackle sustainability challenges. Thus, ESD promotes an inter- and a transdisciplinary, learner-centered, participatory, and locally relevant approach to learning and teaching [44]. Sustainability problems are often acknowledged as complex or "wicked problems" that require a multifaceted approach, and this is where transdisciplinary education plays a pivotal role. Transdisciplinarity is characterized by its focus on "wicked problems" that need creative solutions, its reliance on stakeholder involvement, and engaged, socially responsible education [45]. According to UNESCO, "transdisciplinary approach is an approach to curriculum integration which dissolves the boundaries between the conventional disciplines and organizes teaching and learning around the construction of meaning in the context of real-world problems" [46]. This approach focuses on producing knowledge with the help of non-academic stakeholders who bring in practice-based, local and indigenous knowledges [47]. Mutual learning, collaboration, decision-making and problem solving amongst educational institutions, businesses, government and the society characterize transdisciplinarity in education. A transdisciplinary approach to education can "facilitate transformative learning through a focus on real-world challenges, complex systems thinking, the integration of diverse knowledges and reflexivity" ([48], p. 1). According to Kubisch et al. [44], "transdisciplinarity is characterized by three aspects:

1. The starting points are socially relevant issues, which are jointly identified and which are researched by means of integrative scientific methods, with the aim of developing interdisciplinary solutions or strategies for transformation;

2. during the whole research process there is an exchange between scientific and non-scientific partners, the latter, e.g., politicians, require the generated knowledge for decision-making;

3. integration of non-scientific partners, like citizens, to consider experiences and context-based knowledge" (p. 3).

We focus on one critical aspect of transdisciplinarity, that is, the integration of out-of-school partners or reliance on stakeholder involvement in achieving holistic education. This approach is emphasized in the concept of partnerships [49] and the Ubuntu mindset enables development of successful partnerships [50, 51].

Ubuntu can provide a theoretical foundation for adopting a transdisciplinary approach to education given the fact that community and partnerships are central to the Ubuntu mindset. Achieving the SDGs requires the co-production of knowledge between academic and non-academic actors [52]. Transdisciplinarity considers society as an equal partner and recommends the inclusion of practice-based, local and indigenous knowledges, and to "build capacity and consensus by mutual learning processes" ([47], p. 2). Developing an Ubuntu mindset can help educational institutions to develop strong partnerships with the community that can bring in diverse stakeholders and diverse knowledges within the ambit of learning. Building such partnerships with the community gives students an opportunity to actively conduct research on real-world problems and develop sustainable solutions with out-of-school partners [53]. It enables students to integrate knowledge from diverse domains, recognize real-world complexity and engage affected stakeholders in processes of mutual learning [54]. The inclusion of community partners in setting varied challenges for students provides an important source of practical and contextual knowledge, and helps them understand what they have learnt from a real-world perspective. In partnerships, dissimilarities in knowledge, know-hows, competencies and experiences are not considered as a deterrent but as a foundation of productive partnerships, whereby both students and out-of-school partners stand to gain [49]. Such collaborations offer students access to new and different types of knowledge, such as experiential knowledge and different disciplinary methods [55]. Furthermore, according to Rieckmann [56], partnerships enable students to learn "on the basis of a real societal challenge in local contexts" (p. 57). From an ESD perspective, collaboration with various stakeholders, both in and out-of-school, is desirable as it enables students to engage in competency and societal-oriented learning processes around a real-world sustainability problem. Developing an Ubuntu mindset puts collaboration at the heart of all activities within the school, which helps students learn from diverse stakeholders, value multiple perspectives, analyze their own viewpoints, and make informed sustainable decisions. Ubuntu emphasizes interdependence and relationality, and echoes the ideals of transdisciplinarity.

5. Concluding remarks

> *"We think of ourselves far too frequently as just individuals, separated from one another, whereas you are connected and what you do affects the whole world. When you do well, it spreads out; it is for the whole of humanity".*
>
> *- Archbishop Emeritus Desmond Tutu.*

These words from the late Archbishop Tutu, the embodiment of Ubuntu, captures the essence of the need to re-imagine our individual selves connected to human development that support our collective survival leaving no one behind. This is an Ubuntu mindset that we have argued is needed to drive the transdisciplinary transformative processes required to achieve the Sustainable Development Goals and make the world a better place for us all.

Msengana [57] reiterated that adopting an Ubunutu mindset can help in building social relationships in a socially and racially divided organization. The author further stated that cultivating an Ubuntu mindset would help foster the spirit of harmony and reconciliation within the organization and society as a whole. Inequities, discrimination or biases, on the basis of race, gender, socioeconomic status, etc., existing in societies are replicated in schools as well Covid-19 has shaken up the entire education system globally and our traditionally entrenched ways of learning & schooling. Survival and resilience became the mantra of educational institutions and pushed all stakeholders to test their limits to ensure learning continued. While the pandemic opened up new possibilities, it also revealed several challenges and systematic barriers. To bring about a transformative change where every student can succeed, requires a mindset change. Desired organizational goals cannot be achieved in isolation but only through the collective efforts of all members of the organization. In a transformational change, people are the most important part of the system and hence, are critical partners in the process and the desired state. Achieving the desire state of change requires multiple partners who come together for a greater good. Such a transformation requires everyone to understand our interconnection and interdependence on each other in order to complete the bigger picture. An Ubuntu mindset is one such concept that would help bring these multiple stakeholders together and create sustainable and future-proof school systems based on a transdisciplinary approach to learning and teaching. Responses to Covid-19 have been an emergency fix to ensure there were no interruptions in schooling. So, as we move towards a new post-pandemic era, this necessitates recommitting and reimagining our humanity to inform the fundamental transformation required in our schooling systems, right from academic achievement to building inclusive education systems that leave no child behind.

Author details

George Frempong* and Raavee Kadam*
Delmore "Buddy" Daye Learning Institute, Halifax, Nova Scotia, Canada

*Address all correspondence to: raavee.kadam@dbdli.ca
and george.frempong@dbdli.ca

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] World Economic Forum. Coronavirus has exposed the digital divide like never before. [Internet]. 2020. Available from: https://www.weforum.org/agenda/2020/04/coronavirus-covid-19-pandemic-digital-divide-internet-data-broadband-mobbile/ [Accessed: March 15, 2022]

[2] United Nations. Policy Brief: Education during COVID-19 and beyond. [Internet]. 2020. Available from: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/08/sg_policy_brief_covid-19_and_education_august_2020.pdf [Accessed: March 15, 2022]

[3] UNESCO. Education transforms lives. [Internet]. 2022. Available from: https://www.unesco.org/en/education

[4] McKinsey & Company. COVID-19 and education: The lingering effects of unfinished learning. [Internet]. 2021. Available from: https://www.mckinsey.com/industries/education/our-insights/covid-19-and-education-the-lingering-effects-of-unfinished-learning [Accessed: March 17, 2022]

[5] United Nations. Take Action for the Sustainable Development Goals. [Internet]. 2022. Available from: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

[6] United Nations. 4 Quality Education. [Internet]. 2022. Available from: https://www.un.org/sustainabledevelopment/education/

[7] UNESCO. Education for Sustainable Development. [Internet]. 2022. Available from: https://en.unesco.org/themes/education-sustainable-development

[8] UNESCO. Education for sustainable development for 2030. [Internet]. 2022. Available from: https://en.unesco.org/themes/education-sustainable-development/esd-for-2030

[9] UNESCO. ESD for 2030 toolbox: Priority action areas. [Internet]. 2022. Available from: https://en.unesco.org/themes/education-sustainable-development/toolbox/priorities

[10] Daniella Tilbury. Education for Sustainable Development: An Expert Review of Processes and Learning. [Internet]. 2011. Available from: https://sdgs.un.org/sites/default/files/publications/927unesco10.pdf [Accessed: March 22, 2022]

[11] Mangaliso MP, Mangaliso NA, Ndanga L, Jean-Denis H. Contextualizing organizational change management in Africa: Incorporating the core values of Ubuntu. Journal of African Business. 2021. DOI: 10.1080/15228916.2021.1984817

[12] Ubuntu NB. Reflections of a South African on our common humanity. Reflections: The Sol Journal. 2003;**4**:21-26

[13] Ramose MB. African Philosophy Through Ubuntu. Harare: Mond Books; 1999

[14] Pérezts M, Russon JA, Painter M. This time from Africa: Developing a relational approach to values-driven leadership. Journal of Business Ethics. 2020;**161**:731-748. DOI: 10.1007/s10551-019-04343-0

[15] Tambulasi R, Kayuni H. Can African Feet Divorce Western Shoes? The Case of 'Ubuntu' and Democratic Good

Governance in Malawi. Nordic Journal of African Studies. 2005;**14**(2):147-161

[16] Iwowo V. Leadership in Africa: Rethinking development. Personnel Review. 2015;**44**(3):408-429. DOI: 10.1108/PR-07-2013-0128

[17] Mbigi L. In Search of the African Business Renaissance. Randburg: Knowledge Resources Ltd.; 2000

[18] Lutz D. African Ubuntu philosophy and global management. Journal of Business Ethics. 2009;**84**:313. DOI: 10.1007/s10551-009-0204-z

[19] Turaki Y. Foundations of African Traditional Religion and Worldview. Nairobi: WordAlive Publishers; 2006

[20] Malunga C. Learning leadership development from African cultures: A personal perspective. Praxis Note. 2006;**25**:1-14

[21] Woermann M, Engelbrecht S. The Ubuntu challenge to business: From stakeholders to relationholders. Journal of Business Ethics. 2019;**157**(2):27-44. DOI: 10.1007/s10551-017-3680-6

[22] Horwitz FM. Evolving human resource management in Southern African multinational firms: Towards an Afro-Asian nexus. The International Journal of Human Resource Management. 2012;**23**(14):2938-2958. DOI: 10.1080/09585192.2012.671512

[23] Oviawe J. How to rediscover the ubuntu paradigm in education. International Review of Education. 2016;**62**:1-10. DOI: 10.1007/s11159-016-9545-x

[24] Hofstede G. National Cultures Revisited. Cross-Cultural Research. 1983;**18**(4):285-305. DOI: 10.1177/106939718301800403

[25] Chilisa B. Indigenous Research Methodologies. Los Angeles: Sage; 2012

[26] Luthans F, Van Wyk R, Walumbwa FO. Recognition and development of hope for South African organizational leaders. Leadership & Organization Development Journal. 2004;**25**(6):512-527. DOI: 10.1108/01437730410556752

[27] Msila V. Ubuntu: Shaping the Current Workplace with (African) Wisdom. Randburg: Knowres Publishing; 2015

[28] Msila V. Ubuntu and school leadership. Journal of Education. 2008;**44**(1):67-84

[29] Karsten L, Illa H. Ubuntu as a key African management concept: Contextual background and practical insights for knowledge application. Journal of Managerial Psychology. 2005;**20**(7):607-620. DOI: 10.1108/02683940510623416

[30] McFarlin DB, Coster EA. South African management development in the twenty-first century: Moving towards an Africanized model. Journal of Management Development. 1999;**18**(1):63-78. DOI: 10.1108/02621719910250474

[31] Msila V. Challenges to the introduction of an alternative leadership style: A school principal's journey in the introduction of an 'Ubuntu Leadership Model'. Mediterranean Journal of Social Sciences. 2014;**5**(20):1738-1747

[32] Mbigi L, Maree J. Ubuntu: The Spirit of African Transformation Management. Randburg: Knowres Publishing; 2005

[33] Mboyo JP. Reimagining Ubuntu in schools: A perspective from two primary school leaders in the Democratic Republic of Congo. Educational Management Administration

and Leadership. 2017;**47**(2):1-18. DOI: 10.1177/1741143217728085

[34] Omodan TC, Tsotetsi CT. Framing Ubuntu philosophy to reconstruct principals' behavior and teachers' effectiveness in secondary schools. Interdisciplinary Journal of Education Research. 2019;**1**(1):25-45. DOI: 10.10520/EJC-19ade7e3de

[35] Maphalala MC. Embracing Ubuntu in managing effective classrooms. Gender and Behavior. 2017;**15**(4):10237-10250

[36] Broodryk J. Ubuntu: Life Coping Skills from Africa. Randburg: Knowres Publishing; 2006

[37] Bush T. Educational leadership and management: Theory, policy, and practice. South African Journal of Education. 2007;**27**(3):391-406

[38] Mutanga O. Perceptions and experiences of teachers in Zimbabwe on inclusive education and teacher training: The value of Unhu/Ubuntu philosophy. International Journal of Inclusive Education. 2022. DOI: 10.1080/13603116.2022.2048102

[39] Pather S. Confronting inclusive education in Africa since Salamanca. International Journal of Inclusive Education. 2019;**23**(7-8):782-795. DOI: 10.1080/13603116.2019.1623329

[40] Elder BC, Damian ML, Oswago BO. From attitudes to practice: Utilizing inclusive teaching strategies in Kenyan primary schools. International Journal of Inclusive Education. 2015

[41] Beets P. Strengthening morality and ethics in educational assessment through Ubuntu in South Africa. Educational Philosophy and Theory. 2021;**44**(s2):68-83. DOI: 10.1080/13603116.2019.1623329

[42] Brock-Utne B. The ubuntu paradigm in curriculum work, language of instruction and assessment. International Review of Education. 2016;**62**:29-44. DOI: 10.1007/s11159-016-9540-2

[43] Nxumalo SA, Mncube DW. Using indigenous games and knowledge to decolonise the school curriculum: Ubuntu perspectives. Perspectives in Education. 2019;**36**(2):103-118. DOI: 10.18820/2519593X/pie.v36i2.9

[44] Kubisch S, Parth S, Deisenrieder V, Oberauer K, Stötter J, Keller L. From transdisciplinary research to transdisciplinary education—The role of schools in contributing to community well-being and sustainable development. Sustainability. 2021;**13**:306-319. DOI: 10.3390/su13010306

[45] Bernstein JH. Transdisciplinarity: A review of its origins, development, and current issues. Journal of Research Practice. 2015;**11**(1):Article R1

[46] International Bureau of Education. Transdisciplinary approach. [Internet]. 2022. Available from: http://www.ibe.unesco.org/en/glossary-curriculum-terminology/t/transdisciplinary-approach

[47] Scholz RW, Steiner G. Transdisciplinarity at the crossroads. Sustainability Science. 2015;**10**:521-526. DOI: 10.1007/s11625-015-0338-0

[48] Baumber A. Transforming sustainability education through transdisciplinary practice. Environment, Development and Sustainability. 2021;**24**:7622-7639. DOI: 10.1007/s10668-021-01731-3

[49] Baumber A, Kligyte G, van der Bijl-Brouwer M, Pratt S. Learning together: A transdisciplinary approach to student–staff partnerships in higher

education. Higher Education Research & Development. 2020;**39**(3):395-410. DOI: 10.1080/07294360.2019.1684454

[50] Takyi-Amoako EJ. Towards an Alternative Approach to Education Partnerships in Africa: Ubuntu, the Confluence and the Post-2015 Agenda. In: Takyi-Amoako E, Assié-Lumumba N, editors. Re-Visioning Education in Africa. Cham: Springer International Publishing; 2018

[51] Mnguni H, Sabela T, Masuku MM, Nishimwe-Niyimbanira R. Through the lens of Ubuntu: The value of partnerships and corporate social responsibility towards community development in the city of uMhlathuze, South Africa. Journal of Social Science. 2021;**69**(1-3). DOI:10.31901/24566756.2021/69.1-3.2280

[52] Keitsch MM, Vermeulen WJV. Transdisciplinarity for Sustainability: Aligning Diverse Practices. London: Routledge; 2020

[53] EdCan Network. A whole school approach to teaching the Un sustainable development goals [Internet]. 2021. Available from: https://www.edcan.ca/articles/a-whole-school-approach-to-teaching-the-un-sustainable-development-goals/

[54] Klein T. Learning in transdisciplinary collaborations: A conceptual vocabulary. In: Fam D, Neuhauser L, Gibbs P, editors. Transdisciplinary Theory. Springer, Cham: Practice and Education; 2018. pp. 11-23

[55] Gröschl S, Pavie X. Transdisciplinarity applied to management education: A case study. Journal of Education for Business. 2020;**95**(7):451-457. DOI: 10.1080/08832323.2019.1671781

[56] Rieckmann M. Learning to transform the world: Key competencies in ESD. In: Leicht A, Heiss J, Byun WJ, editors. Issues and trends in Education for Sustainable Development. 2018.

[57] Msengana NW. The Significance of the Concept "Ubuntu" for Educational Management and Leadership during Democratic Transformation in South Africa. Cape Town, South Africa: University of Stellenbosch; 2006

Chapter 15

Early Childhood: Enriched Environments and Roles of Caring Adults

Analía Mignaton

Abstract

In recent years, with the arrival of the pandemic, children and families have had to reduce their exchange environments. It has been necessary to reconfigure play spaces at home, redefine the roles of adult caregivers, and plan strategies to accompany early childhood without digital screens being the only option to explore and discover the world. The enriched environments are a game and exchange proposal to support the role of the adult who cares for young children. The care systems that are offered are based on stimulating functions and leave aside fundamental actions, such as interacting and perceiving sensitive transformations in the exchange with the little ones. Prioritizing these early interactions favors children's learning and play if they are supported by social and cultural educational spaces that include the entire community as a basis for meeting and collaborative care.

Keywords: family network, context, enriched environments, playful experiences, affective support, opportune interactions, community

1. Introduction

Childhood is a particular time in people's lives and has been going through important changes in their social representations, in their characteristics, in the forms of bonding with people and objects in the environment, and in the spaces destined for their care. In recent years, with the arrival of the pandemic, children and families had to reduce their exchange environments, among other variables, due to the isolation proposed to prevent the spread of the virus. This situation put distance between family and institutional ties and families, leaving them in a situation of certain solitude and individuality within their homes. Although the virtual educational proposals were sustained in this period, each child and adult was physically in a different place without the possibility of bodily contact, essential in these first moments. From there, it has been necessary to reconfigure play spaces at home, redefine the roles of adult caregivers, and plan strategies to accompany early childhood without digital screens being the privileged option to explore and discover the world, and also take care of adults if they are alone or exhausted by the task of raising and educating.

The forms of bonding between children and adults are strongly influenced by the coordinates of time, where adults are performing multiple tasks, in a temporal and spatial configuration that leaves little room for leisure, spontaneity in relationships, bodily availability for an approach, a close and affective exchange, in a world where knowable objects and new technologies abound in everyday spaces and come into direct contact with children and adolescents, often without the mediation of adults.

In this framework, the care systems that are offered are frequently based on stimulating functions (motor, cognitive, and linguistic), and fundamental actions, such as interacting from a place of bodily implications and perceiving sensitive transformations in this dialogue of bodies, are usually left aside, in the exchange with the little ones through multiple sensory modalities. Prioritizing these early interactions promotes children's learning and play. At this point, proposing enriched environments consists of thinking of coordinates to generate or enhance the game and the exchange of spaces and times to support the role of the adult who cares for young children in the daily interactions of early childhood.

2. Current coordinates to think about early childhood and families in postmodernity

In each space-time, the variables have undergone visible transformations that show the characteristics of the direction of the human era. Geography, architecture, cultural and aesthetic expressions, ways of relating, material and symbolic conditions of our existence change, and homes and educational spaces change. In these configurations, everyday life acquires meanings that materialize in concrete and natural settings for each generation. "The dimensions of space and time have been sustained in that period by the constant pressure of the circulation and accumulation of capital, and have culminated (...) in disconcerting and distressing accesses of space-time compression" [1].

We live in a time that is not chronological, continuous, or without interruptions, but rather an event, of instants [2]. The temporal order acquires special dimensions in our time, constituting an ephemeral, vertiginous time. These times of liquid modernity are characterized by a punctuated or "pointillist" time, marked by ruptures and discontinuities, more prominent for its inconsistency and lack of cohesion than for its cohesive and continuous elements (...) Pointillist time is broken, or more well, pulverized, in a multitude of "eternal instants" -events, incidents, accidents, adventures, episodes-, monads closed on themselves, different morsels (...)" [3]. The current experience of time is fleeting, we feel that it is getting out of hand, divided into a thousand moments.

We move in a fragmented time, characterized by cascades of knowledge. For Harvey, already in the 90s,

> *"The experience of time has changed, confidence in the association between scientific and moral judgments has disappeared, aesthetics have triumphed over ethics as a fundamental social and intellectual concern, images dominate narratives, transience and fragmentation take precedence over eternal truths and unified politics, and explanations have moved from the realm of material and economic-political foundations to the consideration of autonomous cultural and political practices" [4].*

We also notice that we are going through times of confusion and uncertainty, where the appeal of aesthetics (whatever its form) becomes more pronounced. The forms of production after modernity allow us to access a series of goods and services that make our lives comfortable in a different way from that of our ancestors. We access multiple objects quickly, and at home, we have a wide variety of gadgets and devices that make our lives easier and more comfortable. Some arise from the intention of collaborating with the task of caring for and raising young children. We are also governed by the logic of the image, a visual aesthetic that marks its mark on each daily act. "Today we no longer seek our truth within ourselves, opaque to the gaze of others, the search is directed to the media outside before which we feel transparent" [5].

We can think that the connection with the media is responsible for the connective immediacy but also productivity influences the speed of life in our times. We live in rushed times, where the times of childhood are also affected, childhood is reduced, children rush to learn skills for the future, the productive logic of the adult world organizes the day, both at home and in institutions, adults feel that they do not have time, that it is not easy to accompany and respect the times of childhood.

In general terms, homes have changed, as well as the times and spaces where children spend their lives, work/home time, productive and leisure time, shared time, and the objects we use on a day-to-day basis, objects called toys, etc., the sensations and experience of being a boy or a girl in this concrete material and the symbolic world have changed.

We can say that there is a plurality of worlds within postmodernist fiction. It is useful for our analysis to reflect on a certain fragmentation, pluralism, and the authenticity of other voices and other worlds, so that communication can circulate and not only exercise dominance over our ways of seeing. The rise of postmodern thought can be traced back to the communication languages of advanced capitalist societies as a major force of alienation and domination [6].

The modern liquid structure of consumerist society and culture is characterized by "an advanced state of deregulation and deroutinization of human behavior in direct relation to the collapse of human bonds, known as individualization" [7]. How to move then in the midst of fragmentation, the liquidity of relationships and the social, cultural, and material elements that cross us? Faced with the tendency toward individuality in the course of people's lives, is it possible to propose collective proposals that contain us and allow us to reflect on our daily lives, to find other ways of caring for and educating?

We can see that we live in the age of mass television. At present, aesthetics predominates over any other cultural form and supposes a transformation in the habits and attitudes of consumers. The postmodernist current is rooted in everyday life under the premises of capitalism. We can perceive this in the large number of objects that are in our homes and in the constant need to upload images to social networks to be rewarded by followers, and in the advertising invasion that we experience daily. Today there is more concern for surfaces than for roots, for collage than for depth, for superimposed images to the detriment of elaborate surfaces. There is also a sense of time and space that disdains solid artifacts, alluding to the transience of our time, a transience and liquid feel against the weight of the solidity of earlier times. From a materialist point of view, objective conceptions of time and space have necessarily been created through the material practices and processes that serve to reproduce social life, which vary geographically and historically. We will review these categories since each particular mode of production or social formation embodies a set of practices and concepts of time and space" [8].

In this then-fragmented landscape, governed by image, which weakens social ties in the face of individual proposals, dominated by the idea of consumption and crossed by a pandemic situation, is where betting on recovering ties becomes an indispensable task. We require a pause, a time to listen to alterity as an experience and sustaining exchange for children and adults.

2.1 Reflections on everyday space and time

Space and time are basic categories of human existence. They are intimately involved in the processes of production and transformation of social relations. The history of social change is evidenced in part by the history of conceptions of space and time. It is then necessary to reflect on the space experienced, perceived, and imagined in a dialectical relationship within everyday life [9].

If we stop to analyze the spaces and the passage of time today, we notice that the places for children's games have been significantly reduced. It is rare to find children playing on the sidewalks, and in homes, the distribution of play spaces for children is variable. Childhood usually takes place in institutional spaces, regulated by the logic of teaching and skills for future life. In homes, technological devices coexist with us on a regular basis, and it is common to find the television on, even as "background noise".

In terms of time, the distribution of tasks revolves around the work of the parents and the care of the children, where on many occasions the time for leisure and sharing has been reduced. There is a "family time" as time for raising children and transmission of knowledge and goods between generations through kinship networks, and this time responds to the demands of an "industrial time that distributes and redistributes the workforce in relation to tasks, according to the powerful rhythms of technological and locational change brought about by the relentless pursuit of capital accumulation" [8].

Looking at our time is complex because it requires a certain distance from our time and from our own representations of life and the current world. To do this, it is necessary to find clues about where we are and broaden our own perspectives. It is necessary to review the symbolic orders of our own spaces and times.

It is possible to glimpse in the internal arrangement of the houses and the external arrangements the relationships with the annual, weekly calendar, and the divisions between day and night, work, rest, activity, leisure, etc. Capital production systems suppose the constant disorganization of temporal and spatial rhythms, times that follow the logic of work and consumption, where "one of the missions of modernism is to produce new meanings for space and time in a world of the ephemeral and fragmented" [9].

2.2 Objects and materiality of space

To refer to the materiality in current life systems, we focus on the spaces of daily life, in which there are many objects, functional and decorative, also intended for children's play. It is common to see baskets or boxes with stored objects that are usually emptied by the little ones to carry out a quick exploration of them. These toy objects are part of the everyday scene, even with all their regional or social diversity, and they carry the problem of storage and order that is difficult for adults to maintain. In addition, among the objects that are offered to the little ones are the screens, which are already part of the space and participate in the organization of parenting time.

Adults are thus immersed in a vicious circle where ordering, entertaining, and caring for the little ones becomes difficult and laborious. Whether because of the speed of modern life, social and cultural demands, adults in charge of young children find few alternatives to these situations or because of the diverse and simultaneous tasks of the adult world. If we go back a few decades, there was no such number of toy objects for children, and these have arisen from consumerism that sneaks into each advertisement. Is it possible to recover the idea of exploring the world by offering "natural" or everyday objects instead of consumer objects? In a way, the proposal is to give in the sense of donating objects to be explored, instead of acquiring toy objects, especially in the era of the advent of plastic.

It is also possible to review the way they are offered, in small doses, in baskets, or storage boxes within the reach of children, as Montessori proposed more than a century ago. Is it possible to take care of a small child at home and at the same time work from home or do housework? The exhaustion expressed by adults is enormous. And that is why we resort to objects that replace us at certain times, instead of offering objects within a bonding relationship of interest that promotes the discovery (cognitive and affective) of the world.

Both in homes and in institutions for the care of young children, there have been instances that regulate the presence and absence of the significant adult, not always in a respectful manner, although in recent times with greater criteria on the affectivity of babies in the early stages of life. At present, it is necessary to rethink the existence of a certain presence/absence alternation, since the premise is usually to care for and protect the little ones, leaving the development of their personal and social autonomy in the background. Although it is sought to protect children from domestic accidents, children remain under strict control with few possibilities to move, be creative and autonomous and develop a "being alone in the presence of the adult" as Winnicott proposed in the path of mental health [10].

In Argentina, there is a great variety of styles in the care of young children, ranging from the demand for personal autonomy to overprotection and the constant presence of hypervigilant caregivers. It is necessary to reflect on the attitude of adults toward children, care, ways to encourage play, and actions that adults favor in children's lives. Paying attention to our attitudes will allow us to think about childhood in terms of rights and carry out care practices that favor child development.

Among the privileged objects of today are the screens, mobile phones, tablets, and televisions. All of them coexist and pre-exist with today's children, are part of their natural world and are usually available from an early age. Ana Bloj, a doctor in psychology in Argentina, wonders if perhaps technologies are producers of subjectivity. And he adds that it is often heard that the work of parents and teachers in relation to new technologies is to try to "get them out" of them [11]. The author also states that it is possible to ignore a person and the environment itself to focus on mobile technology, a new way of being connected since this disconnection implies new ways of connecting, different ways of relating to colleagues, to the world, and with parents.

The experience of disconnection due to cell phone use is a different experience. That is to say that the boys are connected, but in a different reality, in a virtual space. There is a generational difference, parents, educators, and adults today did not grow up in the midst of the virtual reality that screens propose, those fictional worlds that are imposed on us from the consumer society as instant paradisiacal spaces, without resistance [12]. In addition, Bloj adds that it is impossible for parents to know how, where, and when to regulate their children's use of new technologies because that use was not part of their own childhood experiences. But we have, as in any generational difference, other experiences to pass on. The problem is that these other experiences are overshadowed by the brightness and mobile sound of the cell phone, and are difficult to recover as valuable cultural assets for new generations. This is where it makes sense to think about time, shared, offered, and lived.

It is necessary to review cultural spaces, to detect if they have been reduced or modified during the pandemic, if they coexist with virtual spaces, if they replace them, and to what extent they do so, and the possible consequences that this may have on people's lives, especially in childhood. In order not to generate alarms about the new ways of being connected and linked, but above all to know if the creative experiences lived in each home or early childhood space are sufficient, from the beginning of life in a background of shared pleasure in interaction with others.

Background noise and images are now part of the everyday scene. Let us think that there is, in addition, a difference in terms of the age of the boy, girl, or adolescent. In the early years, it is the closest adults who offer or have a cell phone or screen for the little ones on certain occasions, because they are there as part of the daily scenario, because they "help" or relieve the adult in the task, and have fun for a while. In addition, we are surprised by the speed and dexterity with which children handle technology from an early age and to see the fascination that the flash of images, sounds, and movements with the concomitant arrest of the body produces on their faces. In addition, adults sometimes leave their little ones at the mercy of their mobiles to recover some leisure/rest time after the working day, even considering that they are harmful to the little ones. But we surrender to the need to have our own personal space, without bodily involvement, both during the confinement due to the pandemic and in previous or subsequent work periods.

We can think that this offering of screens to the little ones can be shared between both, they can be "given" to explore and they can be given to the mercy of the child, sometimes without filter, with a significant share of guilt because it is not easy to resolve in that situation or it can be a non-affective involvement situation. Can we think of childhoods without screens? It is not possible to generalize the attitude of the adults involved in each scene, but it is noted that they are part of the daily scenarios of what we call parenting. As Moreno, an Argentine psychoanalyst, affirms,

> *"Kids today definitely prefer connective presentations. They are able to connect the central threads of the plots they inhabit and respond to them even when they cannot explain them. Perhaps that is why they love and are fascinated by screens. The initial stitches of the child's subjectivity are conditioned by the fact that he connectively captures the threads of the situations he inhabits, such as family expectations and experiences, even when he does not understand them from a rational, causal or associative point of view. They are open to the content of the representative packages and not necessarily to the representations that from the associative point of view could be considered essential to "understand" [13].*

The experiences of children in front of the screen circulate through another scenario, as already mentioned, virtual, often alien to adults. The little ones connect, capture, and capture with their senses in extraordinary ways. In certain situations, screens can offer pleasurable experiences linked to fast and effective sensations that quickly reward the nervous system. What they cannot offer (at least at present) are modulations to the behavior of the little ones, exchanges of rhythms, or gestural or corporal communications; only with their wide variety of sensory modalities do they capture the attention of children who stop their bodies to observe the virtual representations. This can produce fascination instead of propitiating interactions between the subjects. As Bloj states, "we then have a displacement of adults for the exercise of their functions in these scenarios and an advance in the capture of new technologies, especially video games, to seduce them in a new virtual space/scenario" [14].

It is not about rejecting screens and the use of new technologies, after all, adults participate in virtual spaces interacting with other people, recreating times of exchange, sometimes longer and more unique than in face-to-face interaction direct. It is important to recognize that there is an enormous attraction to screens so as not to fight in vain against them, but to place ourselves in a possible place as adults and offer significant experiences in other areas that favor exchange and communication. Be mediators and provide opportunities for intersubjective experiences. The challenge then would be not to relinquish the place of co-star in early childhood development.

María Emilia López, pedagogue and childhood specialist, points out that in our industrialized societies intersubjective spaces have been reduced, that is, interpersonal spaces, mediated by language. It would not be possible or desirable for screens to replace the human voice, embodied, "embodied in another real in simultaneity of presence, cooing and cooing made of voice, contact and breath are replaced by television machines, tenderness displaced by the image -merchandise coming from the screen" [15].

How then to think about the role of the adult, in the face of such an offer of continuous, asynchronous stimuli and with the potential to capture the attention of boys and girls? Redefining a place for adults, from a container asymmetry that does not block or leave without borders the actions of childhood is the current challenge. Rethinking the places of authority in times of reparation and historical vulnerability is a complex and arduous task that requires a lot of personal and social reflection. For Lutereau, an Argentine psychoanalyst,

> *"Authority today is not tied to the knowledge that a child may suppose the adult possesses. Children no longer believe that adults know a lot, nor are they afraid that they will get angry. Because they are the ones who teach parents to solve problems – in this aspect, technology has played a fundamental engine of change – in the same way that students are no longer ashamed of not knowing (...) It does not mean that the authority has disappeared and, therefore, that there are no limits. In any case, limits cannot be imposed today in the same way as before" [12].*

The displacement of adults is not reduced to a matter of authority against children and adolescents, it is a complex problem that overwhelms us and exceeds us as individual subjects. What is at stake is the level of participation, a certain asymmetry that guides and protects, and the revision of the ways of imposing authority from a few decades ago, to generate situations of mutual respect and emotional support for the new generations. That is to say, another place, new to the extent that it opens up to the novelty of childhood, but also that gives meaning to certain gestures of care in which their participation is essential.

In any case, adults can participate in this strong interest of children and adolescents in virtual content, dialoguing, questioning, putting into words, opening up to participation, and pulling toward reality. "This would open a path that could perhaps lead to a rapprochement between generations. But they are just hypotheses to continue thinking among all" [16].

It is necessary to recover shared spaces where it is possible to dialogue, play, offer experiences with objects, allow exploration, transform space, etc., as a path toward exploration, creation, fiction, and narration—that intermediate zone where play and creative experience exist, as Winnicott [10] proposed. Both to offer spaces of resistance against the experience in front of the screens, and proposals to stimulate certain functions with objects, reducing the child to an apprentice who reacts to the flow of information that is offered.

So, we notice that having available materials and objects and the use of new technologies do not always generate an experience, they do not necessarily go through our subjectivity. Currently, there are cascades of stimuli and this does not guarantee that there is a subjective appropriation of them, including the experience in front of the screens, but not only these, but all experiences with objects in the real world. In these times, it is difficult for us to produce a common sense, a certain bodily distance from the adult, which, although it allows us to explore objects, to know their physical characteristics, is not enough to enter the middle ground, a space generated between the internal world and the external world with the adult during the first interactions.

Reflecting on the subject, María Emilia López tells us:

"If in exchange for the human voice, the tenderness, the conversation and the cognitive possibilities offered by books, games with music, body cooing to babies, exploration and investigation in the game itself, several hours a day of connection to the television or the computer screen, with the children still and hypnotized by the image, the expectation of enrichment from parenting vanishes. If the proposed activities always focus on instructions with results predetermined by the adult, the spontaneity so typical of early childhood is buried, and this loss brings negative consequences for the symbolic and cultural development of children" [14].

When speaking of "experience" in the sense of what moves us, María Emilia López proposes offering materials, offering stimuli; but he also adds that the mediating role of the adult is indispensable in the construction of shared events. The author affirms that "there is no possibility of imaginary construction without the other human who helps to organize experiences, who names, who accompanies, who offers the cultural richness that precedes the child and, above all, who favors the creation of time and space. Experiencing something more than the actions of survival or everyday life" [17].

3. Encounters and disagreements between adults and new generations

In this section, the proposal is to review some conditions for communication and interaction in early childhood, especially the first year of life, from conceptualizations that allow recovering the leading role in the exchange between the new generations and the adults in charge of their care and education.

Thanks to the contribution of psychology and other disciplines that include a corporeal vision of development, we know the existence of certain fundamental functions of the adult and the child that are vital for the construction of the psyche. At first, the support capacity of the young child, a body wrap that offers a relationship of proximity, continuity, and security for the little ones at an early age [18]. And then, the first affective exchanges, the playful activities between the baby and the adult, the joint gaze and the attention shared by both interlocutors and other founding functions of this stage. The joint gaze is understood as bodily intentionality, as a triangulation between the child's gaze, the adult's face and mimicry, and the object to be explored; the little one reads, intuits in the gestures of the adult, and even questions him to know his intentions about that imagined, performed, or desired action on the object. It is in these interactions in which both direct their gaze toward a common fact, and somehow communicate their intentions through this gesture, that is to say, that a bodily, gestural, affective dialogue takes place, in an affective exchange between child and adult.

The subjectivation process then occurs within this interactive, participatory dynamic of construction of meanings between both subjects of the relationship. The little one, with the help of the adult, participates in the experience of giving meaning to his experiences, supported by the attitudes, gestures, and corporal expression of the adults.

For the Uruguayan psychoanalyst Víctor Guerra, the subjectivation process also refers to "the construction of the self from the body-mind association, with the passage from a sensory function to a representational one, and the need to link the drive and sexuality to one desiring another who can also open it to others" [19], that is, to thirdness, as Winnicott proposed in the construction of the real [10].

In short, we could explain the process of subjectivation as the process through which the baby could build his own perspective together with that of the other based on the ego support offered by the adult. With this, Guerra prioritizes the nature of the process, in that active exchange between the two where the child is being built as a subject and has an adult who allows him to open a space for the baby to show "his perspective, his way" to explore "objects with their time and rhythm" [20]. This process would be possible, thanks to the availability of the adult, giving rise to the Winnicottian concept of a mother (as a function) sufficient, neither good nor perfect, but capable of putting herself in the baby's place in the early stages and be open to their expressions [21].

This capacity of the adult to allow himself to be transformed by the gesture of the child is the foundation of the intersubjective process and requires a certain availability, both of presence, level of attention, and participation, as well as possibilities of involvement that the caregiver has. With this idea, let us review whether in the daily times of people's lives (perceived as fleeting, as mentioned above) it is possible to generate spaces and times for this encounter. This malleability of the adult, essential for the expression of childhood experiences, "implies a slow step in the construction of their psychic life, through a body language that integrates step by step the value of words and metaphors" [20]. This slowness is due to the necessary continuity and frequency in the contact that allows a subjective event to be recorded.

The author uses the term "silent colloquy of glances," similar to the tonic emotional dialogue proposed by Julián de Ajuriaguerra [22]. This is the metaphor of a dialogue (perhaps silent in terms of words) but significant, impregnated with meanings, encounters, and mutual transformations. He adds that "the beginning of contact and human subjectivation refers to an encounter that starts from the body, from sensory experience and opens up to music, to a rhythm, to a drawing, to a game. Significant signs that open the way to the emergence of the word" [23].

This step from sensory to representational functioning allows us to go from sensations to words, but not just any word, but the word that, impregnated with sensoriality and charged with emotions, allows us to go from the "blind instinct" to the drive. It is about building a continent, "a house" that houses the polychrome set of experiences that we call subjectivity… [24]. Let us go back to the idea of wrapping or containing the child's body during early body support. But also the need to rethink the offer of stimulating objects to children to recover the rich multisensory flow offered by the bodily exchange, contact, support, and affective dialogue as a source of pleasure and communication.

Also, in the process of discovering how babies are interested in understanding and understanding the intentionality of the actions of others, the concept of intersubjectivity emerges.

For Martínez, a doctor in psychology in our country, "Colwyn Trevarthen" attributes the concepts of primary and secondary intersubjectivity, qualifying them as "two different ways in which babies intersubjectively engage with their parental figures" [25]. Trevarthen used the term "primary intersubjectivity to describe the temporally and emotionally regulated exchanges observed in early dyadic interactions between mother and child between 2 and 9 months" [26]. There are also other indicators or manifestations of primary intersubjectivity, such as neonatal imitation, proto-conversations, and interactive synchrony, functions that originate in the early communicative exchange with the significant other.

He also uses the term secondary intersubjectivity "to describe those situations in which the baby is able to combine two types of acts, praxis - pointing, showing, giving, offering, taking an object, consecutive manipulation, in interaction with his mother, praxic imitation, regulating the action on the object, resisting, touching the object, extending the hand- and the interpersonal ones -smiling, vocalizing, looking at the other's face, extending the arms towards the adult, touching the other, vocal imitation- (...). This type of exchange or psychological contact arises between 9 and 12 months" [25]. These gestures, signs, and exchanges given to another constitute an early communicative repertoire (preverbal) that occurs between the child and the adult.

Many authors propose the concept of intersubjectivity as a fundamental aspect in the construction of the child's psyche. Even with different theoretical positions, they invite us to think of the baby as an active subject, a co-star in his process of subjectivation. Today there is scientific evidence of the influence of the environment on the baby, for example, from epigenetics, and we also know that it is a spiral process of mutual transformation. The conceptualizations of the interactive possibilities of babies and the evidence of the first ludic exchanges are fundamental. For example, see refs. [18, 26–28].

For Guerra, intersubjectivity would function as a "universal language" that is expressed at the beginning of life through non-verbal communication codes that include, in addition to verbal content, message, envelopes, prosody, rhythm, tone of the voice, the face and the gaze as a mirror, imitation and empathy. And he says: "All the semiology of human gestures that comes into play when there is the possibility of gradually discovering the desires inside the human being" [29]. This multidimensional, bodily, and affective communication is at the base of intersubjectivity, it is not limited to verbal exchange, but to tonic and affective modulations and adjustments between the baby and the caregiver. Intersubjectivity constitutes "the experience of sharing emotional states with others" [29]. Recovering corporality in the first affective exchanges between a baby and the adult caregiver is a priority, then, redefining times and spaces that enable these dialogic instances in development.

Raising the idea of the construction of subjectivity and intersubjectivity is essential to support interactive processes between infants, young children, and adults in the early stages of life. Our lifestyle can lead us to physically distance ourselves from children, or to the aforementioned difficulty of alternating moments of presence and absence based on shared pleasure, in a process of building the inner and outer world of the little ones. Recovering these conceptualizations can guide us toward favorable attitudes in adult caregivers and their affective and temporal needs for this to happen.

The availability, the affective charge, and the exchange that can occur from the introduction of the world in that small dyadic or triadic world is a founding fact in childhood experiences. Every object that appears in a child's life is placed there by their referring adults. It is not a question of minimizing the presence of objects, but of offering them in a link that links each subject from the beginning with the human world that receives it. Neither gives prominence to replace the presence and interactive participation of the adult nor exacerbates their physical characteristics (color, size, and name) to the detriment of the experience that occurs in the act of exploring or playing to produce a transformation at a symbolic level.

The mother (or whoever performs the care function) is bodily and affectively involved in the exchange to try to decipher and share her baby's emotional states, for which she experiences a libidinal encounter, based on the pleasure of the exchange. This encounter has a sexual dimension with all its phantasmatic unconsciousness and makes possible the separation of the self. It is an experience of separation and of feeling accompanied by another. For Guerra, the intersubjectivity derived from cognitive psychology must dialogue with the theory of drives, calling it "interpulsionality" [19].

It is also suggested that the task of those who surround the little ones and their first links (we could think of educators, therapists, caregivers, and people from the immediate environment) should not impose our own music, but identify and tune the instrument that they must play to reproduce your own music.

It is important to highlight the role of initial support and also of a joint rhythmic exchange, early social play, shared attention directed toward a common event, body and gestural dialogue, and the narration of the first affective exchanges between the baby and the adult significantly. These are the elements of the process of subjectivation in the first year of life. An "adult malleability during play" [30] is also necessary. This refers to a malleable, accessible, available environment, as the basis of symbolization processes, ideas that are based on Winnicott's premises [18], as long as the mother or whoever fulfills that function allows herself to be transformed by the child, thus creating the fantasy of action in the outside world. We could say that without psychic and bodily malleability, the creation of the transition space would not take place [30].

In this same sense, the term "interludicity" arises to explain the action of the child, co-creator with the adult, as he seeks "to find in the other a playful malleability that also allows him to co-construct his psychic life: express his desires, integrate the experiences of the mind and body, explore and tolerate their adaptation to reality, and elaborate potentially distressing situations" [31]. These first games between the baby and the adult are loaded with multimodal elements (voices, sounds, contacts, waiting, rhythms, synchronicities, smiles, also misunderstandings, etc.) that occur between the child and the adult and introduce them to the dynamics of communication. It is a pre-verbal dialogue and a prelude to verbal dialogue, loaded with musical, sound, temporal, rhythmic, affective, and interactive elements, the basis of affective exchange and basic security.

4. Build and enrich children's environments

Now we can raise the need to review family spaces and institutional spaces that collaborate with the first interpersonal context of the little ones, and public spaces that could make possible on a large scale the inclusion of shared instances of babies, small children, and adults in the environments. These environments empower and make room for the need to weave support networks for adult caregivers.

There are several functions to review as potential spaces to strengthen daily and institutional practices. Here I will list some possible ones.

The first refers to recovering the bodily proximity of the first times in the lives of babies without objects that hinder this early contact, publicized as necessary or indispensable objects for a good upbringing. In other words, to recover the body as a space for contact and early communication, as a source of experiences of envelopment and emotional support that provide security and pleasure in the early stages. To do this, adults must recover their own bodily experiences, to understand that the early interactive process is full of multimodal sensations, not just language and visual stimulation.

Another aspect to take into account is the times of shared experiences, not only of the individual subject who discovers the world but also of the adult who reveals the world in small doses. An adult who offers, makes available, and is bodily involved in the relationship, but without losing his dynamic spaces, so as not to exhaust the caregiver and raze his own subjectivity in search of an idealized childhood. Let us think of the failures that Winnicott talks about [18], of doing enough, of questioning the good of motherhood and fatherhood, and focus on the adjective sufficient, that reaches, that lays the foundation for development, instead of masking an adult attitude of total presence, which only leaves powerless when exhaustion reaches a physical, emotional, and mental limit. Find quality time, at a leisurely pace necessary to get in touch with the rhythm of babies and toddlers, in the midst of the accelerated time that productive life offers us today.

Also the idea of resignifying the spaces and times that collaborate in the construction of the body as a psychic and corporal knot, in the performance of daily functions, such as feeding, bathing, hygiene, children's sleep and a time of interludicity. developed in the previous section. This playful adult attitude towards play and early interactions.

In these moments of adult-child exchange, the independence of the little ones is often demanded instead of opening up to contact and communication. These situations have the children's bodies as protagonists of the scene, and the attitudes of the adults are varied, they allow themselves to be relieved by the presence of the screens, and they limit themselves to caring without getting bodily or spontaneously involved. For Calmels, an Argentine psychomotricity professional, the embodying function of adults is "a construction product of the (asymmetric) relationship established between the adult and the child. The child is embodied by another that fulfills this function, this link is the foundation of the gesture of various bodily manifestations, such as the look, the listening, the contact, the expressive gestures, the face, the voice, the praxis, the attitude posture, tastes, awareness of pain and pleasure, etc." [32]. The adult collaborates in the construction of the body of the other, offers border, contact, proximity, security, and in vital functions, such as eating, sleeping, and cleaning, regulates and supports the forms of coping of the own body. We understand the body as a construction that is assembled in the bond with others, in an asymmetric relationship, of care, where the child is loved, imagined, and named before being able to love, imagine and name and assume his own body functions.

Adults fulfill this embodying function, although sometimes upbringing or education is understood as a mere application of stimuli. It is necessary to be alert about these and their "stimulating effects," intentional or not, but present in the environment of the little ones. Calmels states that "deficiencies do not exist for lack of stimuli, but for the absence of stimulating links [33].

The bet is to value human exchange as a source of pleasant, rich, and diversified experience, in the family context, but also to have support networks to carry out this task in the company of other caregivers who contribute their experiences. In this way, we highlight the role of the other, adult, caregiver as a mediator, who offers, donates objects and meanings to be taken by newcomers. It gets involved, shares meanings, and bathes the baby or young child in language, respectfully accompanies bodily processes in early childhood as a basis for mental health.

Body care (understood as a dedication to hugs, caresses, and words) are apparently natural instances that require much review and reflection on the part of the educator or caregiver and a careful accompaniment" [34]. This is a valid contribution for both family groups and early childhood institutions. And it is necessary to review the ways in which we carry it out, to put in tension the knowledge reproduced in an uncritical way that does not generate subjectivizing situations. To do this, reflection and "doing with others" are a source of exchange and production of new knowledge that creates new ways of caring.

The possibility of opening accompaniment networks in the face of the individuality of the subjects is raised here. Although there are unique ways of being a mother, father, caregiver, or educator; there is a need to review old precepts and the new ideals that underlie the cataract of images of happiness that are projected on social networks. Generate listening spaces, where being one is possible, in a group that supports the idea of humanity for both new members and adult caregivers. These spaces, experiential workshops, meetings, rounds of exchange, nurseries, libraries for babies, toy libraries, and meeting instances, can be generated from the public, health, educational, or social sphere, from private or semi-private proposals and constitute a source of exchange extremely rich. It is a privileged way of weaving support networks for caregivers of young children and parents.

For Maria Emilia Lopez,

"Traditionally, where there were children there were social networks. The children invite to community life; (…) Gathering around the human cub guaranteed the continuity of cultural gestures transmitted generationally. The encounter with others facilitates in itself the emergence of the game, the entertainment, the fun, the conversation, the flow of the word, and the narration. But social spaces move away from community practices" [35].

The enrichment of children's spaces also includes attending to the availability of adults, since as adults we put aside the richness of the languages we have to express ourselves. Addressing this aspect includes reflection, games, and workshops that allow us to open ourselves to a free and creative corporality, and also containment during the child-rearing process, sharing experiences as axes of revision and transformation of practices and knowledge.

For López, the care of babies and young children requires "learning to read to children" as a complex task, "it is about reading between the lines, reading between gestures, reading timestamps, or reading without words. The task of interpreting their feelings and their needs, their ways of thinking, requires particular sensitivity and availability, in addition to certain specific knowledge about child development" [36]. This task also includes unlearning certain knowledge and retracing the path of certain teaching to enter into shared reciprocity that gives rise to the new.

This availability involves us and moves us; it is attention directed toward the other that makes us resonate and enter into an emotional, tonic, and affective dialogue; and it is a bodily activity (muscular, tonic, affective, and cognitive) that offers support to the activity of the little boy. And it constitutes an important demand of the adults who care, hence the need to have social spaces that strengthen and support those who care, that overcome individualism as a common way of doing and communicating. López proposes "Betting on a richer cultural development for early childhood also implies an endowment of social, affective, and cultural resources in the mediators" [37]. It refers to parents, relatives, educators, librarians, and social agents who participate in the process of raising and being hospitable to young children.

The author proposes to speak of "didactics of tenderness," as a metaphor, which implies "an integral intervention" that "is hospitable to the baby and the small child and their family in a physically and mentally supportive creative space, with affective availability and in good conditions they are generated for cognitive development" [38]. This idea allows us to think of the child as a bonding subject, and not just a learning subject who is "taught" certain skills. This subtle but enormous difference places the child in an active place, in relation to another theme that offers and chooses elements of the world to share with newcomers: "For children, tenderness is something that is received (...). It is something that is only learned to do from second-hand, tender if it has received tenderness" [39]. Let us think of the exchange in the key of intersubjectivity, of sharing the experience of discovering the world with another who welcomes, allows himself to be malleable, gives meaning, and stops the gesture while waiting for the expressiveness of the baby. Tenderness here does not refer only to caresses but to a hospitable affective exchange of the other.

Those who go through motherhood, fatherhood, or the process of raising a child, find themselves crossed by the ideal of being "good parents," longing for times of happiness without conflicts or anguish. The anguish of fatherhood is intrinsic to that role. For Lutereau, "Many times we think that we have to do everything quickly, like when we are at work. As if living with the family were just another job. And we think that children's play is something they do alone, that they should put aside to come and be with us" [40]. This aspect, of personal reflection on one's own role, can occur in therapeutic spaces, but they must also be accessible in collective, educational spaces, generated from various social spheres, and that allows us to think of ourselves as subjects of training in relation to other subjects and with forms diverse and respectful care alternatives.

Another fundamental aspect to think about environments rich in experiences and creativity are playful environments. Shared spaces and times, both family and social, where the fictional experience of acting and interacting with others can take place. For Lutereau "long before being neurologically ready, even before pronouncing a word, the human being is ready to play" [41]. Speaking of play in early childhood, he adds that "all the early games consist of the art of manifesting the alternation between what appears and disappears, such as the little sheet, the little face in the hands, the hide-and-seek, among others, as well as what disappears, what is imagined, puts our utilitarian life in parentheses, so that the only time that matters is that of the complicity of the search" [41]. There is a playful attitude shared between adults and children that offers the possibility of recreating a fun and innovative way of being together.

Playing is doing, stated Winnicott [10]. We could say that playing is also undoing time and space, reinventing it, transforming it, letting adult logic explore the unknown, apprehending it, dominating it, and conquering it over and over again. For this reason, it is essential to propose a time of observation, carefully observe the children's play and let the children explore, suspending the knowledge about what a child should do, but giving rise to unproductive times where they explore without knowing very well what to do. Just observe. This would allow us to make more adjusted interventions in the game, prepare better spaces and relevant objects and promote the game with an empathetic and open attitude as it is presented to us at each stage.

Playing with children is discovering other logics of doing and knowing, without imposing our own, it is waiting, stripping ourselves of certain certainties, stopping and making room for the new. Currently "few parents really know what their children like to play, much less allow themselves to be tempted to enter that territory where time is wasted" [42]. For Lutereau "Raising a child is not knowing what to do, but enduring times of maladjustment that growth implies" [43]. And it proposes to adults the task of carefully and disinterestedly observing the playful activity of children, without pretending to dominate it but rather to understand and accompany the processes in children.

It is also possible to recover the traditional games in the transgenerational dialogue to inhabit that space and gain ground in the virtual space [43]. Let us think about these and other possible responses and trials in the face of the advancement of new technologies within the home, of exchange spaces and in the ways of caring for and raising a young child. It is important to value the use of new technologies, as part of our daily reality, and if necessary, giving them a place, but not everything. It is proposed to bet on the power of childhood and "invent ways of being together, of producing dialogic situations, of generosity and listening, and, in these spaces, generate an own experience around the artistic objects of cultural assets" [44]. It is about producing and creating new cultural goods, and not just transmission or teaching.

Together with López, we can propose the idea of carrying out a cultural intervention, that is, promoting "access to play, art, reading, speech and narration as community events, in addition to expanding the universe of family practices that spontaneously accompany boys and girls from their arrival. For her, children are those who are learning to express themselves, those who seek to understand the world and need a loving and dialogical environment to enter the culture and build their own psyche [45]. But at the same time, he points out that they are also the least visible in society. Let us think about the spaces we pass through every day: how many of them are prepared to receive young children, and how many do not include them yet?

Within these proposals, it is possible to think of other objects, such as puppets, mediator dolls, and recreational spaces that house and contain characters that express emotions and share collective meanings. Elena Sana Cruz, renowned Argentine puppeteer, talks about playful objects. These are mediating resources between the individual and the collective, emotions and words, the inner world and artistic expressions. For the author, they are "intermediary objects and embodied metaphors that allow, in short times, to generate enormous spaces. They are not just pleasant objects to attract attention: they are bridges to reach the other, affective and effective scaffolding (...). Playful objects can arise in many ways. Some for a specific need to say or show something in particular; others because someone needs to speak and so that they can scaffold their expressive capacity" [46].

"The insertion of dolls as transitional objects in different contexts allows resuming communications interrupted by pain and traumatic situations" [47]. He defines the puppet as a doll to play with, an intermediary object to connect with someone, a cultural artifact, created with a purpose where the natural object acquires meaning, and a theatrical character [47]. That is to say, with it you can act, exchange with others, weave stories, put together sequences, represent, in the here and now, not to entertain but to create.

Understanding upbringing in all its modalities and the links between children and adults as "a high-density cultural background in the lives of children and families" [48], requires reflecting on parenting practices and the forms of accompaniment that are offered by the family, community, and social spheres. So the bet here is the construction of daily or institutional spaces, in the public and private spheres that bring the cultural baggage closer to families, to recover reading practices, narrations, music and bodily expressiveness, and play as transversal to any proposal where the commitment of the entire community makes it possible. The recognition of the playful attitude of the adult, its malleability, and its permeability to the actions of the little ones, are the gateway to the creative, cultural, fictional world and to language.

Proposing a proposal for the rights of early childhood, which expands the cultural offer and the spaces it offers for exploration, the creation of the little ones, and also for the exchange with significant adults and between family groups, is a huge and complex task. And it is a challenge to our current society. It is necessary to promote and guarantee the cultural rights of children in environments enriched by subjectivizing practices, in spaces that contain them and also their affective ties.

5. Conclusions

It is difficult to conclude the debate when we are traversed by this particular time and space. But it is necessary to point out some ideas to broaden our perspective and not to propose certainties but rather possible paths that allow us to transform our practices.

It is important to accompany children and the adults who care for them on the road to autonomy, offering exchange spaces to those responsible for generating a secure base for early childhood, with elements ranging from corporality, affectivity, proximity, and the early wrapping, the exchange between children and adults, and valuable cultural assets for our community.

Also care for and support the function of accompaniment of the child's body process, as a guarantee of the present and future mental health of our society. Support and promote the availability of those who care for young children with the creation of networks and meeting and exchange spaces. Promote affective and bodily contact in the early stages of life. Allow the origin of fiction, play, creativity, expression, and cultural interventions in their broad manifestations. It is necessary to claim the significant role of the adult to gain ground in new technologies and allow the experience to be an inexhaustible source of creativity and solidarity.

In addition to acting and interacting in the midst of uncertainty to walk toward new terrain, populated by words, metaphors, throbbing bodies, and human subjects emotionally capable of accommodating their various ways of being and relating. These new ways of acting together with children cannot occur in the individuality of each educational space or family. They must be based on a network of multicultural spaces, a network that forms a community and that listens and offers other ways of being and communicating with early childhood. It is about accompanying adults and children in their subjectivation process. Forming a community means working with others and designing spaces where words and imagination circulate, where adults feel accompanied in the face of the overflow produced by raising, educating and accompanying children in their growth process.

I borrow the words of María Emilia López to conclude:

> *"Producing community around babies and young children through books, songs, stories, games, is a form of emotional, cultural, and poetic care. Who cares for the one who raises, protects humanity" [49].*

DOI: http://dx.doi.org/10.5772/intechopen.105157

Author details

Analía Mignaton
Superior Institute of Teacher Training N°1, Neuquén, Argentina

*Address all correspondence to: analia.mignaton@mail.com

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Harvey D. La condición de la posmodernidad. In: Investigación sobre los orígenes del cambio cultural. Editorial Amorrortu; 1990. p. 359

[2] Moreno J. Elogio a cierta ignorancia. In: El psicoanálisis en clave vincular. Editorial Letra Viva; 2020

[3] Bauman Z. Vida de consumo. In: Fondo de Cultura. Económica; 2007. p. 39

[4] Harvey D. La condición de la posmodernidad. In: Investigación sobre los orígenes del cambio cultural. Editorial Amorrortu; 1990. p. 360

[5] Moreno J. Elogio a cierta ignorancia. In: El psicoanálisis en clave vincular. Editorial Letra Viva; 2020. p. 92

[6] Lyotard JF. La condición posmoderna. Ediciones Cátedra; 1984

[7] Bauman Z. Vida de consumo. In: Fondo de Cultura. Económica; 2007. p. 55

[8] Harvey D. La condición de la posmodernidad. In: Investigación sobre los orígenes del cambio cultural. Editorial Amorrortu; 1990. p. 217

[9] Harvey D. La condición de la posmodernidad. In: Investigación sobre los orígenes del cambio cultural. Editorial Amorrortu; 1990. p. 32

[10] Winnicott DW. Realidad y juego. Gedisa editorial; 1971

[11] Bloj A. ¿Nuevos escenarios para el procesamiento psíquico infantil? Docentes y parentalidades 'bloqueadas' en sus funciones Realidad virtual/nuevas tecnologías. En Resistidas y desafiadas: las prácticas en las instituciones entre demandas, legalidades y discursos/ Perla Zelmanovich. et al. Facultad Latinoamericana de Ceicnias Sociales (FLACSO). 2018. p. 54

[12] Lutereau L. Más crianza menos terapia. 7ma edición ed. Paidós; 2018. p. 144

[13] Moreno J. Elogio a cierta ignorancia. In: El psicoanálisis en clave vincular. Editorial Letra Viva; 2020. p. 18

[14] López L, López ME, Emilia M. Didáctica de la ternura. In: Reflexiones y controversias sobre la didáctica en el jardín maternal. 2019. p. 4. Recuperado de https://campuseducativo.santafe.edu.ar/wp-content/uploads/Didactica-de-la-ternura-Maria-Emilia-Lopez.pdf

[15] López ME, Emilia LM. Didáctica de la ternura. In: Reflexiones y controversias sobre la didáctica en el jardín maternal. 2019. p. 30. Recuperado de https://campuseducativo.santafe.edu.ar/wp-content/uploads/Didactica-de-la-ternura-Maria-Emilia-Lopez.pdf

[16] Bloj A. ¿Nuevos escenarios para el procesamiento psíquico infantil? Docentes y parentalidades 'bloqueadas' en sus funciones Realidad virtual/nuevas tecnologías. En Resistidas y desafiadas: las prácticas en las instituciones entre demandas, legalidades y discursos/ Perla Zelmanovich ... et al. Facultad Latinoamericana de Ceicnias Sociales (FLACSO). 2018. p. 57

[17] López ME. Un mundo abierto. Cultura y primera infancia. Editorial Lugar; 2019. p. 51

[18] Winnicott DW. La relación inicial entre una madre y su bebé. La Función materna. La Familia y el desarrollo del individuo. 5° edición ed. Editorial Lumen Hormé; 1995. pp. 29-35

[19] Guerra V. Indicadores de intersubjetividad 0-12 m: del encuentro de miradas al placer de jugar juntos2014. p. 7. Recuperado de https://www.redpikleruruguay.com.uy/docs/indicadores-de-intersubjetividad.pdf

[20] Guerra V. Indicadores de intersubjetividad 0-12 m: del encuentro de miradas al placer de jugar juntos2014. p. 8. Recuperado de https://www.redpikleruruguay.com.uy/docs/indicadores-de-intersubjetividad.pdf

[21] Winnicott DW. La relación inicial entre una madre y su bebé. La Función materna. La Familia y el desarrollo del individuo. 5° edición ed. Editorial Lumen Hormé; 1995. pp. 29-35

[22] de Ajuriaguerra J. Ontogénesis de las posturas Yo y el otro "cuerpo y comunicación". Madrid: Ed. Pirámide; 1982

[23] Guerra V. Indicadores de intersubjetividad 0-12 m: del encuentro de miradas al placer de jugar juntos2014. p. 9. Recuperado de https://www.redpikleruruguay.com.uy/docs/indicadores-de-intersubjetividad.pdf

[24] Guerra V. Indicadores de intersubjetividad 0-12 m: del encuentro de miradas al placer de jugar juntos2014. p. 10. Recuperado de https://www.redpikleruruguay.com.uy/docs/indicadores-de-intersubjetividad.pdf

[25] Martinez M. Intersubjetividad y teoría de la mente. In: ANPCyT – FLACSO – APAdeA. Vol. I (II). Psicología del Desarrollo; 2011. pp. 9-28. ISSN 1853-8746 2011. p. 11

[26] Trevarthen The concept and foundations of infant intersubjectivity, En Braten, S. (ed) Intersubjective communication and emotion in early ontogeny. Cambridge: Cambridge University Press. 1998. p. 15-46.

[27] Stern D. El mundo interpersonal del infante. Ed. Paidós.; 1990

[28] Golse B. El bebé, el niño y la violencia de acceso al lenguaje. Revista de psicopatología y salud mental del niño y del adolescente. 2005;**5**:67-81

[29] Guerra V. Indicadores de intersubjetividad 0-12 m: del encuentro de miradas al placer de jugar juntos2014. p. 6. Recuperado de https://www.redpikleruruguay.com.uy/docs/indicadores-de-intersubjetividad.pdf

[30] Guerra V. Indicadores de intersubjetividad 0-12 m: del encuentro de miradas al placer de jugar juntos. 2014. Recuperado de https://www.redpikleruruguay.com.uy/docs/indicadores-de-intersubjetividad.pdf

[31] Guerra V. Indicadores de intersubjetividad 0-12 m: del encuentro de miradas al placer de jugar juntos2014. p. 11. Recuperado de https://www.redpikleruruguay.com.uy/docs/indicadores-de-intersubjetividad.pdf

[32] Calmels D. El cuerpo en la infancia. Clase 8. Módulo 2. Diploma superior en Pedagogías de las diferencias. Argentina: FLACSO; 2019. p. 2

[33] Calmels D. El cuerpo en la infancia. Clase 8. Módulo 2. Diploma superior en Pedagogías de las diferencias. FLACSO. Argentina; 2019. p. 3

[34] López ME. Un mundo abierto. Cultura y primera infancia. Editorial Lugar; 2019

[35] López ME. Un mundo abierto. Cultura y primera infancia. Editorial Lugar; 2019. pp. 107-108

[36] López ME. Un mundo abierto. Cultura y primera infancia. Editorial Lugar; 2019. p. 114

[37] López ME. Un mundo abierto. Cultura y primera infancia. Editorial Lugar; 2019. p. 115

[38] López ME. Didáctica de la ternura. In: Reflexiones y controversias sobre la didáctica en el jardín maternal. 2019. p. 11. Recuperado de https://campuseducativo.santafe.edu.ar/wp-content/uploads/Didactica-de-la-ternura-Maria-Emilia-Lopez.pdf

[39] Lutereau L. Más crianza menos terapia. 7ma edición ed. Paidós; 2018. pp. 184-185

[40] Lutereau L. Más crianza menos terapia. 7ma edición ed. Paidós; 2018. p. 120

[41] Lutereau L. Más crianza menos terapia. 7ma edición ed. Paidós; 2018. p. 121

[42] Lutereau L. Más crianza menos terapia. 7ma edición ed. Paidós; 2018. p. 164

[43] Lutereau L. Más crianza menos terapia. 7ma edición ed. Paidós; 2018. p 128

[44] López ME. Un mundo abierto. Cultura y primera infancia. Editorial Lugar; 2019. p. 110

[45] López ME. Un mundo abierto. Cultura y primera infancia. Editorial Lugar; 2019. p. 8

[46] Santa Cruz E. Objetos lúdicos mediadores de ternura. Editorial Noveduc; 2019. p. 17

[47] Santa Cruz E. Objetos lúdicos mediadores de ternura. Editorial Noveduc; 2019. p. 19

[48] Santa Cruz E. Objetos lúdicos mediadores de ternura. Editorial Noveduc; 2019. pp. 22-23

[49] López ME. Un mundo abierto. Cultura y primera infancia. Editorial Lugar; 2019. p. 121

Chapter 16

Visual Discrimination: Spatial Reasoning Activity for Enhancing Children's Spatial Skills

Samuel Obara and Jake L. Hammons

Abstract

Children can connect with and grasp complex geometric concepts when we harness and integrate spatial thinking into learning situations. In this chapter, we'll look at a couple warm-ups and a few classroom exercises that show how thoughtful resources and unique geometry assignments may help students enhance their understanding in the complex context of the K-12 classroom. Throughout the class, students used a number of spatial abilities, such as visualization and mental rotations, while building and working with polyominoes.

Keywords: visual discrimination, spatial thinking, polyomino, isometry, spatial skills

1. Introduction

A person's capacity to display and manage spatial figures, relationships, and figure formations are referred to as their "spatial reasoning aptitude" [1, 2]. In other words, when it comes to thinking spatially, we think about the placement and movement of things and ourselves, both mentally and physically. There are many ideas, tools, and methods that make up this skill or process [3]. Mathematical exploration and solutions, especially non-routine ones, depend largely on spatial thinking, and many students find mathematics easier to learn when it is handled spatially [4].

Although it is seldom that spatial thinking is explicitly taught in schools, spatial vocabulary and principles like rotation, visualization, identification, and translation are indeed often employed in math disciplines like geometry and calculus. Researchers have developed a strategy for providing explicit spatial instruction that involves collaborating with classroom instructors to create spatial interventions [5, 6]. Such instruction typically focuses on developing selected aspects of spatial reasoning skills through the use of up-to-date methods and processes that are helpful for solving nuanced math classroom problems. There is a need to distinguish between spatial ability and spatial skills. Spatial ability is described as a person's natural capacity to envision a solution before having received any formal instruction, i.e., a person is born with the ability. In contrast, spatial skills are learned or gained via training. Tartre [7] distinguishes two types of spatial skills: spatial visualization and spatial orientation. Spatial visualization is the art of visualizing 2- and 3-dimensional objects in one's mind. At rest and in motion, spatial orientation is the capacity to maintain our bodily orientation and posture concerning the surrounding environment (physical space) [8]. According to research, spatial thinking skills and geometric reasoning are essential to the development of problem-solving abilities, mathematics learning, and reading [9, 10]. Strengthening the link between spatial thinking and mathematical accomplishment. Mathematical knowledge improves as spatial thinking improves since both can be learned and improved through practice [11–15]. This study will explore activities that help students enhance their spatial skills.

2. Research method

The subjects of this qualitative case study were 40 middle school students from low-income neighborhoods in one of the southern states of the United States. Throughout the 2017–2018 school year, students worked on honing their spatial reasoning abilities by using manipulatives. Data was collected using various methods, including interviews, observations, artifacts, and video recordings. Data was initially input into a word processor before being entered into NVivo (qualitative data analysis software) to be coded and evaluated.

3. Results

3.1 The warm-up activity

The teacher started the class with a warm-up activity involving visual discrimination, which is a visual perception skill that refers to the ability to differentiate one object from another. The development of visual discrimination skills can help a person to compare and contrast visual images accurately and can likewise enhance one's ability to think and see things differently. The capacity to visually identify letters and words becomes vital in learning to read; visual discrimination must essentially occur at all times while a person is reading [16]. One must be able to discriminate visually in terms of color, foreground-background, form, size, and position in space. Observation is a fundamental thinking skill as it underlies and supports other identification skills for gathering information.

The warm-up activity was called "I'm going on a hike." For this activity, students were shown on the overhead projector a picture of a jungle with twigs, leaves, trees, and a snake that required careful observation to identify. Some students were able to locate the snake, whereas others did not see it until the teacher traced it out.

Teacher: Alright, visual discrimination, I'm going on a hike. I'm going on a hike. Do you see anything?

Student 1: Grass.

Student 2: Grass, leaves, twigs.

Teacher: I see a tree. I see branches. I see dirt.

Student 3: I see a cobra head

Teacher: You see a cobra head? Come forward and show me.

Student 3: I lost it.

Teacher: Maybe under the leaves?

Student 4: I see it. It looks like a mop, though. You don't see… It's right there.

Student 4: Oh, I see it. I might get excited if I see that when I go on a hike.

The students used visual discrimination to find the snake, which was not apparent to some students.

The teacher also gave another warm-up about going on a picnic.

Teacher: Okay, the game we're going to play is called, "I'm going on a picnic." You happen to know it; don't give any hints out, okay? We're going to see who can figure this out. Alright, are you all ready to get started?

Students: Yeah [nodding].

Teacher: Alright, here it goes [crosses her arms]. I'm going on a picnic, and I'm going to bring... chocolate chips. Good job, Ms. Hanes, you can go. Okay [calls on Student 38].

Student 38: I'm going on a picnic, and I'm bringing apple pie?

Teacher: You want to bring apple pie. Well, come on up here with me [Student 38 goes to stand next to the teacher in front of the class].

Student 39: I'm going on a picnic, and I want to bring pizza.

Teacher: Can she come [asks Student 38]?

Student 38: No [shakes his head].

Teacher: Nope. Uh, I hope you can come to our thing too, or you... I think you might not be doing the right thing [to Student 38]. Oops, did you forget [to Student 38]? You have to sit back down. You're not remembering [sends Student 38 back to his seat]. Alright, yes, ma'am [to Student 40].

Student 40: I'm going on a picnic, and I'm going to bring blueberries.

Teacher: Oh, I'm sorry, I don't need blueberries. Yes [to Student 41].

Student 41: I'm going on a picnic, and I'm bringing an elephant.

Teacher: An elephant, I would love an elephant; come on up here! [Other students in the class laugh.] Okay, yes, ma'am [to Student 42].

Student 42: I'm going on a picnic, and I'm bringing sandwiches. [At the same time Student 42 is speaking, Student 43 is also saying the following].

Student 43: I'm going on a picnic, and I'm bringing watermelon.

Teacher: Uh, watermelon and sandwiches, you said watermelon, right? Okay, both of you all come up. The purpose of the exercise was for students to emulate the teacher's body language while declaring in front of the class what they would bring to qualify for the picnic. It did not matter what one brought to the picnic; what was important was how well the students emulated the teacher's body language.

For example, the instructor crossed her arms while discussing what to bring to the picnic and expected pupils to do the same. Other physical signals utilized were eye closure, making a fist, and standing on one leg. Many students did not qualify for going on a picnic as they did not visually discriminate what was going on with the teacher's body language. The students loved the game and engaged in what was going on. The teacher transitioned to the next activity, which involved distributing one domino to each student.

3.2 Dominoes

Teacher: Okay, now that is awesome. We're going to be doing many things here that have to do with visual [points to her eyes]. So, when you walk in here, make sure your eyes are open because they will do great stuff. Now, since we just talked about visualization and I'm going to give everybody one of these things [holds up bucket of dominoes and starts passing out dominoes to the students]. You all know what these things are?

Students: No, yeah, dominoes! (**Figure 1**)

Figure 1.
Dominoes.

Teacher: This is your vision at the moment, so pay attention to it. What did you observe about these dominos?

Student 4: There's a dragon on the back.

Teacher: Alright, cool, so there's an animal on the back. What else did you notice [points to Student 5]?

Student 5: They're black.

Teacher: What else did you notice [points to Student 6]?

Student 6: White dots.

Teacher: What did you see [points to Student 8]?

Student 8: They have a middle line separate.

Teacher: Ooh, a line, 2 sections. Ooh, I want to work on that little line thing; if you all can think of more things about her line, that's a good start there.

Student 10: Have two sections.

Teacher: Ooh, two sections; kind of goes with her idea, thing. Tell me about those two sections [to Student 10]. What shape are they?

Student 10: Square, two square sections...

Teacher: Hmm, 2 squares... What else [points to Student 11]?

Student 11: They're rectangular.

Student 17: The dragon on the back is asymmetrical.

Teacher: What? [Exclaims and then turns and writes on the board.]

Student 18: No, it's not

Teacher: The dragon on the back is asymmetrical... Can you tell us what asymmetrical means? (**Figure 2**)

The teacher's goal was to lead the conversation as students came up with terms that describe dominoes. Their description stated that dominoes have texture, black and white spots, two line-separated sections, two squares, and eight corners.

Teacher: Two squares, okay. What we're going to be working with are called... All the "ominos."

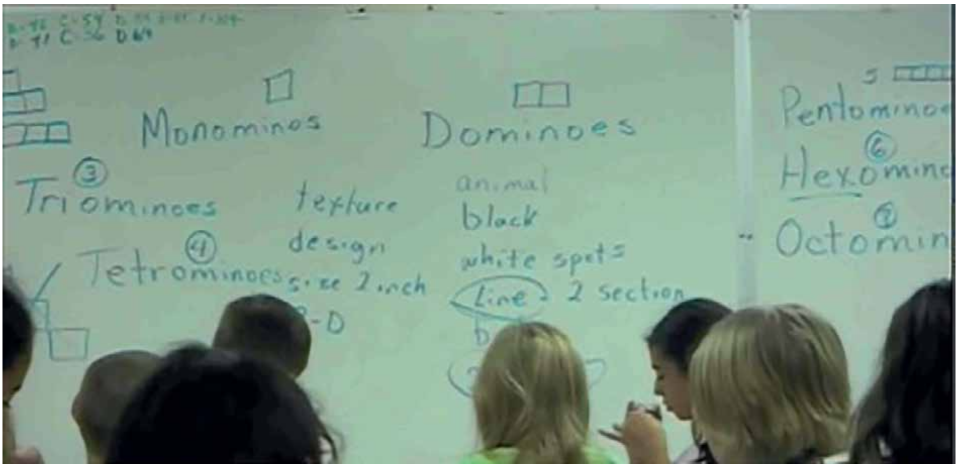


Figure 2.
Polyomino.

Students: Ominos. All the dominoes...

Teacher: Did you know that there's a bunch of ominos?

Student 33: Yes.

Student 34: Yeah.

Student 35: No.

Teacher: Well when you start what we did now [pointing to the board]. Was that dom... The dominoes... Do you think there are other ones?

Student 36: Yeah.

Teacher: Okay...

Student 37: Yes...

Teacher: So if I wrote...

Student 38: Pentomino.

Student 39: A what?

Teacher: If you saw a monomino, what in the world, I mean, what do you think about that one? For this one [circles two squares on the board], we wanted to make sure we saw that they were two squares. What do you think the monominoes would look like?

Student 40: One square.

Teacher: Ooh, it would look like one square, right?

Then the teacher drew the shape of one square above where she had written "monominoes" and drew two squares joined by a single side above where she had written "dominoes" for students to make the connection between monominoes and dominoes.

Teacher: You know about the pentominoes; how many squares?

Student 40: Five.

Teacher: Okay...

Teacher: Triominoes, how many do you think?

Student 50: Three.

Teacher: Okay, anybody thinks they have another one?

Student 43: A hexomino?

Teacher: Ooh! How many do you think are on the hexominoes?

Student 45: Eight.
Teacher: Hexominoes.
Student 46: Six!
Teacher: Okay, anybody thinks they have another one?
Student 50: Did you say there was a quadromino?
Teacher: Quadr…
Student 50: Four [holding up four fingers].
Teacher: I don't know because my thing doesn't have one… Yes [to Student 51]?

Student 50 was trying to associate quadr- with the number four in that instance; the teacher turned it into a learning moment by asking Student 50 about a game played on the computer with four blocks. The teacher turned to the board and wrote, "tetrominoes." The teacher's purpose was to reference the game Tetris, which the students knew and even played.

Teacher: Tetrominoes has how many?
Students 54: Four; Tetris!

The teacher then asked the students if there was any other way to make dominoes using two squares since they had made dominoes with two squares. Some students thought it was possible by only using one square, but they were making monominoes in the real sense, whereas others vertically placed a domino next to the original horizontal one.

Teacher: Ooh, she said to put it like this [horizontal and vertical placement].
Student 64: Right.
Teacher: Hold on a second, let's think about math stuff. Is that the same [pointing to the two placements of a domino]?
Student 65: Yes.
Student 67: It's all turned…
Teacher: Yes, it's turned… Or rotation, remember those words?

3.3 Triominoes

The teacher used the learning moment to capture mathematics concepts like flip and turn that change the orientation without changing the figure. That is to say, one could move it anywhere, but it would still be the same. Using only two squares to make dominoes, students were asked to pick three squares to make triominoes. The teacher reminded students that a triomino consists of three equal-sized squares connected edge-to-edge.

Many students had a bit of an issue with making trinominoes when joining edges with the three squares. The task was to find all triominoes formed by the three squares. Most students came up with **Figure 3**, which sparked a conversation among classmates.

Teacher: Uh oh, remember when we talked about the dominoes [pointing to the board]? Wouldn't that be the same if you put it up like this [gesturing towards a vertical arrangement of the figure]? Does it not look different?
Student 82: Yes
Teacher: Okay, no matter how I turn it or move or reflect, it is still the exact figure.

Most students moved one of the squares in the first picture and then continually moved one of the squares to generate the remaining four photos after creating the first two images in **Figure 3**. Some pupils, it seems, were unaware that they were producing identical triominoes and only shifting them around (rotating or reflecting the item). This sparked a debate on whether rotating, translating, or reflecting an entity

DOI: http://dx.doi.org/10.5772/intechopen.106189

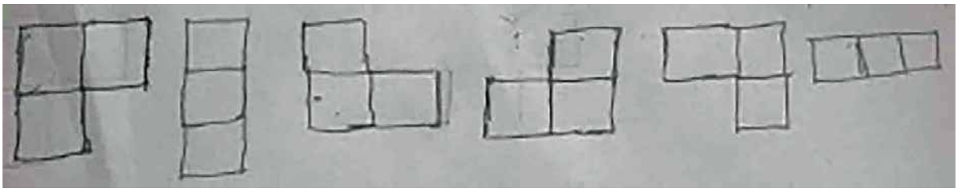


Figure 3.
Trinominoes first stage.

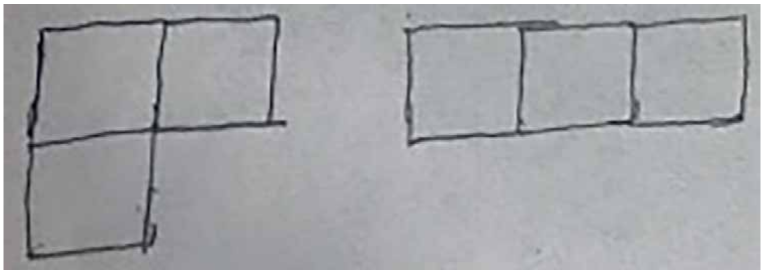


Figure 4.
Triominoes final.

changes its shape (length). As seen in **Figure 4**, some pupils understood that there are only two triominoes. This activity effectively brought the concept of isometry to the forefront (**Figure 5**).

3.4 Tetrominoes

Teacher: Okay, we just did the triominoes right now, I want you to grab one more piece, the same color. Okay, if we have four, what are those called?

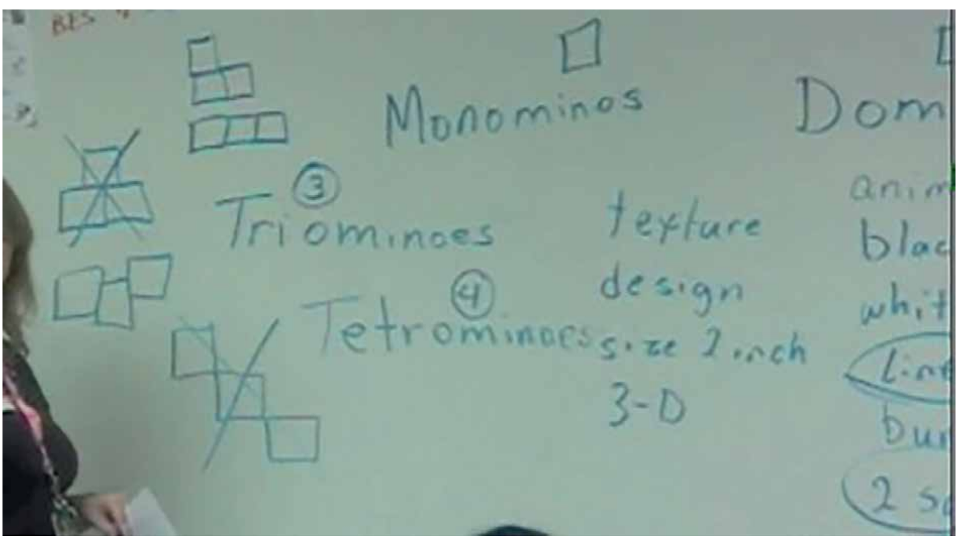


Figure 5.
Student responses.

Student 87: Tetrominoes.

Teacher: Tetrominoes, okay, build it and see... Raise your hand if you can tell me a way to make it.

Student 91: Uh, like, uh, up and down.

Teacher: Up [gesturing with her finger in a vertical motion]. Like a real long rectangle?

Student 89: You could have two at the bottom and two at the top.

Teacher: Two at the bottom [draws two squares] and two at the top [draws two more squares]. Looks like a big square; is that kind of what it's looking like? Awesome. What else [points to Student 90]?

Student 90: L-shaped.

The students utilized their newly acquired visualization skills to link the four squares edge-to-edge to generate various combinations that comprise the set of tetrominoes. At that moment, examples in **Figure 6** demonstrated what edge-to-edge implies for constructing tetrominoes or any other polyomino.

Student 90 began with a large square, then shifted one of the squares to make an L shape. The student then moved the top square to the left to form Z-shaped tetrominoes. Finally, one of the Z-shaped tetrominoes had one of its squares moved to become T-shaped tetrominoes.

Teacher: Put it on the table so I can see. I need to use my visualization skills [pointing to her eyes as she walks over to Student 90].

Student 90: [Shows the teacher his table.]

Teacher: Alright, fantastic!

The student argument continues as the lecturer sketches what the students come up with on the board. Student 90 anticipated that any more movement of the squares would lead to isometry. The students could tell it was the same picture even when the orientation reversed, and there were five alternative ways to construct the tetromino pieces.

3.5 Pentominoes

After the discussion and the exposure of students to dominoes, triominoes, and tetrominoes, the teacher wanted to take students to another level using pentominoes.

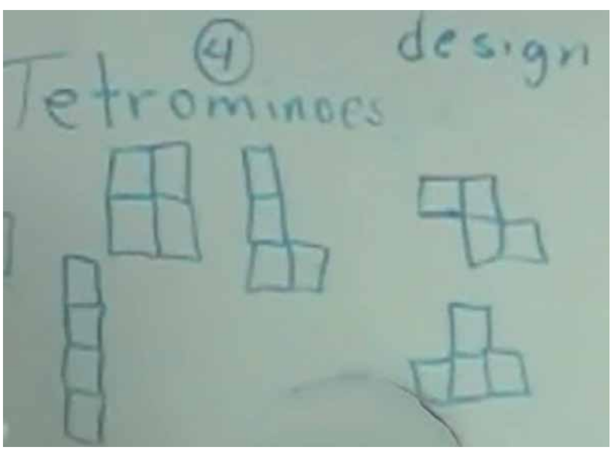


Figure 6.
Tetrominoes.

Teacher: As discussed in other polyominoes, a pentomino is a polygon made up of five equal-sized squares joined edge-to-edge. When rotations and reflections are not seen to be separate forms. Pentominoes... So right now, make sure you have five square pieces. I'm going to put a pentomino piece down on your table. Cool enough? Then, we're going to try to find all of them. Students worked in groups of five at five separate tables to create pentominoes using the information they had been provided. Working in groups enabled students to contribute to the making of pentominoes from five squares and facilitated assistance for those who were having problems learning. The instructor exchanged the produced pentomino piece with a genuine pentomino while the kids worked out the parts. This continued until the kids found all twelve pentominoes. The instructor noted that the twelve pentominoes pieces represented alphabet letters and utilized FLIPNTUVWXYZ, which is the mnemonic for the twelve pentominoes. As opposed to other polyominoes, pentominoes feature special properties that may be employed in spatial thinking, particularly in puzzle games. Before the game, students were given twelve pentomino pieces and invited to play with them to build a rectangle. Using their eyes only, they were asked to try using their free hand to build the rectangle on the table using all the pieces. This puzzle was very intense and the students were deeply engrossed in what they were doing. During the making of the rectangles, the discussion at one table was particularly interesting.

Teacher: Can you talk more about the strategy used in making the rectangle?

Student 90: I know that since each piece has five squares and sixty squares in total, I had to decide which type of rectangle I could make. I decided to come up with a six by ten rectangle.

Teacher: Why six by ten?

Student 90: I just decided to because to me it seemed easy to work with.

Student 90 did have a strategy on how to make the rectangle by starting with the shortest side on the right and working to the left. The student made sure that the number of squares along the longest side added up to ten. The student then had to select which remaining pieces to use. That strategy paid off for the students who completed the square shown in **Figure 7**. The student also noted that at each point they had to keep asking themselves how many squares were needed at that particular point and also what impact this could have on the assembly of the rectangle going forward.

At the same table, four students came up with six-by-ten rectangles, but the pieces were located in different places. Students were curious, and even asked how many different arrangements of the pieces had been created for the six-by-ten rectangles.

But at other tables across the classroom, other groups of students were dealing with different dimensions of rectangles, which were five by twelve, four by fifteen, and three by twenty. It was noted that some students had different rectangle patterns but identical dimensions, whereas others had different dimensions but identical patterns. This elicited discussion in the classroom about how many possibilities might exist for each dimension.

Student 89: This seems familiar with what we learned last week about positive divisors of 60, right? The number 60 has 12 positive divisors: 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60.

Student 89 was looking at possible rectangles that can be created by factors of 60 (1×60, 2×30, 3×20, 4×15, 5×12, and 6×10).

Teacher: Can we generate each one of those rectangles using 12 pieces of pentominoes?

Students: Yes, no, yes, yes, no.

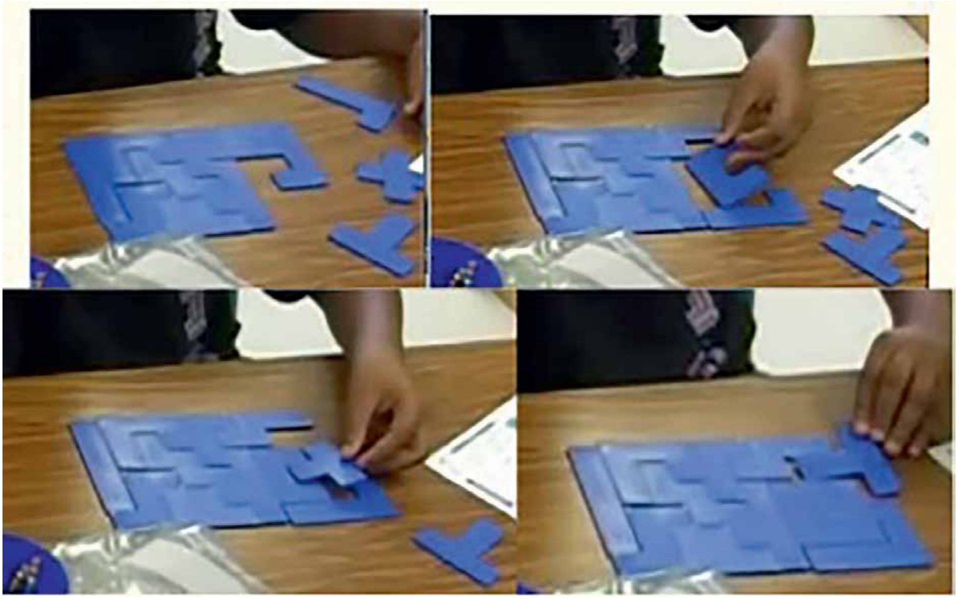


Figure 7.
Six by ten rectangle.

Some students believed that all conceivable rectangles (1 × 60, 2 × 30, 3 × 20, 4 × 15, 5 × 12, and 6 × 10) could be built with the 12 pieces of pentominoes, while others disagreed. Some students pointed out that it is not feasible to make a 1 × 60 rectangle, which can only be done if all of the parts are formed like the letter "I." However, a rectangle with dimensions of 2 × 30 cannot be constructed since parts like x are generated by three squares attached together, and hence cannot fit into the 2 × 30 rectangle size. One of the problems asks the participant to create a rectangle from twelve pentominoes; this is a frequent introduction to polyominoes. Because 60 has 12 divisors, there are six alternatives (1 × 60, 2 × 30, 3 × 20, 4 × 15, 5 × 12, and 6 × 10). Once again, due to the construction of certain pentominoes pieces, building a 1 × 60 rectangle or a 2 × 30 rectangle with pentominoes is unfeasible. Each of the other dimensions offers multiple options. Although these puzzles are rather basic, they are nonetheless highly effective for their essential didactic purpose.

3.6 Extension

Another set of simple-sounding yet challenging rectangle problems involves building two rectangles at the same time with twelve pentominoes. The better puzzles involving pentominoes are the ones that allow for multiple solutions for each rectangle. However, the best puzzles in this regard are those that don't require the use of a rectangle at all. Here below is an example of an extension for this activity:

Form a 3 × 5 rectangle and a 5 × 9 rectangle with twelve pentominoes at the same time.

Form a 4 × 5 rectangle and a 4 × 10 rectangle with twelve pentominoes at the same time.

Form a 5 × 5 rectangle and a 5 × 7 rectangle with twelve pentominoes at the same time.

Form two 5 × 6 rectangles with twelve pentominoes at the same time.

DOI: http://dx.doi.org/10.5772/intechopen.106189

4. Conclusions

The study of spatial visualization is significant because of the correlational and logical-intuitive evidence for its relevance to most technical and scientific jobs, including mathematics, science, art, and engineering. Involving students in activities that stimulated spatial skills are critical in equipping students with this needed skill. Activities can range from visual discrimination, games, and activities involving polyominoes. It allows students to create polyominoes pieces using squares manipulatives and then use the real polyominoes pieces for class activities createing a spirit of collaboration and promoting active learning.

Author details

Samuel Obara[1*] and Jake L. Hammons[2]

1 Department of Mathematics, Texas State University, USA

2 Department of Mathematics and Statistics, University of the Incarnate Word, USA

*Address all correspondence to: so16@txstate.edu

IntechOpen

© 2022 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

References

[1] Nurlaelah E. Improving junior high school students' spatial reasoning ability through model eliciting activities with cabri 3D. International Education Studies. 2018;**11**(1):148-154

[2] Clements DH, Batista M. Handbook of Research on Mathematics Teaching and Learning: Geometri and Spatial Reasoning. New York: MacMillan Publishing Company; 1992

[3] Council NR. Learning to Think Spatially—GIS as a Support System in the K–12 Curriculum. Washington, DC: National Academies Press; 2006

[4] Ontario Ministry of Education. Paying Attention to Spatial Thinking: Support Document for Paying Attention to Mathematical Education. Toronto: ON: Queen's Printer for Ontario; 2014

[5] Hawes Z, Moss J, Caswell B, Naqvi S, MacKinnon S. Enhancing children's spatial and numerical skills through a dynamic spatial approach to early geometry instruction: Effects of a 32-week intervention. Cognition and Instruction. 2017;**35**(3):236-264

[6] Lowrie T, Logan T, Ramful A. Visuospatial training improves elementary students' mathematics performance. The British Journal of Educational Psychology. 2017;**87**(2):170-186

[7] Tartre LA. Spatial orientation skill and mathematical problem solving. Journal for Research in Mathematics Education. 1990;**21**(3):216-229

[8] Dilling F, Vogler A. Fostering spatial ability through computer-aided design: A case study. Digital Experiences in Mathematics Education. 2021;**7**(2):323-336

[9] Clements DH, Sarama J. Early childhood teacher education: The case of geometry. Journal of Mathematics Teacher Education. 2011;**14**(2):133-148

[10] Wheatley G, Brown D, Solano A. Long term relationship between spatial ability and mathematical knowledge. In: 16th Annual Meeting of the Psychology of Mathematics Education, Baton Rouge, LA, USA. 1994

[11] Resnick I, Harris D, Logan T, Lowrie T. The relation between mathematics achievement and spatial reasoning. Mathematics Education Research Journal. 2020;**32**(2):171-174

[12] Resnick I, Newcombe NS, Jordan NC. The relation between spatial reasoning and mathematical achievement in children with mathematical learning difficulties. In: International Handbook of Mathematical Learning Difficulties. Switzerland: Springer; 2019. pp. 423-435

[13] Lowrie T, Logan T, Harris D, Hegarty M. The impact of an intervention program on students' spatial reasoning: Student engagement through mathematics-enhanced learning activities. Cognitive Research: Principles and Implications. 2018;**3**(1):1-10

[14] Uttal DH, Meadow NG, Tipton E, Hand LL, Alden AR, Warren C, et al. The malleability of spatial skills: A meta-analysis of training studies. Psychological Bulletin. 2013;**139**(2):352

[15] Cheng Y-L, Mix KS. Spatial training improves children's mathematics ability. Journal of Cognition and Development. 2014;**15**(1):2-11

[16] Pegado F, Nakamura K, Cohen L, Dehaene S. Breaking the symmetry: Mirror discrimination for single letters but not for pictures in the Visual Word Form Area. NeuroImage. 2011;**55**(2):742-749

Edited by Delfín Ortega-Sánchez

This book provides theoretical answers, applied methodological models, and didactic experiences that seek to reflect and analyze the potentialities and challenges of the active learning concept in STEAM disciplines and social sciences education. It also contributes to the understanding, intervention, and resolution of contemporary social problems and to the United Nations Sustainable Development Goals through the design, implementation, and evaluation of educational programs that incorporate integrated active learning as one of its explanatory axes.

Katherine K.M. Stavropoulos,
Education and Human Development Series Editor

ISSN 2755-9513
ISBN 978-1-80356-358-9
9 781803 563589

Published in London, UK
© 2022 IntechOpen
© NeoLeo / iStock

IntechOpen