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SCIENCE EDUCATION - RESEARCH AND NEW TECHNOLOGIES

Edited by **Antonio Vanderlei Dos Santos**
and **João Carlos Krause**

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Notice

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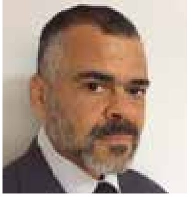
Meet the editors



Antonio Vanderlei Dos Santos is a scientist, and he graduated with a physics degree at the Federal University of Santa Maria (UFSM, 1990), master's degree in Physics at the Federal University of Santa Catarina (UFSC, 1993), and doctorate degree in Science with emphasis in Physics at the Federal University of Rio Grande do Sul (UFRGS, 1997). Currently, he is an integral teacher at the Integrated Regional University of Alto Uruguai e das Missões (URI). He has experience in Physics with emphasis in condensed matter physics, acting mainly in the following subjects: electronic structure, band structure, nitriding, teaching of physics and magnetic alloys. He is a teacher of the Masters' Course in Scientific and Technologic Teaching acting in the following subject lines: information technology and science teaching, educational practices in the science and technology teaching. He also teaches the Masters' Course in Strategic Management of Organizations ministering the discipline of "Knowledge and Innovation Management" and acting in the following subject line: development and social organization in the innovation management. He is a coordinator of the Nucleus of Innovation and Technological Transfer of Santo Angelo's campus (NITT), acting in many projects. He is a head of department in Exact Sciences and Exact Earth.

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Contents

Preface

Technology applied to education, when treated as an interdisciplinary study, is a tool that has been used in several universities and research institutions, where several disciplines that switch theoretical concepts are grouped in previously non-existent areas. Therefore, we must demonstrate not only that this type of study is important, but also develop methodologies so that we can really work on the integration of concepts. But this is of no use unless the appropriate teaching technique is applied, being based on a solid theory, since the optimization of the professional future passes through the mastery of the basic concepts of several areas of knowledge.

The book is divided into two major sections: the first one is "Didactics Applied to Science", which is a branch of the Pedagogical Sciences that deals with methods and techniques that enable students to learn through a mediator of contents. It is the practical part of the bases of pedagogical theories. In this section we present the following chapters: "Introductory chapter: Science Education - Research and New Technologies", a preliminary chapter that has the function of presenting the theme of the book to the reader; followed by the second chapter "Mathematics Instruction Based on Science Using Didactical Phenomenology Approach in Junior Secondary School in Indonesia", the third chapter, "Transformative Orientation in Learning to Teach Physics and Chemistry" ,the fourth chapter, "Teaching and Learning Primary Science for Marginalised Children". Finally, the fifth chapter, "Discussing Socioscientific Controversies in Primary and Secondary Education: Potentials and Constraints in Science Lessons", wrapping up the first section of the book.

In the second section, we have the simulation models applied to science education entitled "Simulation in Science Teaching". In this section we have the chapter "Electric Power System Simulator Tool in MATLAB", in the same theme we present the chapter "Software for Simulation of Static Switch Controllers". The third chapter in this section presents "Computer Science Education and Interdisciplinarity" and at the end of this section and the book itself we present "Electric Machines: Tool in MATLAB".

This book presents chapters that summarize what is best today in the universe of science and technology education, by the diversity of authors, themes and participating countries. Also, the researchers' varied backgrounds highlight the diversity of thoughts and paradigms, not to mention the cultural formation of each one of the researchers, thus, making a book of science with diverse scientific thoughts in a democratic system of evaluation and therefore presenting a product of high editorial quality.

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Section 1

Didactics Applied to Science

Chapter 1

Introductory Chapter: Science Education - Research and New Technologies

Antonio Vanderlei Dos Santos and
João Carlos Krause

Additional information is available at the end of the chapter

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1. Introduction

The scientific education has passed through many transformations in the last years, but the main one is the rise of cheaper and more efficient computers, allowing teachers and students to use it in a discriminated way. With this easy access, other devices like cell phones and similar communication products emerged allowing the rise of the information and communication technologies (ICTs). In this book, we will have chapters that present various use types of the ICTs applied in teaching, allowing a pleasurable and interesting reading to this theme, showing researching works from many nationalities that converge to a common theme which is the technological education, and demonstrating that this labor is a world class issue and not just a local one.

Nowadays, the new ways of seeing and obtaining information of the teaching processes have triggered a new teaching approach, allowing the incorporation of new teaching methodologies to the process of teaching. These new methodologies include flexible and creative strategies and resources that enable new models of interaction between teacher, student, and community. That positively influences the whole process, also being experimented in the formation of several other professionals, not only for science teachers.

These new methodologies should provide and/or provide these professionals with new assistance, management, teaching, and research skills, in which the student should be encouraged to develop skills, criticality, and creativity in their actions.

A more critical look at the use of technologies in education and its various resources bring us new ways of seeing and obtaining information, transforming them into useful products for learning, an aspect that inspired the work presented here.

The rapid evolution of ICTs has created opportunities for networking environments with enormous amounts of information. In this scenario, people can easily find everything that interests them, favoring the use of these tools in several sectors, including teaching, research, and extension, thus recreating new models of interaction between humans.

The teaching of content in the area of exact and land sciences is undergoing changes in several aspects. This is the content presented and its relation to other contents of other areas, such as polytechnic teaching, as well as in its presentation to students, such as video lessons, computer applications, and new hardware, such as high-resolution screens and or Arduino.

These new resources are being inserted in the educational context and, as observed within schools, are still subject to controversy and little use; this has been occurring for several reasons, from the lack of teacher training to the economic factor; but one of the main causes is the lack of pedagogical innovation in educational systems.

In this context, there remains a gap to be filled with new research that seeks to solve these problems, collecting real data, and presenting more appropriate solutions and tools.

Thus, we are led to think of some disciplines that are the main causes of this controversy, as well as the low motivation of the students; we can observe this in the exact sciences, as well as the use, or lack, of technologies to encourage students in the study of these disciplines.

The use of technology in education is not restricted only to computer, pen, whiteboard, and slide projector, for example, other technologies, that already are or may be inserted in the classroom, can also be considered. But what is most striking is the computer "because it is a tool not only of classroom study, but also a tool of work after school" and is still the great responsible for the doubts and inquiries of most teachers of basic education.

Another problem commonly encountered in high school classrooms is the teaching of the Physics, which is often a problem for teachers, and it is common sense among students that the discipline is difficult. It is also noted that Physics is not very appealing to high school students, mainly because of the difficulties presented to them while studying, causing serious problems to the students in the course of their academic life, even after entering university.

Computation, as a teaching and learning tool, has been developing throughout this century, with enormous advances in the area of software, such as implementations in the area of scientific visualization and in the development of computational calculations.

The evolution of concepts and new products in the area of hardware has also brought advances in teaching, but not all of these products are positively associated with the conceptual part, both in terms of content to be taught and teaching itself.

One of the questions about computing resources in schools that has been extensively debated is that, in addition to the obvious lack of trained human resources, the lack of application of these computational resources available in schools makes these resources idle. And this lack coupled with the lack of preparation of human resources in schools (not to say clearly of the teacher) ends up harming the application of harder contents to the detriment of an easy visualization of the same with the aid of the ICTs.

In the formation of future specialists, computer education cannot ignore the reality of a society in which research and technological progress are based mainly on interdisciplinarity and transdisciplinarity.

Finally, certain practices, discussions, methodologies, and/or components that would aid in science classes should always be based on the day to day of educators, since education must be the gear that moves the evolution of the human being. Therefore, the incessant research on ways to facilitate teaching learning and/or improving the coexistence between teachers and students should be continuous.

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Mathematics Instruction Based on Science Using Didactical Phenomenology Approach in Junior Secondary School in Indonesia

Turmudi, Setya Utari, Suprih Widodo and Ratnaningsih

Additional information is available at the end of the chapter

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Abstract

This chapter presents the result of research that is motivated by a sense of concern where mathematics learning in the class now has been rarely associated with science lesson. We tried to see the existing phenomenon, then we designed science-based teaching materials of mathematics using that phenomenon as an approach to teaching for students. There are two levels when developing instructional design that is at the level of research conducted in the laboratory of physics, by weighing the sugar and water proportionally, then stirred the sugar solution to obtain a wide range concentration of sugar solutions which are stored in the experiment tubes. This experimental tool is then used to facilitate students learning the relationship between two variables such as sugar concentration is expressed in percent on one hand and sedimentation time (in second) of "a clay ball" on each of the sugar solution on the other hand. Pairs of numbers concentration and sedimentation time of "ball" in each solution were plotted in a Cartesian coordinate. The graph reflects a phenomenon of solution viscosity and sedimentation rate of a ball in a solution that can be aligned with the level of consistency of "blood in our body" and that circulation is disturbed when the blood concentration increases. The results of this study indicate that students have an awareness of the importance of the health while maintaining the concentration of the solution for being drunk and eaten. Suggestion from this research is that the readers could consider that sugary drinks with low concentrations, which still be able to maintain a person's health, are better than the sugary drinks with very high concentration.

Keywords: science-based, didactical phenomenology, mathematics instruction

1. Introduction

Didactic phenomena in our understanding are exploiting the phenomenon as medium or bridge for learning concepts. In learning mathematics, didactical phenomenology interpreted as a means to learn math concepts as [1] stated that the didactical phenomenology is a way to show the teacher place where the learner may step into the learning process of mankind (p. ix).

Starting from the situation that the human body contains thousands or even millions of mysterious phenomena, some of which we can observe through the sheets of the doctor who advised us to go to the lab for having general checkup for our health, having our solutions or body fluids to be tested. It turned out that the concentration of the solutions in the body affects the healthy condition of our body. When the glucose in our body exceeding the normal size, then our health would be affected. When a less glucose (very low concentration) is present in our body then obviously the balance of our body also affected. This situation encourages the research team to take advantage of this phenomenon in mathematics.

Data in the **Figure 1**, represent the result of health lab test of the first author of this chapter (health of Turmudi's lab test) which was conducted in February 25th, 2014 in the Pramita Lab of Bandung. Suppose the number 130 mg/dl for triglycerides showed that as many as 130 mg of triglycerides in 1 dl solution, a healthy person is when she/he has less than 150 mg/dl (<150 mg/dl).

Learning mathematics using mathematician framework usually takes place when introducing the concept of sets and functions and then the "set approach" is used. Therefore, the function is understood without using illustration. Function concept is understood as verbatim. Most mathematics teachers in Indonesia usually introduce relationship or function concepts using arrow diagram. Relating two sets of quantities, such as group of students in one hand, and their shoes number size in the other hand. He/she used arrows to link among two sets of quantities.

Figure 2 represents the relationships among two quantities such as name of persons in set A and numbers of their shoes in set B. The research team, however, prefers to take advantage of this phenomenon by associating two specific situations. Rather than using data without

PROFIL LEMAK
Profil Lemak Lengkap

Cholesterol ®	158	Yang diinginkan : < 200 Batas tinggi : 200 - 239 Tinggi : > 239	mg/dL	CHOD PAP
Trigliserida ®	130	Normal : < 150 Batas tinggi : 150 - 199 Tinggi : 200 - 499 Sangat tinggi : >= 500	mg/dL	ENZYMATIC
HDL Cholesterol ®	47	Rendah : < 40 Tinggi : >= 60	mg/dL	IMUNOTURBIDIMETRI
LDL Cholesterol Direct ®	96	Optimal : < 100 Mendekati Optimal: 100-129 Batas tinggi : 130-159 Tinggi : 160-189 Sangat tinggi : > 190	mg/dL	DIRECT ENZIMATIK
Ratio LDL/HDL	2.0	CARDIO RISK INDEX (CRI) < 3 : Resiko rendah 3 - 5 : Moderat > 5 : Resiko tinggi		CALCULATION

Figure 1. Data from a health laboratory.

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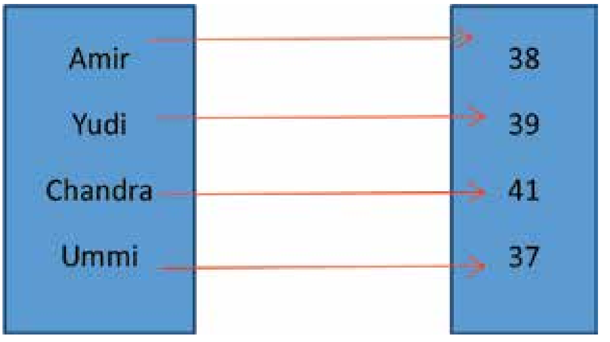

Figure 2. Example of relation between name and shoes number.

meaning (meaningless), the research team prefers to observe variety of sugar solution concentration, and checking the time sneaking by an object at any percentage of sugar solution. The research team chose some phenomena by conducting experiments for each of these phenomena, and all served in front of students in the classroom. The result is quite amazing because students turned out to have an awareness of the usefulness of the relationship between a quantity and other quantities in the phenomenon.

Sugar solution is prepared with varying concentrations of 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50% by the researcher team (**Figures 3** and **11**). Then an object in this case is a small sphere like "ball" made of plasticine dipped in each solution. Here, we have two quantities when a dipping clay ball, i.e., concentrations of the solution expressed in percent and time crept from plasticine ball measured using stopwatch and expressed in seconds. We note the plasticine ball sneaked time in different percentage of sugar solution, so we have ordered pair numbers,

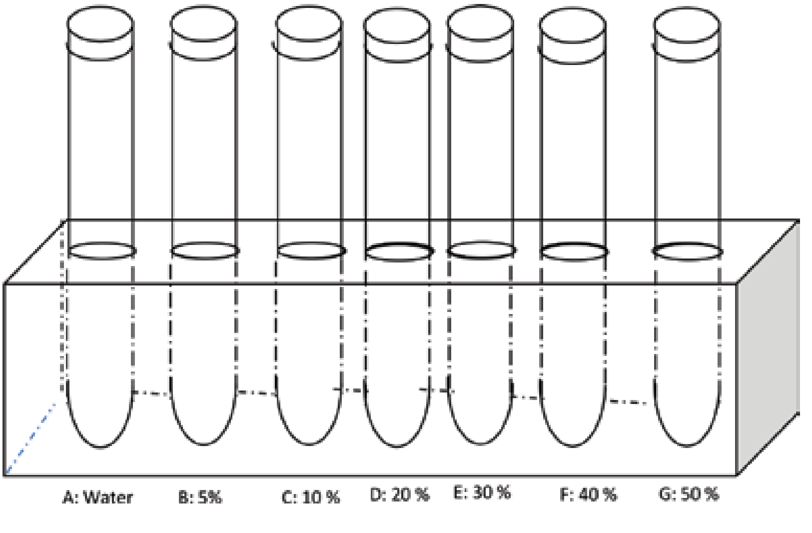

Figure 3. Solutions of sugar cane in percents.

that is the number percentage of sugar solution and sedimentation time of "ball" on each of these solutions.

Figure 3 represents various concentrations of solutions. Practically, we used more details of sugar solutions by inserting 15, 25, 35, and 45% of sugar solution. Instructional design of mathematics based on the science using didactical phenomenology approaches was presented to the students, so that the students have a sense of the relationship between two quantities. Students have the ability to represent it in a variety of mathematical representations. Furthermore, numbers obtained are processed and then packaged in various forms of mathematical representations. Using this reflective thinking, students can think mathematically and scientifically to instill their awareness to be able to live in a healthy life and harmony.

The chapter presents the results of this study synergically involving scientific activities. Didactical phenomena of instructional design of mathematics were designed by the team in the laboratory activities, recorded using video camera, transferred to the power point presentation. The student tasks in the classroom were to make mathematical model or mathematical graph related to the data as the result of observation was recorded in video camera and power point presentation. These data were presented in the form of table. The pair numbers in the table as coordinates were then be plotted in the Cartesian coordinates. By graphing this phenomenon, the students were asked to interpret the phenomena.

As a design proposed by Verschaffel, Greer, and De Corte (2002, cited by Turmudi et al. [2], **Figure 4**), the process of learning mathematics that involves the modeling process includes the observation of phenomena (reading), understand the situation, modeling, analyzing the model, formulate the results, interpretation, and then make a communication:

The teaching materials of mathematics in this study used the didactical phenomenon in the form of a natural situation or similar situations that conditioned the models created in the science laboratory. The students in the classroom are faced with these instructional materials and the materials were manipulated in the form of power point presentation.

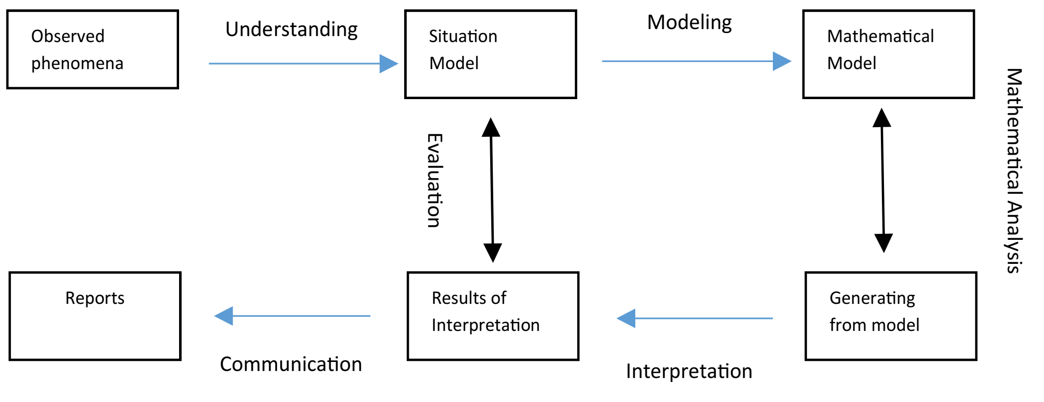

Figure 4. Diagram of mathematical modeling process.

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2. Background

After doing some research in a clump of innovative teaching, research teams are interested in trying out the learning of mathematics with science-based didactic phenomena within reasonable time. Research studies on realistic mathematics have been conducted with the result that is very promising and could attract the attention of students [3, 4]; encourage teachers in the Bandung city area to realize that they already know their innovative ideas but do not have the ability to present learning with innovative ideas because of the absence of exemplary prototypes [5, 6], the teachers realized that the training through lesson-study has opened their insight to continue working and improving the learning for teaching of mathematics in the classroom [7] but the teachers still require exemplary prototype of mathematics learning using scientific approach that can be implemented in the classroom, so that openly they can watch in open-lesson setting, and in turn the teachers be able to implement it in their respective classes.

Results of research on mathematical modeling by [2, 8] show that the students involved in the study felt there was something new in mathematics instruction. For example in view of the variables that were not visible, but after attending the workshop the participants were able to see the variables in the phenomena, so they were able to make the association among variables that exist to make a mathematical model. Consider the following figures:

Figure 5 is the pattern model that originally taken from the floor of JICA-FPMIPA building of UPI on the second floor (**Figure 6**, personal collection of photograph), the tile patterns can be seen in the image (**Figure 7**, personal collection of photograph).

At first time, the images were just as the pictures without meaning, the students are not too concerned with tile patterns like that, but with a small call "Let us see and we noticed a pattern (in **Figure 7**), as well as how to process it so we could have an interesting mathematical concept." The invitation make a number of students feel surprised by the mathematical patterns that exist in the JICA Building, in Bandung. When the students were able to see the pattern of the picture and are able to associate with the image number and the area of the geometry shapes, then they obtained a mathematical model that previously did not figure

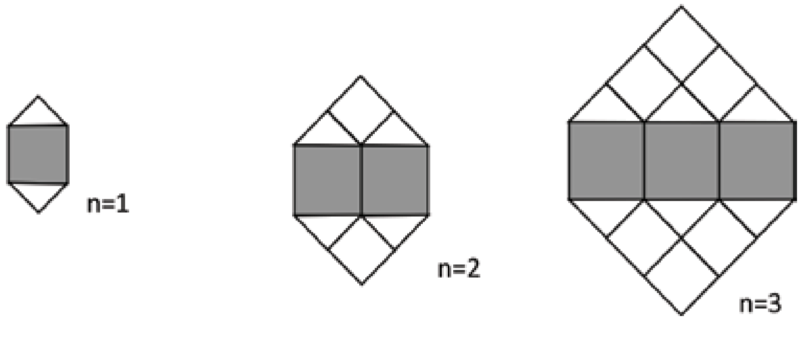


Figure 5. Patterns of floor in JICA-FPMIPA building.

Figure 6. JICA-FPMIPA building in UPI.

out. This association when we continued to the 4th, 5th , 6th terms and so on until the n-th term, it will get the functional formula by following form of $F(n) = n^2 + 2n$ with n is the image number (term) and F(n) is the area of geometrical shapes. By knowing how to build and determine the formula of model, the students can reach through the process of horizontal and vertical mathematization [9] and the process of progressive mathematization [10]). Teacher's capabilities to view such situations nowadays are needed urgently, so that they can try out these competences at the microlevel of the classroom. Such capabilities are seemed urgent, because the implementation of the 2013-curriculum [11], which was characterized scientifically, in fact, was not absorbed completely by the teachers during the 2013-curriculum upgrading. Therefore, the presence of such learning is a positive contribution toward building the current curriculum innovation in Indonesia.

Provisioning capabilities of mathematical concepts, and the pedagogical content knowledge (PCK) of mathematics for teachers would give effects to a teacher as an actor of mathematics learning in action in front of the class. The ability to see the phenomena should be the part of the teachers' as well as the students' competences, so that they always think continuously

Figure 7. Floor in JICA-FPMIPA building.

over time and will always able to find connections between the existing phenomena by taking into account the specific quantities or the shapes in the flat geometry (2D) or space geometry (3D), therefore it can intertwined the functional relationship between the quantities that appeared in Ref. [54].

3. Statement of the problems

Implementation of mathematics instruction based on science using didactical phenomenology approach is asking the question "Does the teaching material of mathematics using science-based didactical phenomenology approach effect positively to the students' cognitive abilities?" This formulation was translated into a number of formulations more specifically as follows: (a) How is the prototype mathematics learning using science-based didactical phenomenology approach? (b) How does the implementation process of learning mathematics using science-based didactical phenomenology approach? (c) What was the students' reaction to the teaching materials? These questions are answered by designing instructional materials, which are prepared in the science-laboratory and implementing them in the real classroom.

4. Theoretical framework

Equipped teachers with a number of competencies [12] suggested teachers [mathematics, in addition to the author] to follow the development of professionalism in order to gain new knowledge and skills so as to improve their teaching in the classroom. Nevertheless, we do not deny the condition that the change turned out to be only on the surface, as stated in Ref. [13] "There were not a lot of professional development activities for teachers or other types of innovations implemented as a routine activity for the next stage but there is only the result of the professional development (PD) or innovation is communicated through questionnaires, interviews, or a survey" (p. 77). Symptoms such as those indicating innovation through PD (seminars, training, workshops) face the problem of sustainability, so often teachers are still applying old habits, otherwise known as the "back to basic," even though they have attended a number of times the workshops, seminars, and others. But the situation now is different, although the general teachers feel less comfortable when seen and observed by other teaching [14, 55].

Now gradually the teachers' perception have changed, at least felt by the teachers who attended the lesson-study in Bandung [7]. They have changed their habits according to an anecdote, quoted by [15], "Two jobs that do not like to see by other people. That are work as a teacher and work as a thief," and if this anecdote is true, then for teachers, they are now open to be observed by others either by the teacher (another)or by policy makers (supervisors, department heads, principals). Now, they are open to learn from each other in improving the quality of learning at the microlevel in the classroom. Openness like this makes the chances of a teacher to have the optimal ability to make the classroom productive and allow teachers to apply science-based mathematics instruction, so that the students have an opportunity to be creative in learning mathematics and sciences.

Through the implementation of these learning materials, it was difficult for students to forget it, because it has a very deep impression and also encourages teachers to apply them in their own learning accomplishments.

In a study paper, Ref. [15] recommends to examine deeply whether the teachers' willingness to improve their professionalism in teaching tasks can improve their perform in teaching? Moreover, whether their better perform can improve students' achievement in mathematics? What kind of professionalism improvement could boost their strong willingness to innovate mathematics instruction? To answer the challenge of the recommendation, the author offers a study on the implementation of learning mathematics using science-based of didactical phenomena [1, 54], and empirically tested the implementation of this learning in the classroom.

Mathematics classes with the types of "transmission" as described by Senk and Thompson [16], include the introduction of each topic by declaring a rule which is followed by an example of how to apply the rules (rules, the arguments, the law), and then given a number of exercises, have encouraged developers who are looking for alternatives. Now, the effort to reform the mathematics is to portray the students participation actively, to transform the learning characterized by the "transmission" and to the learning characterized by the "participation."

In studying mathematics and science, the role of the students is constructing knowledge with the teachers. The teacher reveals the problems, asking questions, listening to students' answers, pursuing with follow-up questions (probing questions), and then wait for the responses of the students in the formation of knowledge or mathematical concepts expected. Teachers should be little patience to listen to the arguments, presentation, and reasoning expressed by the students, either in the form of oral or written communication.

Hearing the mathematical ideas of students is an important aspect in learning sound constructivism, i.e., to shift from "telling and describing" to "listening and questioning" and "probing for understanding" [17]. With science-based instruction of mathematics, students are directly retrieving data, processing the data, presenting the data in tables, and describing the data in the table into a chart and then it becomes possible to make a mathematical model of images.

5. Didactical phenomenology

The idea of a didactical phenomenology of [42, 1] provided the inspiration to explore the mathematical content through a search phenomenon that is suitable for regions in Indonesia. Suppose how to introduce the concept of linear equations using scales [43], introduce the concept of equation of a straight line or linear function using taxi fares and the cost of photocopying [44], teaches the volume of flat sides of space objects using sand beach [45], teaches the volume of balls and tubes using watermelon [46, 15], and many numbers of phenomena that can be appointed as a "bridge" to understand the concepts of mathematics for students.

An example of how the phenomenon of ball volume is approximated by cleavage of a watermelon is discussed as (**Figure 8** is personal collection of photograph) follows:

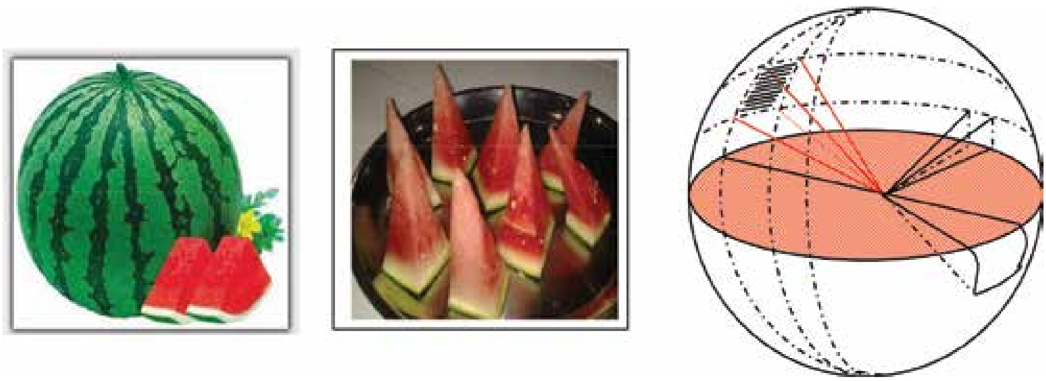


Figure 8. Watermelon ball to show the formula of sphere volume.

By adding the volume of "pyramid models" that are created from a watermelon ball accurately obtained the volume of ball [46], although students are still in doubt because the base of the pyramid-like model was a curved surface. However, this is in line with that proposed by [47].

Using the third figure of **Figure 8**, you can notice the role of "pyramid" in the sphere, that in a sphere we can make many "pyramids-like" models. One can make it easily by using watermelon.

Furthermore, the professional mathematics society which among them are mathematics teachers can help learning how to apply the kind of inquiry studied in the context of exploring didactical phenomenon. Ref. [48] distinguishes between the teachers who are looking for success in their career and teachers who tested their practice in relation to their thoughts. When teachers are tested on the basis of meaning of broad principles, in practice, they are involved in the alteration [48]. Such tests provide support for teachers to learn continuously and make them able to improve their teaching practices continuously anyway.

The existence of such a professional society is very important in supporting experienced teachers to teach in new ways [49, 50]. Professional societies not only provide space and time, but also can provide an environment for teaching practice. Mathematics teachers are the part of the communities involved in the effort to introduce the proceedings of their teaching practices, and can experience this type of learning for students as suggested above. These reforms initiated teachers to strengthen their classrooms with "learning society" in which students explore mathematics in depth [51].

Furthermore, [52] explains that the assumption of "communities of learners" is a form of learning that occurs when people participate actively and discuss with each other. In learning communities, students who are mature or not will share the responsibility to determine, direct, and manage the joint efforts. In view of the innovation, teachers organize students way of thinking, but the role of the teacher is a facilitator not a provider of answers. Mathematics class is seen as a place where students can actively make meaning of themselves and emphasize the process of learning mathematics [50].

The articles on the research and learning in the lesson-study are a matter of joint publications between teachers and lecturers. Students see "the form of linear equations" by comparing it with the "model of scales" a very pleasant experience. Forming a linear function using the "taxi rates and photocopy expenses" is an attribution according to the mathematics teacher that mathematics is so close to the real situation that is faced by the students. Moreover, study the volume of the tube using a "long watermelon" and make it easier for students construct so that they can find the formula for volume of tubes and balls. After mathematics learning students are allowed to consume the watermelon.

6. Roadmap of research

Researches that have been carried out by the authors that contribute to this study were presented in the form of road maps (fish backbone), such as research on RME (Realistic Mathematics Education), contextual learning of mathematics [3, 4, 18], mathematical modeling [2], planting consciousness of innovation on mathematics teacher [7], research on ethnomathematics [19, 56], learning with the nuanced phenomenon of didactic in junior secondary student [20], as well as the learning of mathematics using didactical phenomenology in primary school students [54]. The results of the study of RME turned out to encourage students' enthusiasm for learning mathematics [3, 4, 18], mathematical modeling has opened the horizons of students to be able to see the phenomena that can be modeled [2], it turns ethnomathematics research opens up new horizons of research in the domain of mathematical culture [19, 21]. **Figure 9** is a fish bone of research roadmap within several years which covered realistic mathematic education and contextual teaching of mathematics, mathematical modeling, ethnomathematics, didactical phenomenology in mathematical areas.

Further, Ref. [22] added that for a group of teachers they observed, "the teachers reflection anf involvement in professional development opportunities seemed to provide of catalyst and

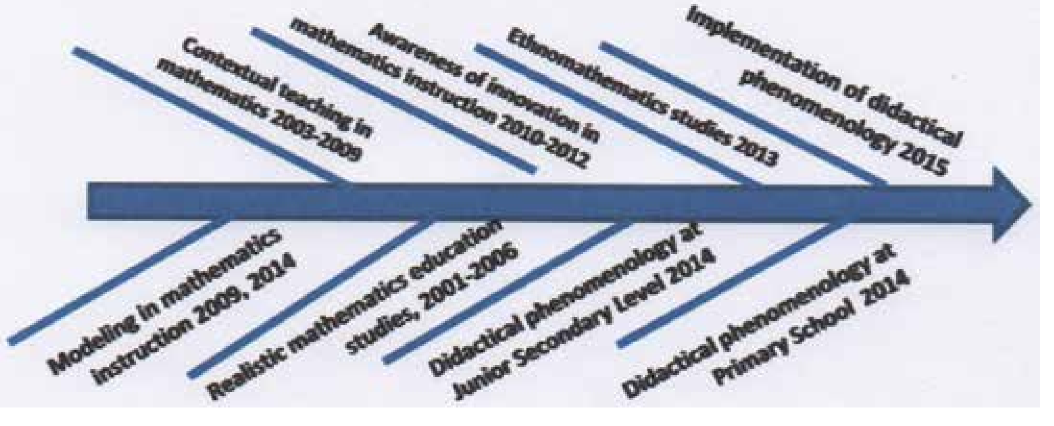


Figure 9. Fish backbone of research roadmap.

change" (p. 130). Professional development of teachers often focuses on helping the teachers to improve learning in the classroom by developing the knowledge and pedagogical skills of the teachers. Professional society engaged in teaching suggests effective ways to provide support to teachers in implementing models of the new learning in their practice [23–27]. But Ref. [27] notes, "… is not so clear how people do or how they create or continue programs and policies" (p. 165).

In conjunction with the program of learning and professional development of teachers, Ref. [28] notes that "one of the two premises report of Glenda (US dept of Education-2000), that better quality learning is at the heart of change, and professional development program cannot be separated from the essence of improving the quality of learning" (p. 331). Our team of researchers, looked at the strength and nature of the professional teacher community, somewhere has significance because (1) the professional community can bridge and translate the efforts of renewal, (2) the professional community can provide support in introducing the kinds of renewal of learning mathematics (e.g., inquiry) required for the practical development of the principles and values are discussed. Empirical evidence and theory suggest that the strength, nature, and focus the professional community in the field of teacher training can bridge the efforts of the school when students learn. Furthermore, the school community can filter the principles, which vary knowledgeably as well as affect the interpretation of the goals of reform (renewal) in mathematics [29–31].

There is a serious criticism of the views of the previous example of the insights that mathematics is a knowledge that is fixed and static [32], as a system, rule, and formal procedure [33], as the rules and right procedures [34], as a set of concepts and skills that must be mastered by students [35]. Suggestions successor is the shift to alternative views, suppose the mathematics as a dynamic subject, as a human activity [10, 32], as the activity of the human senses and problem solving activities [35], or mathematics as humanized and antiabsolutist [36–39]. To facilitate students actively learn mathematics through investigation and exploration, there should be provided a phenomenon that was built by the designer of learning mathematics.

Research on realistic mathematics and their implications on the performance and abilities of students in mathematics further encourages depth curiosity of the research team, how much effect if we add or take properties of learning [56, 40]. From studies conducted on RME, contextual learning, ethnomathematics, modeling, and the phenomenon of didactic raise new questions, "What if the mathematics and science synergize so that students can conduct investigations either individually or together in group in the classroom." Let the students simulated such as how long the water flow from each faucet with various diameter sizes that range from a tub of water.

Suppose a liter of water was expelled through a Faucet A with hole diameter of 2 mm, then we measured how long the pouring time, compared to a Faucet B with hole diameter of 4 mm, we also measured how long the pouring time. Students are required to collect and record the information obtained in the form of a table for which they are asked to describe the graph and determine the mathematical models, equations associating the faucet diameter with the flowing time.

Further to the solution of sugar water with various concentrations of submerged objects that sank in all of the solution, students are asked to interpret the meaning of drowning and are associated with a ratio of the density of objects with the density of each solution. Students are also asked to investigate for how long the objects undergoing the process of sinking from the surface of the solution to the base of the tube solution. The stopwatch is used for recording of each liquid in the tube. Students are also able to model mathematically the magnitude of the solution concentration by the length of the time (in seconds) the object taken to fell from the surface of the solution to the bottom of the bottle.

I wonder what effect it has on the health of the body, if someone drinks a thick liquid of sugar continuously compared with drinking fluids diluting the sugar. Continued impact of what happened to our body turns into increased blood viscosity? How did it effect the blood circulation and the transport of oxygen from the lungs to the brain by the blood? These consequences are expected to sensitize students to maintain their own health.

7. Innovative perspectives

The views of this innovative approach affect how the teacher in the classroom and how teachers evaluate students learn mathematics. This is related to the questions of the students related to mathematical ideas, the introduction of mathematical concepts, encourage and promote discussion and group work. The Minister of Education and Culture of Indonesia in the era of 1990s reminds us through his views on mathematics and science "Most schools and teachers treat students as a 'vessel' or something to be filled with knowledge." Another well-known example is the tendency toward right-wrong answer/fact-based learning. School and teachers focus on getting the right answer from the students at the cost of developing the processes that generate the answer [41]. Furthermore, he argued "I would like to challenge you to create greater understanding on how students learn as prerequisite for improving our teaching methods in mathematics and science, and improving the education of teachers for these subjects" (p. 36). These challenges need to be captured and acted wisely, of course. Similar challenges also presented by the President of the National Council of the Teacher of Mathematics (NCTM), Glenda Lappan "Throughout the more recent mathematics education research literature, there have been expressions of growing dissatisfaction with the limitations of the traditionally formal ways of teaching mathematics." Suppose, Lappan (1999, cited by [16]) provides arguments "We have had the longest running experiment in human history about whether rote memorization of facts and skills works." And it does not. Students are coming to universities and to the work place for not understanding mathematics. Why would not I want to try something new?

Challenges like that should be welcomed "Why we do not want to try something new?" After Lappan [16] we had a long trial of the history of humanity, about whether rote memorization of facts and skills can take place either? Challenges of Minister of Education and Culture, to (1) create a better understanding and to create a method of learning in mathematics and science [41], and (2) the growing dissatisfaction with the limited ways of teaching mathematics is traditionally formal (Glenda Lappan in Ref. [16]), gave rise to the urge to try something new, for example learning by using didactical phenomenon. Lappan (in Refs. [16, 41]) was one of international proponents who are very concerned for better innovative changes.

The underlying issue is how do we support the desire of teachers to improve learning in the classroom and how to provide examples and ideas that can be utilized in a practical way by the teacher in the classroom.

8. Action plan

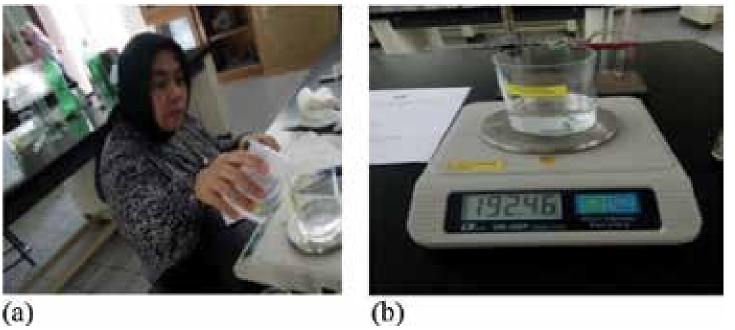
Teaching materials designed in the planning of learning include sugar solution, water fountain with various sized holes, burning fireworks, and opening faucets (various sizes of angle) to record the time of flowing for a certain volume of water. However, because of limited space for reporting in this chapter, learning implementation of sugar solution is only discussed, while others will be described in other chapters.

The research team succeeded designing instructional materials that tried to link the two quantities, namely the percentage of sugar solution and long-time sneaking of a ball of clay.

Sugar solution is formulated by weighing the sugar and water. In **Figure 10**, the researcher team made sugar solutions by balancing the sugar and water proportionally and stirred them, and the results were presented in the tube as in **Figure 11** (personal collection of photographs).

8.1. Sugar solution

The instructional design resulted by researcher team produces sugar solution with varying concentrations, as appear in **Figure 12**. With the sugar solution, it is expected that students are able to obtain the numbers as domain and its pair numbers as member of codomain. Suppose that 5% sugar solution is stored in glass tubes. We enter a small ball made of plasticine, then measure the time duration of sneaking the ball when put in a 5% sugar solution. The trial results showed that the sedimentation time of plasticine ball in a 5% sugar solution is 1.22 s;



(a) (b)

Figure 10. Balancing the sugar and water.

Figure 11. Sugar solutions with various concentrations.

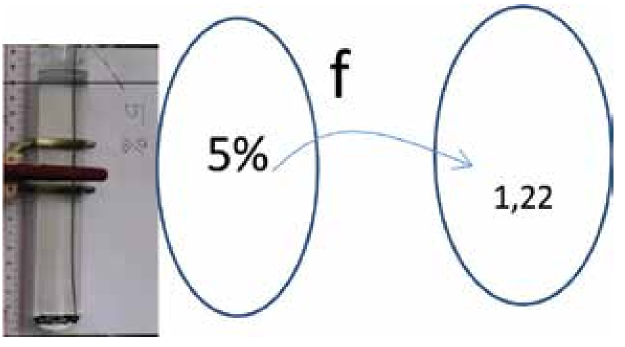


Figure 12. Five percent sugar solution with “time sneaking”.

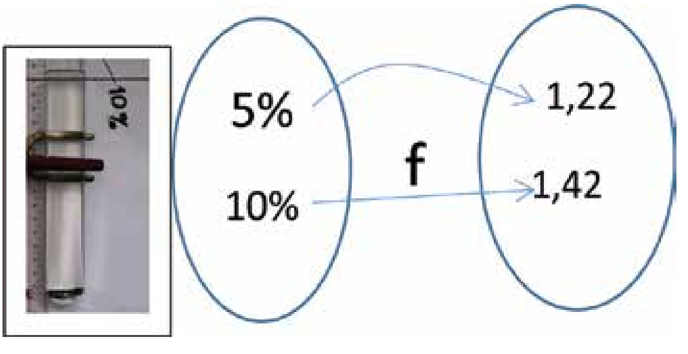


Figure 13. Five percent and 10% sugar solutions with “time sneaking”.

and in 10% sugar solution time is 1.42 s, and so on. Therefore we can present the results as in **Figures 12** and **13** (personal collection of photographs).

If we continued this work then we would obtain functional relationship between percentage of sugar solution and time taken by the ball sneaking in the sugar solution. So students can describe

Figure 14. (a) Discussion in Sci Lab, (b) working in Sci Lab.

"function that occurs in the form of graphs of functions in Cartesian coordinates". **Figure 14** indicated the team researcher to obtain the sugar solution accurately (personal collection of the photographs).

9. Implementation in the classroom

Learning in the classroom begins with understanding the concept of relations and functions using conventional approaches, but students are asked to make the association between the two functions without involving the phenomenon. Then introduced didactical phenomena of science to the students by presenting a power point presentation as an observation summary of the sneaking of a "clay ball", asking students for taking note the time in respective bottle of sugar solution (0-50%). Furthermore, students record each of the events and copy them into a table that has been provided. Moreover, the students also observe how the burning of fireworks takes place and record the time duration of fireworks burning from start to finish. Other thing that be learned by the students in the classroom was in making association between the wide hole of diameter of faucet and the debit of flowing water for each faucet. However, due to space limitations to address all the learnings in this chapter, a team of authors only discussed part of the sugar solution.

10. Discussion

10.1. Design phase

There is one interesting thing that happens when the sugar solution reaches to 50% solution. It turns out that "ball clay" is not sinking, the ball in the solution is not dropped or immersed in the 50% sugar solution, but went up and floating. A member of the researcher who is a junior high school teacher was alarmed and shocked and thus raises the question "Why not down?" Why and why? She relayed the question over and over again while still in the physics lab, during a process of designing instructional materials that have not been brought into the junior secondary class.

Because the solution that is available only up to 40–50%, while 45% is not yet available, so he had the initiative and desire to deeply make a solution of 45% immediately and she wanted to know how the time crept to the 45% sugar solution. The research team soon made the 45% sugar solution, and measured how long time (how many seconds) a plasticine "clay ball" felt down in the sugar solution. In fact it took 61,22 seconds.

For an ideal situation after discussion with the team (persons of mathematics, physics, computer science, and mathematics teachers), the team suggested we should also know the duration of time sneaking of the "ball" in the solutions of sugar 41, 42, 43, 44, 46, 47, 48, and 49%, but due to time constraints and opportunities, the team finally just gave a prediction of duration time that in graph will look roughly like the image below in **Figure 15** (the graph is made by the researcher team using excel).

For junior secondary students, drawing graph smoothly was not a main target. There was no obligation for students to draw graph smoothly. But the researcher and developer team in this study try to interpret and predict the form of graph look like. It encourage students and recommend the researcher team to investigate further for the numbers around the 45%. It provides an impetus and a recommendation to investigate further around earlier numbers.

Equations or mathematical models in relation to the concentration of the solution with time of "sneaking ball" into a particular function, again for junior high school students, have not been the main target. The junior high school students are required to put or plot dots of various observation results as coordinates (solution, time) or coordinates (time, solution).

10.2. Discussion in implementation phase

Before getting into the observation using teaching materials (model) that have been prepared in the laboratory to the students, worksheets were also presented which aim to explore

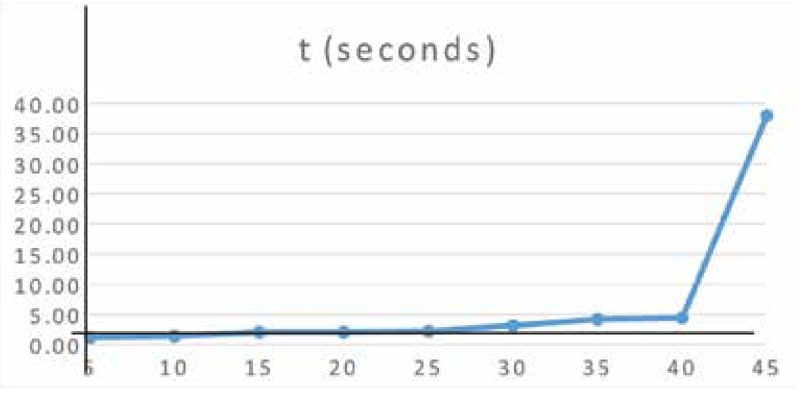


Figure 15. Graph prediction of the sugar solutions.

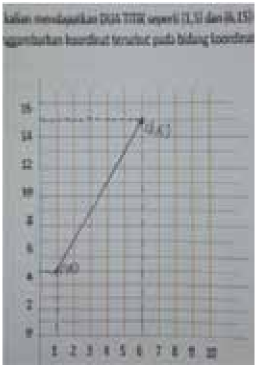


Figure 16. Incorrect graph {(1,5), (6,15)} graph.

knowledge of whether the student has been able to plot the points of known coordinates. In the "worksheet" the known point (1.5) and point (6.15), appears from the existing worksheets, students were asked to plot them in the Cartesian coordinates. There is a group of students who describes a straight line that contains the point (1.5) and (6.15), that is supposed to only two points, namely (1.5) and (6.15). The students plotted correctly, but wrote (0,5) wrongly, it supposed to be (1,5) (see **Figure 16**). Students should only plot the coordinates (1,5) and (6,15), not necessary to draw the line from (1,5) to (6,15) (the graph were made by students and were photographed by the authors, **Figure 16-18**).

In plotting the coordinate points of {(1,5), (2,7),(3,9),(4,11),(5,13) (6,15)}, generally students worked corretly, but some of students were not correct. The graph of the points are dots as figuring out by students in the **Figure 19**, not as a line segment as figuring out in the **Figure 16** and **20**. (the graphs of **Figure 19** and **20** were made by the students and photographed by researcher team).

Teachers began to deliver lessons after asking a number of questions above and confirmed that the correct point coordinates are the pairs of points (x, y) such that x and y are integers in a couple of points {(1.5),(6.15)} and do not represent a straight line.

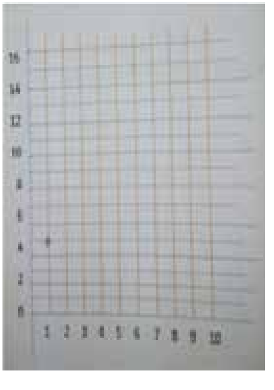


Figure 17. {(1,5), (6,15)} correct graph.

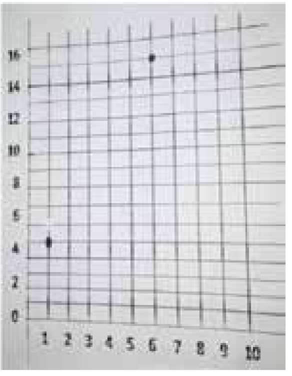


Figure 18. {(1,5), (6, 15)} correct graph.

However, the research team did not worry, because in general the students were able to plot the coordinate points that should be described in the coordinate plane.

10.3. Sugar solutions and graph

The next steps, after the students were able to draw coordinate points, they start to learn the part of sugar solutions in relation to viscosity (velocity) of sneaking ball in the various sugar solutions (percent solution of 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50%). They are exposed to the tools that have been recorded in the power point presentation. Furthermore, students use stopwatch (in their mobile phone) to measure the sneaking time of "ball clay" in each of the sugar solution. In this case the student does not measure speed, but measures how long it takes for sneaking "ball clay."

Some observations of groups of students are outlined in the following table:

Solution	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Time	1.22	1.55	1.93	2.45	2.85	4.76	5.28	6.0	6.95	61.22	~

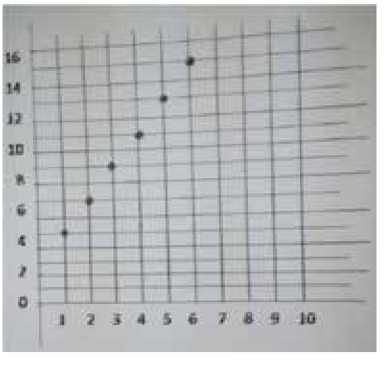


Figure 19. {(1,5),(2,7), (3,9) (4,11), (5,13), (6,15)}.

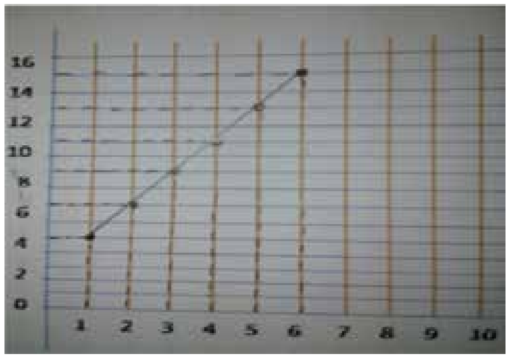


Figure 20. $\{(x,y)\ y = 2x + 3,\ x$ dan y real dengan $1 \le x \le 6\}$.

By plotting the points in the above table, there was obtained the following graph (**Figure 21**).

The graph in **Figure 21** indicated the original students' work that can be plotted using excel without any adjustment, except for the data of 35% just predicted. But after entering the data corrected by 35% and the estimate (approximate) data for a solution of 41, 42, 43, and 44%, the graph time-solution was obtained as follows:

Figure 22 represents the relationship between percentage of sugar solution and the sedimentation time of the ball. Each point in the graph represented the number ordered of *solution* (%) *and time*.

Students either individually or in groups in the classroom have already understood the concept of the functions and relationships. Modeling of the sugar solution above depicts a phenomenon that in order to precipitate an object into the solution, the more concentrated the solution the longer the time required to precipitate an object. In other words, the more concentrated the solution is, the greater the obstacles encountered objects to penetrate the solution (see **Figures 23–25** as students' work after their observation the solution-time. The tables are made by the students, but photographs are made by the researcher team as the personal collections).

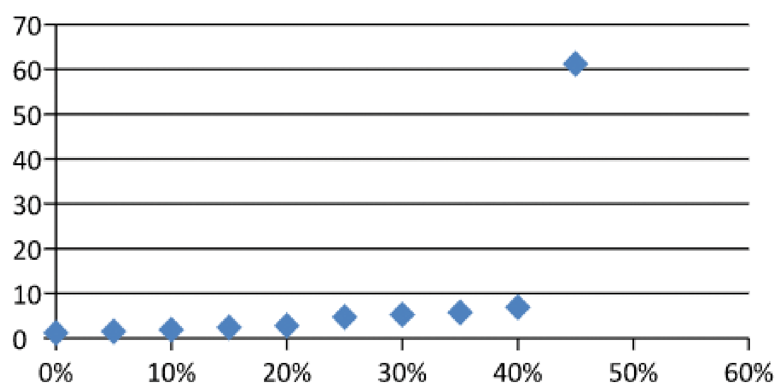


Figure 21. Plotting graph of sugar solution to sedimentation time.

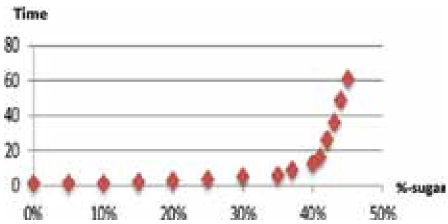


Figure 22. Plotting the percentage of sugar solution versus sedimentation time of plasticine ball.

The conclusion above can be used as a metaphor for our body liquid. If the liquid of our blood in our body more concentrated, the more difficult this liquid transforming objects (e.g., blood carries oxygen" from the heart to the brain). If transport is hindered then the patient will feel pain in his head. **Figure 26** is a circulation system of our body, the blood from the heart transports the oxygen to the brain. When the blood concentration gets high, then the stability of our health will influence.

About the extent to which the student can give reasons why the following arrow diagram is a function and why is not function, descriptions of student work is displayed as follows:

Students above (**Figure 27**) understood the relationship, as they wrote "A Member of A is only be paired with one quantity," even though, in fact, the relationship is "a very simple relationship among two sets," as far as the two sets are associated. In a particular association, this relationship was named function, this group gives reason "special relationship in A which paired with exactly one member of C." Suppose "special relationships that map each member of A with exactly one member of C" (see **Figure 27**).

Students (or other groups) (**Figure 28**) state as to which they answer the following, "because it is the relationship between the set-1 and set-2."

However, the function according to researcher, the term written by students has not written correctly. It is supposed to be the function "The special relationship that links each element in the set-1 (domain) with exactly one element in the set-2 (codomain)" **Figure 29**.

"(a) is a relation which is a function from A to B," while

"(c) is the relation which is not a function, because one of the members in A has two images in B."

Siswa mencatat berapa lama larutan pada masing-masing tabung dijalani oleh kelereng dan siswa membuat tabel:

Larutan	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	46%	47%	48%	50%
Waktu		1,50	1,70	2,22	3,85				6,95	11,34				

Figure 23. Students' work of Cohort-1.

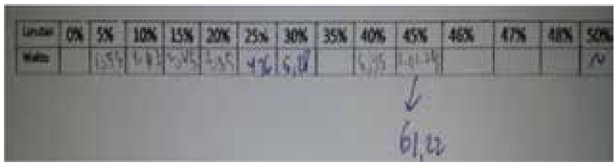


Figure 24. Students' work of Cohort-2 with a correction by researcher.

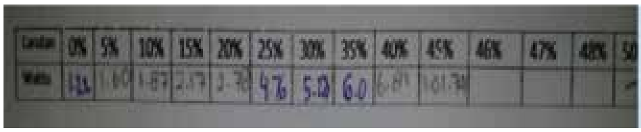


Figure 25. Students' work of Cohort-3.

Figure 29 is a problem to be asked for students whether this diagram is a function or not and why? Similarly, **Figure 30** is a question for the students, whether this diagram is a function or not? And why? Whereas **Figure 31** is student's reasons why the diagram is a relation and function or why the diagram is a relation but not a function. (**Figures 29–31** are personal collection of photographs.)

Although the proposed language is less precise, at least the students have an idea that they can distinguish between the functions and relationships. While other students understand the word "function" as a means "to" or "benefit," as the answer to the following students:

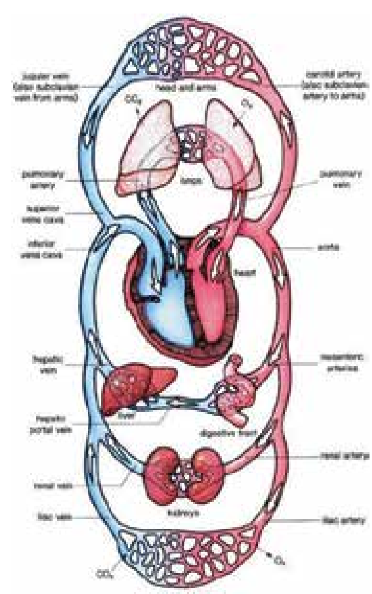


Figure 26. The circulatory system [53].

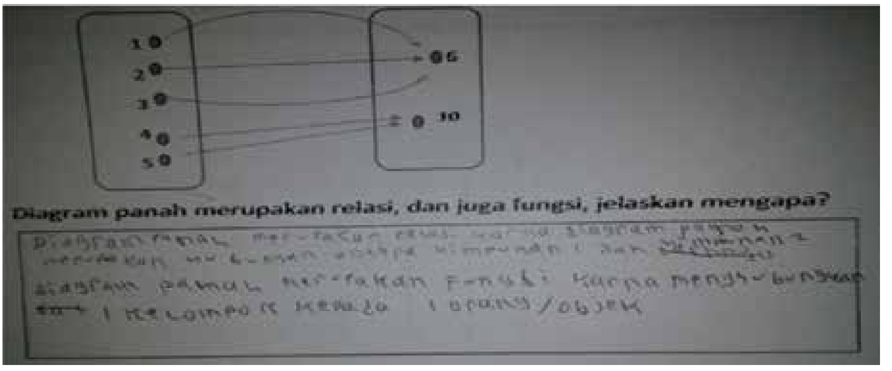


Figure 27. Students' work of function definition.

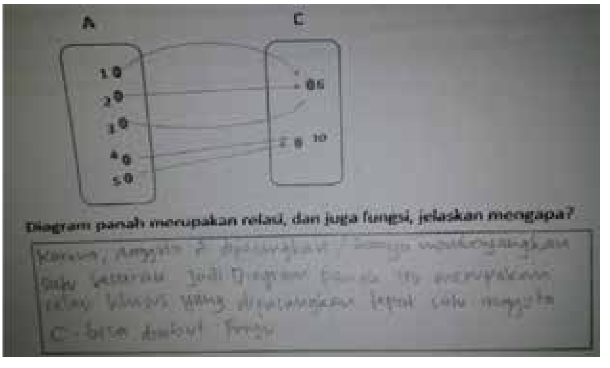


Figure 28. Students' work.

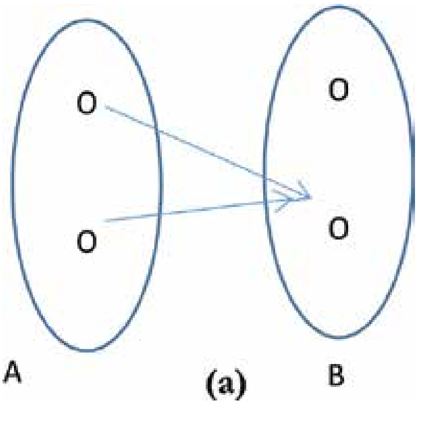


Figure 29. Relation as function.

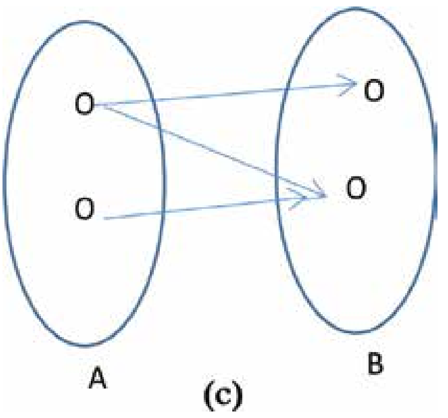


Figure 30. Relation not as function.

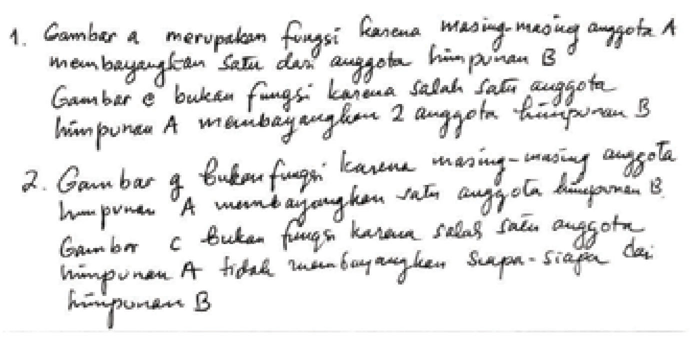


Figure 31. Reason for a function and not a function.

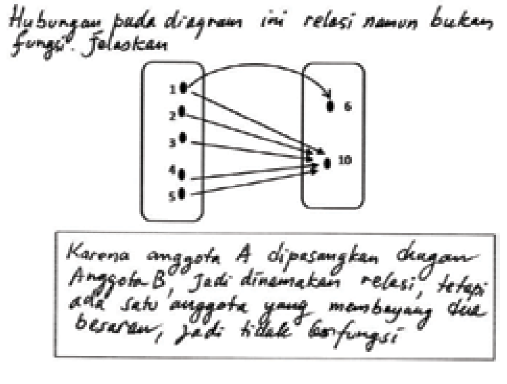


Figure 32. Students' work and reason why this relation is not function.

“There is one member of A that has more than one image in C, then it is not called a function from A to C” (see **Figure 32**, personal collection of photographs).

What do the specific things on the phenomena of “fireworks”,”sugar solution” and “faucet” are in fact a function that each phenomenon can be expressed as diagram of arrow, or with a table, or with the ordered pairs, or with the chart coordinates.

Although the students’ understanding of the concept of relationship is less perfect, the students have already understood the concept of function. They observed a sugar solution and sedimentation time of plasticine ball in each solution through a power point presentation. They detected them using stopwatch provided (or using their own Hand phone or mobile phone (HP)).

11. Conclusion

From the study of the implementation of mathematics instruction based on science using didactical phenomenology approach we conclude that (1) the prototype of learning mathematics can be made simply and scientifically in laboratories either by using sophisticated equipment or by using a simple way, as long as all the equipments can produce two groups of quantities, (2) the implementation process of mathematics learning in the classroom does not always use original tools such as original equipment set in the laboratory, but use equipment or software or a power point presentation as a tool or medium for the presentation of the photo or video animation of the laboratory equipment (video water discharge, video sugar solution, and “deposition” of plasticine ball, fireworks video, and video of swivel angle and discharge of water), (3) the reaction of students toward learning materials of mathematics based on science using didactical phenomenology shows positive attitudes and enthusiasm, (4) achievement of mathematical ability even though a group of students who study mathematics based on science using didactical phenomenology approach have a higher average than students who study using conventional approach, statistically both are not significantly different, (5) there are differences in improvement of mathematical ability among students who study mathematics based on science using didactical phenomenology approach (0.48) with students who studied with conventional approach (0.36). But both are in the same categories (middle) and mathematical models were found to show students the results that can be interpreted. Model of fireworks is considered as linear, water discharge models are considered as linear, and model of the sugar solution is considered as a graph arch.

When the researcher team made an experiment in laboratory, there is an interesting finding. When the clay ball was put on the sugar solution, the smaller percentage of the value of sugar solution, the faster the rate of sedimentation of “clay ball” and the higher concentration of sugar solution or the more concentrated of sugar solution, the slower the clay ball penetrates the solution. So the time to reach the base of the bottle is getting long. When looking at the 40% sugar solution, the ball still can be awaited, when a solution to be 45% the ball still could be awaited although it requires longer time. However, when observing the 50% solution, a teacher who helped designing the study shows surprise and astonishment, “Why is this happening?” In fact she connects the question, “What to do with death?” Then our mutual discussions with the belief held by strengthening the teacher. Approximately what causes happen so? Yes, if the clay ball stops (or floats), it means the same as our blood in our body was stuck because of concentrated so that it can no longer carry oxygen. Interestingly, this teacher seems to associate a sugar solution with the body fluids or blood fluid in our body. The phenomenon of nature (physics) is that a severe type of ball clay is smaller than the density of the sugar solution, so that the “ball clay” floats. If the weight is of the same type, then the ball will be hovering in the 50% sugar solution. For clarifying this situation to the students, then the teachers shares readings about the relationships between viscosity of our blood and maintenance of our health.

Observing this phenomenon, our research team is interested in observing and making a mathematical model of the graph. Apparently, the graph becomes asymptotically at 50% solution. In fact, it still needs to be investigated in a solution with a lower concentration, e.g., 49, 48, 47%, and so on, or fragments are more accurate as 49.5, 49, 48.5, 48, 47.5, 47, 46.5%, 46, 45.5%, and so on. We are talking to mathematicians and they advised to build mathematical models. For students, graphed predictions appear as in **Figure 15**.

Noting the benefits of mathematics instruction based on science using didactical phenomenology approach and its consequences on the students, teachers, and on student achievement, the team delivered the following suggestions.

1. That mathematics instruction based on science using didactical phenomenology approach can be an alternative approach in mathematics education, especially for junior high school students who are in a period of transition from concrete thinking to the future abstract thinking.

2. That the issue of didactical phenomenology, both students and teachers become aware of many phenomena in the area of natural and artificial phenomena, and ultimately both have the ability to see phenomena that become real for students. Therefore, the research team suggested to sharpen the sensitivity of seeing the phenomena by repeating ever trained.

3. Although the achievement of mastery of mathematical statistical did not differ significantly, enhancement of mathematical ability in experimental group is higher than the enhancement in control group, this indication further encourages researchers to enhance teaching model like this, so that the sensitivity of the students improved in terms of understanding the didactical phenomenology.

4. The graph of certain phenomena is not always linear, junior high school students can also see the nonlinear phenomenon.

5. It needs further research to a higher level or junior high school so that they can see the other phenomena that can be modeled.

12. Recommendation

Learning mathematics based on science using didactical phenomenology approach turned out to inspire teachers and students about the importance of mathematics and science in understanding health. Skill and ability of the students to record and present data in table form become a necessity, much less the ability to characterize graphs modeling capabilities. Ultimately, students are able to interpret the asymptote line as a "death" phenomena, after they are easily interpreting the graph of a straight line in the computer screen of ICCU (Intensive Coronary Care Unit) of a hospital. Similar things can be understood, that when the graph in **Figure 15** turns the curve straight up, then the "ball clay" is difficult to penetrate a sugar solution of 50%, so that the "ball clay" floats, and the time duration for penetrating solution was longer or even never again pierce of 50% sugar solution. The analogy is similar to blood fluid that is no longer able to carry oxygen from the lungs to the brain, so that the mortality occurs as consequences. In classroom, the students were able to give such an interpretation within discussions. As a consequence, students will be cautious when consuming sugar water (such as sweet coffee, or syrup).

In the learning process, when the students are able to observe phenomena, able to represent the data into coordinates or in the ordered pairs, and able to draw its graph, then most students have understanding competencies of mathematics. But the higher competencies such as "mathematical modeling" were still need to be learnt more by students in order to be able to make model of equation of phenomena.

The phenomenon of the sugar solution is a model that is very attractive; students are invited to think about the solution of the blood in the body. When the blood has been thinned, it is still possible to "carry" the oxygen from the lungs to the brain, the condition is very good and smooth (the graph would be as in **Figure 33a**). When blood viscosity increases, the ability of the blood to carry oxygen decreases, so such symptoms affect the health of the human body. At the time when blood is no longer able to carry oxygen to the brain, the oxygen supply to

Figure 33. Cardiograph in a hospital [57]. (a) Cardiograph for the normal patient, (b) Cardiograph for a "death" patient.

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the brain is stopped, it can be imagined what would happen to our body, and the graph of **Figure 33b** would represent this situation.

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References

[1] Freudenthal H. Didactical Phenomenology of Mathematical Structures. Dordrecht. Kluwer Academic Publishers; 2002

[2] Turmudi, Hidayat AS, Prabawanto S, Aljupri. Mint: pembelajaran matematika dengan pemodelan (mathematical modeling) berbasis realistik untuk mahasiswa. Dalam Jurnal Pengajaran Matematika dan Ilmu Pengetahuan Alam (JPMIPA). 2014;**19**(1):1-18

[3] Turmudi, Sabandar J. Kerjasama mahasiswa calon guru dan guru bidang studi dalam mengembangkan desain pembelajaran matematika realistic di SMP Negeri Kota Bandung. Grant Research Report, Bandung: Indonesian University of Education, FPMIPA; 2002

[4] Turmudi, Dasari D. Peningkatan kemampuan pemahaman konsep matematika bagi siswa SLTP melalui pendekatan realistik. Grant Research Report, Bandung: Indonesian University of Education, FPMIPA; 2001

[5] Turmudi. Designing contextual learning strategies for mathematics for Junior Secondary School in Indonesia. [PhD Thesis]. Australia: La Trobe University; 2006

[6] Turmudi. Mint: Teachers' perception toward mathematics teaching innovation in Indonesian junior high school: An exploratory factor analysis. Journal of Mathematics Education. 2012;**5**(1):97-120

[7] Turmudi, Juandi D, Harningsih E, Wihatma U. Improving the teacher' awereness to innovaton of mathematics teaching for junior secondary school teachers through lesson study. Research Report. LPPM Universitas Pendidikan Indonesia, un-published; 2010

[8] Turmudi, Hidayat AS, Prabawanto S, Aljupri. Pemodelan matematika dalam pembelajaran Realistik Matematika. Research Report, FPMIPA-LPPM, un-published; 2009

[9] Gravemeijer K. Developmental Research Fosteringa Dialec Relationship Between Theory and Practice. CD-Room of the RME materials produced for the ICME9 Congress in Japan; July 2000

[10] Freudenthal H. Revisiting Mathematics Education: China Lectures. Dordrecht: Kluwer Academic Publishers; 1991

[11] Nuh M. Sosialisasi Kurikulum 2013 di Universitas Pendidikan Indonesia. 16 Maret 2013 di Gedung Gymnasium, UPI, Bandung; 2013

[12] Djazuli A. Upaya dan harapan Kanwil Depdikbud Propinsi Jawa Barat dalam meningkatkan kualitas guru MIPA pada Dikdasmen. In: Rohman I, Imansyah H, Sopandi W, editors. Seminar on Quality Improvement of Mathematics and Science Education in Indonesia. Bandung: JICA-IMSTEP-Bandung Institute of Teaching and Educational Sciences; 1999. pp. 15-27

[13] Coribima D. Proses dan hasil pembelajaran MIPA di SD, SLTP, dan SMU: Perkembangan penalaran siswa tidak dikelola secara terencana (Studi kasus di Malang, Yogyakarta, dan Bandung). In: Rohman I, Imansyah H, Sopandi W, editors. Seminar on Quality Improvement of Mathematics and Science Education in Indonesia. Bandung: JICA-IMSTEP-IKIP Bandung; 1999. pp. 73-84

[14] Shiu C, Hatch G. Professional development. In: Johnston-Wilder S, Johnstone-Wilder P, Pimm D, Westwell J, editors. Learning to Teach Mathematics in the Secondary School: A Companion to School Experiences. London: Rontledge; 2005. pp. 246-257

[15] Turmudi, Suherdi U, Kusmana D. Baby watermelon for Creating the Formula of Cylinder Volume in Junior Secondary Classroom: An Experience in Lesson Study. MCEIS-2013; 2013

[16] Senk SL, Thompson DR. School mathematics curricula: recommendations and issues. In: Senk SL, Thompson DR, editors. Standard-Based School Mathematics Curricula: What are They? And What do Students Learn. New Jersey: Lawrence Erlbaum Associated; 2003. pp. 3-27

[17] Maher CA, Alston A. Mint: Teacher development in mathematics in constructivist view on the teaching and learning of mathematics. Journal for Reseach in Matematics Education, Monograph. 1990;**4**:147-166

[18] Turmudi. Implementasi awal pembelajaran geometri dengan pendekatan realistik di sekolah menengah pertama. Laporan Penelitian mandiri. Bandung: UPI, FPMIPA, unpublished; 2001

[19] Turmudi, Juandi D, Hidayat AS, Puspita E. Eksplorasi etnomatematik masyarakat kampung Baduy dan kampung Naga. Laporan hasil penelitian, FPMIPA-LPPM, un-published; 2013

[20] Turmudi, Hidayat AS, Sispiati R. Pengembangan pembelajaran matematika berbasis fenomena didaktis: (Sebuah Terobosan Inovatif dalam Mengenali, Mendesain, dan Mengimplementasikan serta Memvalidasi Bahan Ajar Matematika di Sekolah Menengah Pertama). Laporan hasil penelitian, FPMIPA-LPPM, un-published; 2014

[21] Turmudi, Juandi D, Hidayat AS, Puspita E, Ulum AS. Mint: Exploring Ethno-Mathematics: How the baduy of indonesia use traditional mathematics skills in weaving. International Journal of Control Theory and Applications. 2016;**9**(23):324-339. ISSN: 0974-5572

[22] Anderson J, White P. Problem solving in learning and teaching mathematics. In: Perry B, Anthony G, Diezmann C, editors. Research in Mathematics Education in Australasia. Flaxton, Queensland: Post Pressed Flaxton; 2003

[23] Cochran-Smith M, Lytle S. Relationships of knowledge and practice: Teacher learning in communities. In: Iran-Nejad A, Pearson PD, editors. Review of Research in Education. Washington, DC: American Educational Research Association; 1999. pp. 249-306

[24] Little JW. Mint: Teachers' professional development in a climate of educational reform. Educational Evaluation and Policy Analysis. 1993;**15**(2):129-151

[25] National Research Council. Adding it up: Helping children learn mathematics. In: Kilpatrick J, Swafford J, Findell B, editors. Mathematics Learning and Study Committee, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press; 2001

[26] Nelson BS. Learning about teacher change in the context of mathematics education reform: Where are we going?. In: Fennema E, Nelson BS, editors. Mathematics Teachers in Transition. Mahwah, NJ: Erlbaum; 1997. pp. 403-419

[27] Smylie MA. Redesigning teachers' work: Connections to the classroom. In Review of Research in Education. 1994;**20**(1):129-177

[28] Farmer JD, Gerretson H, Lassak M. Mint: What teachers take from professional development: Cases and Implication. Journal of Mathematics Teacher Education. 2003;**6**:331-360. DOI: 10.1023/A:1026318709074

[29] Knight P. Mint: A systematic approach to professional development: Learning as practice. Teaching and Teacher Education. 2002;**18**:229-241

[30] Perry RR. The role of teachers' professional communities in the implementation of California mathematics reform. Unpublished doctoral dissertation [thesis]. Palo Alto, CA: Stanford University; 1996

[31] Talbert JE, Perry R. How Department Ommunities Mediate Mathematics and Science Education Reforms. New Orleans, LA: Paper Presented at the Annual Meeting of the American Educational Research Association; 1994

[32] Romberg TA, Kaput JJ. Mathematics worth teaching, mathematics worth understanding. In: Fennema E, Romberg TA, editors. Mathematics Classroom that Promote Understanding. New Jersey: Lawrence Erlbaum Associates Publishers; 1999. pp. 3-17

[33] Clarke B, Clarke D, Sullivan P. The mathematics teachers and curriculum development. In: Bishop AJ, et al. editors. International Handbook of Mathematics Education. Dordrecht, The Netherlands: Kluwer Academics Publishers; 1996. pp. 1207-1234

[34] Ernest P. Image of mathematics, values and gender. In: Allen B, Johnston-Wilder S, editors. Mathematics Education Exploring the Culture of Learning. London: Routledge Falmer; 2004. pp. 11-25

[35] Verschaffel L, De Corte E. Number and arithmetic. In: Bishop AJ, Jeremy K, Colette L, Ken C, Kristine K, editors. International Handbook of Mathematics Education. Dordrecht, the Netherlands: Kluwer Academics Publishers; 1996. pp. 99-137

[36] Cockcroft WH. Mathematics Counts: Report of the Commission of Inquiry into the Teaching of Mathematics in Schools. UK: Her Majesty's Stationary Office; 1982

[37] National Council of Teachers of Mathematics. Principles and standards for school mathematics. Reston, The National Council of Teachers of Mathematics, Inc.; 2000

[38] National Council of Teachers of Mathematics. An agenda for action: Recommendations for school mathematics of the 1980s. Reston, The National Council of Teachers of Mathematics, Inc.; 1980

[39] National Council of Teachers of Mathematics. Curriculum and evaluation standards for school mathematics. Reston, The National Council of Teachers of Mathematics, Inc.; 1989

[40] Turmudi. Students' responses to the realistic mathematics teaching approach in junior secondary school in Indonesia. Proceedings of IICMA -2009. Yogyakarta: Mathematics Education; 2009. pp. 735-754

[41] Djojonegoro W. Opening remark: Minister of Education and Culture Republic of Indonesia at the International seminar on science and mathematics education. In the Proceeding of International Seminar on Science and Mathematics Education (Comparative Study between Indonesia and Japan), Bandung, 1995; pp. 32-39

[42] Freudenthal H. Didactical Phenomenology of Mathematical Structures. Dordrecht: Kluwer Academic Publishers; 1984

[43] Turmudi, Haryanto D. Creating and solving model of linear equation through the balance at junior secondary classroom. In: Proceeding in International seminar and the 4th National Conference of Mathematics Education, Building the Nation Character Through Humanistic Mathematics Education; UNY: Yogyakarta. 2011. pp. 619-630

[44] Turmudi, Ratnaningsih. Tarif Taxi dan Biaya Fotocopy untuk Pengenalan Konsep Fungsi Linear di SMPN 12 Bandung: Lesson Study. Konfrensi Nasional Pendidikan Matematika ke-16 di UNPAD, 3-6 Juli 2012; di Jatinangor, Sumedang; 2012

[45] Turmudi & Erlina E. Constructing formula of Pyramid Volume by Comparing Volume of Prism and Container Media in Junior Secondary School: A Lesson Study. The 5th

International Conference on Research and Education in Mathematics; AIP Conf. Proc. 1450, 2012, pp. 173-182; doi: 10.1063/1.4724136

[46] Turmudi, Julia. Watermelon for proving the volume of ball in Junior Secondary School. UPI-UPSI conference; Bandung-Indonesia; 2014

[47] Keirinkan. Mathematics Gateway to the future Math 1 for Junior High School. Hiroshima, Japan; Shinko Shuppansha Keirinkan Co., Ltd. 2013

[48] Franke ML, Carpenter T, Fennema E, Ansell E, Behrend J. Mint: Understanding teachers' self-sustaining, generative change in the context of professional development. Teaching and Teacher Education. 1998;**14**:67-80

[49] Franke ML, Kazemi E. Teaching as learning within a community of practice: Characterizing generative growth. In: Wood T, Nelson BS, Warfield J, editors. Beyond Classical Pedagogy. Mahweh, NJ: Erlbaum; 2001. pp. 47-74

[50] Stein MK, Silver E, Smith MS. Mathematics reform and teacher development: A community of practice perspective. In: Greeno JG, Goldman S, editors. Thinking Practices in Mathematics and Science Learning. Mahwah, NJ: Lawrence Erlbaum Associates; 1998. pp. 17-52

[51] Thomas G, Wineburg S, Grossman P, Myhre O, Woolworth S. In the company of colleagues: An interim report on the development of a community of teacher learners. Teaching and Teacher Education; 1998;**14**:21-32

[52] Rogoff B. Mint: Developing understanding of the idea of communities of learners. Mind, Culture, and Activity. 1994;**1**:209-229

[53] The circulatory system [Internet] Available in: http://www.daviddarling.info/encyclopedia/C/circulatory_system.html [Accessed: 2017-10-03]

[54] Turmudi, Prabawanto S, Nurlaelah E. Pengembangan pembelajaran matematika sekolah dasar berbasis fenomena didaktis. Research report. SPs-UPI. un-published; 2015

[55] Turmudi. Mint: Professional development for junior secondary school mathematics teacher based on the realistic mathematics framework in Indonesia. Far East Journal of Mathematical Education. 2011;**7**(1):11-56. DOI: ISSN: 0973-5631

[56] Syahrin MA, Turmudi, Puspita E. Study ethnomathematics of aboge (alif, rebo, wage) calendar as determinant of the great days of Islam and traditional ceremony in Cirebon Kasepuhan Palace. In Conference Proceeding of AIP 2015. 1708, 060009 (2016). DOI: 10.1063/1.4941172

[57] EKG (Flatline) - Facebook covers [Internet]. 2017, Available from: http://covermyfb.com/covers/25434/ekg+%28flatline%29 [Accessed: 2017-09-21]

Chapter 3

Transformative Orientation in Learning to Teach Physics and Chemistry

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Additional information is available at the end of the chapter

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Abstract

Initial teacher training (ITT) involves different perspectives regarding the role of theoretical versus practical knowledge in teaching and requires an answer to how students integrate theory and practice and how learning environments contribute to this integration. Many authors have been advocating the idea of teachers as researchers of their own practice as a way to establish connections between theoretical knowledge and the knowledge gained from their practice. The ITT program of the University of Lisbon is based on a conceptual framework that proposes that student-teachers construct professional knowledge from researching their own practice in a context of supervised practice. This paper aims at describing the interpretations that student-teachers make about the Portuguese science curriculum, as well as describe the research questions and methods that they used for collecting data concerning students learning, and their evaluation of the learning process. For that, 31 written reports were analyzed. While involved in the design of the didactic proposals, student-teachers were encouraged to interpret the formal curriculum and turn it into a teaching curriculum, and to critically reflect on the curriculum. By researching their own practice, they developed new understanding regarding students' difficulties, promoting students' conceptual change and managing classroom and students' behavior.

Keywords: initial teacher training, research of own practice, reflection, professional knowledge construction

1. Introduction

Initial teacher training (ITT) is a matter of debate among scientists, educators and educational researchers. Scientists advocate for greater scientific training with explicit criteria about scientific competence based on scientific disciplines, while educators and educational researchers call for greater pedagogical and didactic expertise based on educational research.

Notwithstanding, both sides defend professional practice based on theoretical knowledge. They both acknowledge that through practice, one can acquire professional knowledge, while also recognizing that the dominant influence of the practice may prevent the use of more innovative strategies [1]. Adding to the debate and from a different perspective, students consider the teacher training programs to be too theoretical and are calling for a greater practical component [2]. So ITT involves different perspectives and debate regarding the role of theoretical versus practical knowledge in teaching and requires an answer for how students integrate theory and practice, and how learning environments contribute to this integration.

According to recent perspectives, teaching involves a process of knowing and acting, while simultaneously presupposes the unity of thought and action and the rejection of the duality of knower and the object known [3]. Teaching requires the use of specialized forms of knowledge for promptly responding to the problems arising from teaching practice. Indeed, teachers engage in a process of dialogue with their practice that provides either the construction or the reconstruction of their knowledge concerning practice. Teachers do not just find a solution to a problem; they have to start by equating the problem by understanding a problematic and uncertain situation, and then, they have to go through a specific process of decision making considering the purposes to be achieved and the means to be achieved. So the deliberation process involves thinking about the consequences of the actions outlined, using the knowledge already gained through teaching, and it provides increased knowledge that can change future actions and decisions.

One important point is that problems are reconstructed and interpreted from real situations. Indeed, according to several authors [4, 5], teacher experience is an important source of teachers' learning. However, learning from experience is only made possible if teachers are able to reflect on their own practice, looking at it from different angles and building new meanings from it. This involves a process of personal reconstruction of professional practice, which escapes the *"canons"* of technical rationality. Indeed, the resolution of the problem depends on how it is equated, the meanings attributed to the different aspects that are involved in the problematic situation and the application of knowledge already gained from the professional activity in which teachers have been involved [6, 7].

Many authors have been advocating the idea of teacher as a researcher of his/her own practice, on the base that it is this dimension that allows teacher to go further away in his/her reflections and in exploring new possibilities for action [8]. Research about their own practices begins with an authentic question rooted on teachers' practice [9]. By researching their own practices, teachers are challenged to establish connections between theoretical knowledge and the knowledge gained from their practice [10]; also, it allows teachers to develop a different perspective about their own reality, as they become a participant observer of their own actions and decisions and the consequences of it [11].

Thus, researching own practices is a powerful tool in the teachers' lives, as it helps teachers learn about their students, about school and about themselves as teachers. It should also be noted that researching their own practices can go beyond the resolution of concrete problems and overcome the classroom boundaries, giving voice to teachers and making them constructers of educational knowledge [12].

For this reason, recently, many educational training models are based on the idea of teacher as a research of his/her own practice. Research in practice as a component of ITT has been advocated by several Portuguese researchers [12, 13]. Main arguments are: the investigative dimension allows teachers to become constructors of professional knowledge and not only users of knowledge produced by others [14]. In addition, it facilitates the development of questioning competencies of teaching practice and the contexts of practice, helping student-teachers learn from their own teaching practice, and throughout their professional career [15]. According to an ITT perspective, in the process of learning to teach it is necessary that student-teachers learn to consider the thoughts and actions of other teachers, while simultaneously they begin the process of researching their own practice. This process requires strategies for promoting critical reflection of the teaching practices as well as a learning context where they can communicate the results of their research. These two training processes—research and professional communication—contribute to student-teachers' professional development.

The ITT program of the University of Lisbon is based on a conceptual framework that proposes that student-teachers construct professional knowledge from their teaching supervised practice. According to this model, students design a didactic proposal taking into account the suggestions of the curriculum that they discuss in collaboration with the school teacher and the educational researcher; afterwards, they put the plan into action in the classroom (intervention). Simultaneously, student-teachers plan a research for studying their intervention. They collect data on students' learning that will be the subject of analysis and reflection. Afterwards, student-teachers write a report where they present the research questions, the theoretical rational, the description of the didactic proposal with justification of the chosen tasks, methods of data collection and analysis, the responses to the initial research questions and a reflection concerning the intervention and the research process as well as about their own learning. Finally, they publicly discuss the results of their intervention and research about the intervention.

Considering the importance of the ITT for professional knowledge and also educational research suggesting the importance of the process of researching their own practice for facilitating professional knowledge, it is important to know the student-teachers' perspective regarding this ITT model. This paper aims to describe the interpretations that student-teachers make about the Portuguese science curriculum as they are expressed in their options regarding the didactic proposal, as well as to describe the research questions and methods they used to collect data concerning students learning, and their evaluation of the learning process in which they were involved when they research their own practice.

2. Researching own practice for professional development

Over the last 100 years, many new ideas have been proposed, but few have made significant impact on the way that science is taught or learned [16]. Science education guidelines have been calling for an increase in inquiry-based instruction that situates the learning within the context of scientific process and the nature of science [17]. These curricular documents are grounded in contemporary theories of learning as an active process centered on students. Accordingly, traditional expository teaching is now regarded as inadequate and less than satisfactory for every lesson, while at the same time, a greater emphasis has been put on the role of inquiry in science teaching [17]. This requires a change of teachers' knowledge, competencies, and attitudes. Although some of these ideas have been embedded in past reform efforts, it has proven difficult for teachers to create and sustain these roles in the classroom. Many reasons have been singled out as why innovation tends to be a difficult task.

Learning to teach effectively requires strategies that haven't usually been used by teachers in their classrooms. Through their own educational experiences, and by observing good and bad teachers, student-teachers have constructed models concerning how to teach, often without reflecting on the quality of teaching, and assuming all to be equally good. Thus, personal experience issues may contribute to the conservative character of their concepts and to the development of mechanisms of resistance to change [18].

In fact, student-teachers enter ITT programs with explicit as well as implicit conceptions about their future role as teachers [19–21]. These conceptions reflect and structure the ways in which they intend to behave and interact with their students, how they assess students' learning, and how they organize and manage classrooms. Student-teachers have varying conceptions of teaching and learning, which have a profound impact on their approaches to teaching and may result in resistance to change during the process of learning to teach in ITT programs. So, in the process of learning to teach science, it is necessary to facilitate the (re)construction of conceptions about teaching and help student-teachers to change their science teaching conceptions. Feeling competent and comfortable with the new strategies will be central to involve teachers (and student-teachers) with the required changes. In addition, teachers (and student-teachers) have to construct new content knowledge and a new understanding about the curricular innovations, which is often not an easy task [22].

As it is now widely accepted in the literature on student-teacher learning, new information and knowledge presented to student-teachers in teacher education programs needs to relate to their existing conceptions in order to enable learning [5, 23]. Student-teachers are encouraged to adopt a critical perspective toward the context of their teaching and to question themselves about their didactic conceptions so as to become open to innovation and change. However, often teacher (and student-teachers) are not familiar with basic methods of research and are reluctant to be researchers. Thus, it is important that ITT training provides situations that allow for reflection about actions and the development of research competences.

Research of their practices can be an opportunity to reflect about practice in a guided and sustained way. Research of their practice can be an opportunity to reflect about practice. The idea of teachers as researchers arose from a long process of contestation; presently, there are several conceptual models [1].

Teachers as researchers of their own practice involve developing a systematic and intentional research focused on their classes and school, with the goal to professionally develop as a teacher.

Research of own practice aims to solve professional problems and to increase the professional knowledge concerning those problems; and its main reference is the professional community instead the scientific community [12]. Sagor defines research of own practice as a study conducted by the teachers about their own work or about any aspect that will be a part of their work [24].

Zeichner and Nofke propose a four stage process for conduct a research of own practice. The first stage consists of the formulation of a research problem. The problem arises for any situation of the teacher's practice. The problem has to be clear and has to make an authentic contribution to the practice. During the second stage, the teacher as a researcher collects data. This requires a previous phase of planning the research, considering the research questions, available instruments and other resources. The third stage involves interpretation of the results and reaching conclusions. Finally, teacher as a researcher has to communicate his/her results and conclusions. This can be made formally or informally; nevertheless, this is a very important stage of the research as it allows sharing ideas, discussion different perspectives and evaluation of the research [1].

According to Sagor, there is no unique method to do this kind of research, but several. And he proposes a process consisting of four phases. The first one consists of clarifying goals of the research; at this point, the teacher as a researcher also defines validity criteria. The second phase involves theoretical articulation. At this moment, teacher develops a plan of a lesson (or a sequence of lessons), identifying key factors. Also he/she also plans the research, in order to assure that the research goals will be achieved. During the third phase, teacher implements the intervention and collects data. Finally, the fourth phase involves communication and reflection about the results of the research and also about the research itself [24].

Sagor proposes two types of researches: quasi-experimental research and descriptive research. Teachers are often involved in quasi-experimental research. Daily teachers use diverse teaching strategies. However, seldom students can achieve all defined learning goals. So teachers have to reflect on students' difficulties, raising questions such as: "What would happen if I change my teaching practice or strategy? Would students' difficulties be overcome?" These questions can be researched by means of a quasi-experimental research [24].

Descriptive research starts differently. Sometimes teachers feel that something have happened in their classes with their students or at their school, and they know that they need to do something to solve the problem. However, they do not understand the problem in the context of the school, and so they face difficulties with outlining possible strategies to solve it. Descriptive research aims at providing teacher with a rich description of the context, using operative theories for understanding it. So while in quasi-experimental research, the teacher as a researcher focuses on the efficacy of a new teaching strategy and its impact on students' learning, in a descriptive research, the teacher uses a theory to make sense of the context or a specific situation.

No matter the type of research developed, one important point is that research of own practice has always to follow quality criteria [12], such as the following ones:

(1) Research has to have a liaison with the teacher's practice [25].

(2) Research has to be authentic, by containing the perspective of the teacher and its connection to the social, cultural, economic and politic contexts.

(3) Research has to include a new element, whether in the research questions, in the methods or interpretation of data [26].

(4) Research has to have methodological quality, implying that the research has to be guided by a research question, it has to involve a detailed description of data collection methods and analysis, it has to involve data triangulation, and conclusions have to be supported in evidences [10, 27–29].

(5) Research has to involve a moment of sharing and communicating the results, which will be evaluated by the peers; it is the phase that confers legitimacy and relevance to the study performed [10, 12, 25, 28].

3. Methodology

A qualitative and interpretative approach was used for analyzing student-teachers' didactic proposal, the research of own practice and professional learning.

3.1. Data sources

Data sources were the student-teachers' reports about the didactic proposal and their own research, which were publicly presented and discussed with two experts in Science Education, one expert in Physics and one expert in Chemistry. All the reports were publicly discussed between 2010 and 2016. These are personal and also public documents. Many researchers use written documents to access teachers' thoughts. For instance, Bolin used written diaries to access teachers' thoughts about teaching. This researcher required the teachers to write down their daily lessons plan and to justify their curricular decisions [30, 31].

The reports about the didactic proposal and their own research represent student-teachers decisions concerning didactic proposal and students' tasks. In this study, we analyzed 31 reports, of which 71% were written by female student-teachers.

3.2. Data analysis

Accessing meaning contained in data is a task of the researcher; in this study, meaning was explored after data collection [32]. According to Miles and Huberman, the process of analysis involves the interaction of three types of activities: reduction, representation and organization. In order to reduce all the information, we started with previously defined categories of analysis (research questions, didactic proposal, methods and procedures, and professional learning) [32], and after an initial categorization, we re-read the reports and through a method of constant questioning and comparison, we inductively created sub-categories [33]. These methods are appropriate to the goals of the study, that is, to understand the interpretations that student-teachers make about the curriculum, when they develop and put into action a didactic proposal, and to evaluate student-teachers' professional learning.

4. Results

In this section, we present our results concerning: (1) research question, (2) didactic proposal (3) methods of data collection and analysis and (4) professional learning.

4.1. Research questions

Research questions made by student-teachers as a starting point for their research were presented in the introduction chapter of their report, while the research methods and procedures were presented on the chapter IV, concerning the methodology. The research questions are answered when student-teachers implement their didactic proposal. Answers were presented on chapter III of their report, where they scientifically support their didactic proposal and students' tasks and assessment.

Most research questions are related to students' difficulties (84% of the research questions raised by the student-teachers). In addition, 48% of the research developed by the student- teachers aimed at identifying what students learned by being involved in the didactic proposal (e.g., specific scientific concepts—10% of the research questions, or specific competencies—10% of the research questions) and 19% of the researches focused on the potentialities of specific strategies for facilitating students' learning. In addition, most student-teachers (84%) asked their students to evaluate the didactic proposals (**Table 1**).

One of the student-teacher started with the question: "How does using a story for presenting a problem facilitate students learning of scientific concepts?" In order to answer this question, all

Type of research question	
Students difficulties (i.e., difficulties faced by the students when involved in a learning task)	84%
Students learning (i.e., what have students learnt after being involved in the learning task?)	48%
Specific competencies	
Conceptual change	
Concept learning	
Students' perception of potentialities of specific strategies for improving learning	18%
Other	18%

Table 1. Student-teachers' research questions.

the tasks proposed by this particular student involved reading—they all started with reading a story as a way to engage students with the topic studied. The topic studied was the sound and high and low pitches. After using the stories for engaging students with the topic, and according to the 5 E's model [34], students were then required to distinguish high from low pitches, based on daily sounds and objects.

This research question illustrates a focus on concept learning. Other students reveal similar, though more undefined, interests, such as learning in general. These students wonder how learning can be facilitated using specific teaching strategies. For instance, one student-teacher used a cartoon for engaging students with the task. This cartoon is about a young man who is playing piano and then starts wondering about the different sound produced by the instrument. This student-teacher asked his students to identify the characteristics of the sounds, by selecting a musical instrument that was constructed on the first lesson. Then, they had to design a plan in order to characterize the sound produced by the instrument.

Both didactic proposals have the same goal: to facilitate students learning considering the properties of the sound and to distinguish high and low pitches. Although they have the same didactic focus—concept learning, they started with differing research questions: one wanted to know how involving students in reading activities could facilitate concept learning and the other one, how engaging students by using cartoons would facilitate their involvement with the activities and then students concept learning.

Other student-teachers researched more specific issues, such as the potential associated to the use of wikis or to STS-E tasks. Two student-teachers aimed at identifying the potential that students attribute to learning through using wikis in the classroom. One of this student-teacher used a wiki with ninth-grade students for teaching Periodical Table of Elements, while the other student-teachers used a wiki for teaching a didactic sequence of Physics to 10th grade students. Students from 9th and 10th grades evaluated wikis very positively, identifying some shared positive elements; but also differing in some other issues. For instance, 9th grade students mention that wiki facilitated their learning as they were required to assume a more positive stance toward science classes and increased their motivation for science learning. As students state, they had to ask questions, to do internet search, to organize collected information, to collaborate with peers, and to report by writing. Another mentioned positive issue was improving their competencies and knowledge regarding ICT and group work. Tenth-grade students pointed: easy use, facility of accessing its contents from wherever and whenever, the possibility to upload interesting texts, videos, and/or links and relevant internet pages. Sharing information with peers was seen as very important as they were able to learn from their peers' questions and doubts. Another interesting mentioned point was the fact that as work is registered in the wiki, it is easy for them to monitor work progress and improvement, and also their own learning.

Other students who have also used wikis mention that it is a very important tool for communicating, easily and fast, with the teacher when they have difficulties or any doubt. Student-teachers who have used this resource do share the same perspective. All of them recognized that this type of resources facilitates collaboration with their students and monitoring of students' progress and so it facilitates students' learning.

4.2. Didactic proposal

Didactic proposals were analyzed considering chosen curricular theme, grade level taught, duration of the intervention, tasks presented to the students. Didactic proposals concerned themes from Physics as well as themes from Chemistry. All the interventions have to be put into action from January to May, depending on the schools and school teachers, and aligned with school calendar. So student-teachers are constrained to choose one of the thematic that will hold during a specific period of the school calendar. Also, the proposals were put into action to students varying from 7th grade to 12th grade (**Table 2**).

As proposals are aligned with the Portuguese Physics and Chemistry curriculum, there are some constrains of the themes chosen by the student-teachers. As such, most didactic proposals for seventh grade involve the themes: materials, energy and earth planet—solar system. In what concerns 8th grade, didactic proposals focus on the sound (Physics) and chemical reactions (Chemistry). On ninth grade, didactic proposals involved Periodical Table of Elements (Chemistry) and electric chain and electric circuits (Physics). As all student-teachers taught a class of Physics in 10th and 12th grades, all the didactic proposals focused on Physics. And as all student-teachers taught a class of Chemistry in 11th grade, all of the proposals focused on Chemistry.

Duration of each intervention varied from 450 min (i.e., 10 lessons of 45 min each) to 945 min (i.e., 21 lessons of 45 min). This difference in the duration of the intervention is mainly related to the curricular theme chosen as well as the period of the school calendar when it was implemented.

About 65% of the student-teachers used investigative tasks, according the 5 E's model. According to Bybee et al., investigative tasks allow students to experience learning situations that facilitate questioning, argumentation, and knowledge construction. This model proposes five stages for developing the tasks: engagement, exploration, explanation, elaboration and evaluation [34].

One of the tasks proposed by a student-teacher aimed at studying the characteristics of the sound, by starting with the presentation of a cartoon and some initial questions. Then, students were required to plan a research in order to study sound and high and low pitches, to

School subject		**School grade**	
Physics	55%	7th	26%
Chemistry	45%	8th	13%
		9th	16%
		10th	26%
		11th	13%
		12th	6%

Table 2. Interventions by school subject and school grade.

make and to report observations and to draw conclusions. Afterwards, students were challenged to develop the initial cartoon. Finally, students had to reflect on the task, stating what they have learnt by being involved in the task, the difficulties they faced, the process of group work and what they liked the most.

Another student-teacher presented a problematic question: students were challenged to choose a detergent for a washing machine in a situation where the public water has a high value of pH. In order to answer this question, students in group had to analyze the label of different detergents and to make some questions. Students found the answers for these questions by reading a text provided by the student-teacher. Afterwards, each group presented its ideas to the other groups. In the second part of the task, students had to plan a laboratory activity with the goal to compare hardness of samples of different waters. They then enacted their plan and shared their conclusions with the class. Finally, students were directed to explore a site with information about care of washing machines. The tasks ended up by challenging students to reflect, individually and written, about what they have learnt, their difficulties and the interest they had in the task.

About 16% of student-teachers mentioned solving problems as a teaching strategy. All of these student-teachers started from a problem which solution could only be found after students were involved in a laboratory activity. In general, students involved in the problem resolution task were required to search for specific information either in text books or via the internet, to get involved in group discussion, to prepare replies and presentations to colleagues with debate involving the whole class.

Reading texts is one more teaching strategy, which was used by 16% of the student-teachers; generally, this teaching strategy was used with secondary school students (10th, 11th and 12th grades). In some learning tasks, reading texts is used within a STS-E approach. In all the learning situations, students were required to read alone in order to answer a set of questions; reading was followed by a discussion in small group and exposure of the group ideas to the whole class. In some of the learning tasks, students were required to write questions about the text and then to search for an answer either by reading their text books or searching in the internet.

About 54% of student-teachers used questioning and debates as teaching strategies, mostly used with secondary school students. Student-teachers questioned their students during the lesson, after exposing the theme or after students concluding a learning task.

Lab work was used by 39% of student-teachers, mostly with secondary grade students and in lab-classes. Some of the student-teachers used tasks as proposed in the textbook, which had some investigative characteristics but did not follow 5 Es' model.

Only 9% of the student-teacher used visualizations in their classes. One of the student-teacher started the lesson about the "Role of fossil fuels in World's Development", by asking the students the watch a set of videos available on YouTube ©. After this initial moment, students were then asked to make a list of all the topics and to write down relevant information. Students then had to choose one role and to pretend that they would have to present their position in the Parliament about Exploration of fuel in Alentejo's cost. So watching a video was a starting point for involving students in a role-playing activity.

Finally, many student-teachers (39%) used distinct ICT tools for implementing different proposals, such as YouTube, wikis, internet for searching information or for presenting simulations, *Popplet* platform. These tools were used with students from all grades. In particular, wikis were used as a resource for helping students in the construction of a research plan: Students were challenged to share their plan, how they would put it into action, the observations made and the conclusions reached. All groups were urged to compare their results with the results of other groups.

4.3. Methods and procedures

Developing research competencies is a central goal of the ITT. Indeed, it is intended that the student-teachers will develop this type of competencies, so that when they become teachers, they will keep on researching their own practices, in a systematic and rigorous way. Thus, it is important to describe the kind of methods and procedures that the student-teachers used for collecting and analyzing data concerning the implementation of didactic proposal (**Table 3**). All the student-teachers used participant observation and document analysis of documents produced by the students during the didactic sequence. Only one of the student-teachers did not carry on focus group interview for collecting students' evaluation of the didactic proposal; instead, this student-teacher has used written responses from the students. Audio record of the lessons was used by 29% of the student-teachers, who placed an audio recorder in each of the working groups, while they were working on the assigned tasks.

Two of the student-teachers also videotaped their own lessons besides using students' documents and focus group interviews. Pre- and post-questionnaire was applied by 21% of the student-teachers, before and after their didactic intervention.

All data collected by means of interviews, and audio and video records were totally transcribed for content analysis.

Methods	
Participant observation with field notes after the lesson	100%
Written documents produced by the students	100%
Focus group interview	98%
Audio record of work group	29%
Video record of the lessons	6%
Questionnaire before and after the intervention	21%

Table 3. Methods and procedures.

4.4. Professional learning

The written reports end up with student-teachers' reflections about their own learning during the process of designing and the implementation of the didactic proposal and from the discussions held both with the school teacher and the educational researcher. Student-teachers assigned great importance to the moments of reflection and to the possibility of researching their own practice. They considered that all the process was very important for learning about teaching. Mainly mentioned issues were: students' learning, designing learning tasks, classroom management and teacher's role.

Student-teachers considered that their involvement with this educational program contributed to change how they understand the role of teacher: from a perspective of teacher as a transmitter of knowledge to a perspective of teacher as guiding students' learning. For instance, one of the student-teachers wrote in the report:

"Research on my own practice contributed to develop a critical and reflective attitude about my own performance as a teacher and also to develop specific research tools, which will be useful when in the future I come across problems. On that time, I will be able to design a research and to find out solutions which are sourced on evidences" (Student-teacher 1).

Another student-teacher focused on classroom management, stating that he acquired a better understanding of the dynamics of the classroom which will allow him to improve students' engagement with the learning tasks and a better management of classroom discussions in order to take up the maximum of each individual contribution.

Another important issue mentioned by most of the student-teachers was that they learnt how to design and put into action investigative tasks. In addition, they recognized that these types of tasks create engaging learning contexts; also by being involved in these types of tasks, students are required to engage actively with learning, which is beneficial for their learning. Nevertheless, designing as well as implementing, this type of learning tasks was not difficult-free. For instance, one of the student-teacher mentioned that:

"Initially, I had difficulties in managing class behavior and time. Indeed, in the first classes, challenged by the nature of the task, students constantly cried for my help. As the class had so many students, I had a hard time in helping all the students simultaneously" (Student-teacher 15).

The difficulty that student-teachers experienced in the management of students' behavior led them to test different strategies and roles within the classroom, which reflects professional learning (**Table 4**).

Finally, student-teachers mentioned also the opportunity that they were been provided for improving and developing scientific and didactic knowledge.

	Description
Focused on students	Considering alternative conceptions of students
	Identifying students' difficulties with proposed tasks
	Recognizing learning strategies used by students
	Developing critical reasoning
Focused on teacher	Playing another role in the classroom: from knowledge transmitter to guiding learning
	Researching own practice as a strategy for learning to teach
	Promoting enthusiasm, and motivation for science learning
	Using scientific language carefully in order to avoid the formation of alternative conceptions
	Questioning the students to get them to make predictions, generalizations and formulation of questions
Scientific domain	Deepening Physics and Chemistry scientific knowledge
	Recognizing that in the evolution of science there are contradictory ideas that raise controversy
	Enhancing the role of science in society
	Relating the effects of society on the development of science
Didactic domain	Developing investigative tasks
	Developing open tasks using stories, visualizations, digital resources
	Learning how to assess students
	Selecting tasks that promote conceptual change
Teaching context	Managing different working groups
	Developing behavior-control strategies in the classroom
	Managing time allocated to the different moments of class

Table 4. Professional learning.

5. Discussion and conclusion

Since 2010, the ITT model of the University of Lisbon has intended to create conditions for the student-teachers investigate their own practice. By doing this, this model makes the student-teachers not just consumers of educational knowledge, but also producers of knowledge derived from their own practice.

The acquisition of professional knowledge is influenced by the experiences and conceptions of teaching [21]. Teachers hold different conceptions of teaching, namely traditional experimentalist, constructivist and social [35]. Thus, it is essential to identify student-teachers' conceptions of teaching, to bring it to awareness and to discuss how these conceptions influence their curricular decisions. Within this ITT model, while involved in the design of the didactic proposals, student-teachers were encouraged to interpret the formal curriculum and turn it into a teaching curriculum. And so, they were led to critically reflect on the curriculum, considering such elements as what, how and why to teach this particular subject, and to consider the relevance of the subject taught for students and for society. In addition, student-teachers researched the implementation of the didactic proposal within the classroom. This moment required them to identify a previous research problem, to collect and analyze data and to reflect on students' learning and difficulties, as well as on conceptions affecting their decisions and actions. So by developing and implementing a didactic proposal and by researching their own practice, student-teachers were not only developing theoretical knowledge, but also they were using it to make sense of their teaching experience. In this process, they were confronted with tacit conceptions, which were analyzed and changed.

These experiences facilitated the development of professional knowledge. Indeed, student-teachers developed didactic proposals sourced on educational literature and deeply explored and discuss it in collaboration with the university teacher and the school teacher. The relationship between the university teachers and the school teacher, as recommended by educational research [36], encourages the connection between theory and practice, as student-teacher bring to the classroom "fresh" theoretical knowledge which will be put into action and tested in straight collaboration with the school teacher and his/her insights from the practice. In addition, the reflection about their practices and its impacts on students' experiences, supported with educational knowledge, assists them in building new meanings regarding practices and facilitates critical analysis of previous conceptions at the light of evidences that they collected during their practices.

Student-teachers evaluated positively this ITT model as they had the chance to experience different situations: (1) Discussions held with the educational researcher and school teacher, (2) Designing investigative learning tasks, which improved their didactic knowledge, reasoning and communication competencies, and (3) Researching their own practice, in order to reflect on the impact of their practice on their students' learning and to understand the influence of tactical conceptions on their practice.

However, despite the importance attributed to the reflection and to the construction of professional knowledge by the teachers as a way to break with non-reflected practices and conceptions, research show that teachers' practices remain more or less unchanged [37]. Even beginning teachers involved in recent innovative practices in contexts of ITT tend to adopt more traditional ones when they are placed in contexts of professional practice [38]. So despite the positive evaluation made by the student-teachers about the ITT model presented in this paper, it is important to have in mind that this was a sole experience and to wonder about the durability of its impacts on student-teachers. Indeed, one thing is being involved in a context of teacher training, and another thing is the deliberate will to keep on changing and implementing innovative practices that require effort, confidence and also a supportive school. Considering this, two questions emerge from this study. How do student-teachers transpose knowledge constructed during an ITT experience to contexts of professional practice? How to make the impact of ITT experiences last when student-teachers are involved in contexts of professional practice?

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References

[1] Zeichner KM, Noffke S. Practitioner research. In Richardson V, editor. Handbook of Research on Teaching. Washington, D.C.: American Educational Research Association; 2001. pp. 298-330

[2] Sjolie E. The role of theory in teacher education: Reconsidered from student teacher perspective. Journal of Curriculum Studies. 2014;**46**(6):729-750

[3] Darling-Hammond L. Research on teaching and teacher education and its influences on policy and practice. Educational Researcher. 2016;**45**(2):83-91

[4] Loughran J, Berry A, Mullhall P. Understanding and Developing Science Teachers' Pedagogical Content Knowledge. Rotterdam, The Netherlands: Sense Publishers; 2006

[5] Loughran J, Russell T, editors. Purpose, Passion and Pedagogy in Teacher Education. London: Falmer Press; 1997

[6] Roldão MC. Função docente: Natureza e construção do conhecimento profissional. Revista Brasileira de Educação. 2007;**12**(34):94-103

[7] Schön D. Educating the Reflective Practitioner. São Francisco, CA: Jossey-Bass; 1987

[8] Ponte J. Pesquisar para compreender e transformar a nossa própria prática. In GTI, editor. Reflectir e investigar sobre a prática profissional. Lisboa: APM; 2004

[9] Lankshear C, Knobel M. A Handbook for Teacher Research: From Design to Implementation. Maidenhead, UK: Open University Press; 2004

[10] Cochran-Smith M, Lytle SL. Relationships of knowledge and practice: Teacher learning in communities. Review of Research in Education. 1999;**24**:249-305

[11] Tabachnick R, Zeichner KM. Idea and action: Action research and the development of conceptual change teaching of science. Science Education. 1999;**83**(3):309-322

[12] Ponte J. Investigar a nossa própria prática. In GTI, editors. Reflectir e investigar sobre a prática profissional. Lisboa: APM; 2002. pp. 5-28

[13] Nóvoa A. Formação de professores e profissão docente. In Nóvoa A, editor. Os professores e a sua formação. Lisboa: Publicações D. Quixote; 1992

[14] Tavares J. A formação como construção do conhecimento científico e pedagógico. In Sá-Chaves I, editor. Percursos de formação e desenvolvimento profissional. Porto: Porto Editora; 1997

[15] Andrade V, Baptista M, Freire S. Formação inicial de professores de F/Q. Mudanças reportadas em relação ao processo de ensino e aprendizagem. Atas do XVI ENEC: Ciência como cultura. Lisboa: Instituto de Educação da Universidade de Lisboa; 2015

[16] DeBoer GE. A History of Ideas in Science Education. New York, NY: Teachers College Press; 1991

[17] NRC (National Research Council). Inquiry and the National Science Education Standards. Washington, DC: National Academy; 2000

[18] Fullan M. The New Meaning of Educational Change. New York, NY: Teachers College Press; 2001

[19] Bennett N, Carré C, editors. Learning to Teach. London: Routledge; 1993

[20] Bereiter C, Scardamalia M. Intentional learning as a goal of instruction. In Resnick LB, editors. Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser. Hillsdale, NJ: Lawrence Erlbaum Associates; 1989. pp. 361-392

[21] Hewson PW, Hewson M. An appropriate conception of teaching science: A view from studies of science learning. Science Education. 1988;**72**(5):597-614

[22] Spillane JP. External reform initiatives and teachers' efforts to reconstruct their practice: The mediating role of teachers' zones of enactment. Journal of Curriculum Studies. 1999;**31**(2):143-175

[23] Calderhead J, Shorrock SB. Understanding Teacher Education: Case Studies in the Professional Development of Beginning Teachers. London: Falmer Press; 1997

[24] Sagor R. The Action Research Guidebook. Thousand Oaks, CA: Corwin Press; 2005

[25] Ponte J. Investigar a nossa própria prática: Uma estratégia de formação e de construção do conhecimento profissional. PNA. 2008;**2**(4):153-180

[26] Hubbard R, Power B. The Art of Classroom Inquiry: A Handbook for Teacher-Researchers. Portsmouth, NJ: Heinemann; 2003

[27] Feldman A. Decision making in the practical domain: A model of practical conceptual change. Science Education. 2000;**84**:606-623

[28] Koshy V. Action Research for Improving Practice – A Practical Guide. London: Paul Chapman; 2005

[29] Northfield J. Teacher educators and the practice of science teacher education. In Fraser BJ, Tobin KG, Editors. International Handbook of Science Education. Vol II. Great Britain: Kluwer Academic Publishers; 1998

[30] Bolin FS. Helping student teachers think about teaching. Journal of Teacher Education. 1988**, XXXIX**(2):48-54

[31] Bolin FS. Helping student teachers think about teaching. Another look at Lou. Journal of Teacher Education. 1990;**41**(1):10-19

[32] Milles MB, Huberman M. Qualitative data analysis: An expanded sourcebook. London: Sage Publications; 1994

[33] Strauss A, Corbin J. Basic of qualitative research. Techniques and Procedures for Developing Grounded Theory. Thousand Oaks, CA: Sage Publications; 1998

[34] Bybee R, Taylor J. Gardner A, Scotter P, Powell J, Westbrook A, Landes N. The BSCS 5E instructional model: Origins, effectiveness and applications. Colorado Springs, CO: BSCS; 2006

[35] Freire AM. Mudança de concepções de ensino dos professores num processo de reforma curricular/change teachers' teaching conceptions in a process of curricular reform. In ME-DEB (Coord.), Flexibilidade Curricular, cidadania e comunicação/Flexibility in Curriculum, Citzenship and Communication. Lisboa: DEB; 2004

[36] Berger JG, Boles KC, Troen V. Teacher research and school change: Paradoxes, problems, and possibilities. Teaching and Teacher Education. 2005;**21**(1):93-105

[37] Galvão C, Faria F, Freire S, Baptista M. Curriculum conception, implementation and evaluation: An experience. In Akpan B, editor. Science Education: A Global Perspective. Switzerland: Springer; 2017. pp. 253-272

[38] McGinnis JR, Parker C, Graeber A. A cultural perspective of the induction of five reform-minded beginning mathematics and science teachers. Journal of Research in Science Teaching. 2004;**41**:720-747

Teaching and Learning Primary Science for Marginalised Children

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Abstract

In the twenty-first century, the demand for large scale human capital workforce based on scientific knowledge is rising especially in Science, Technology, Engineering and Mathematics (STEM)-related carriers. Innovative societies need people who are equipped with scientific knowledge and competencies. But, science education has tended to be perceived as irrelevant and not interested by marginalised children. Therefore, this study aimed to determine the impact of the learning outside the classroom (LOC) module on academic achievement and intrinsic motivation of marginalised learners in learning science. For that, quasi-experimental design with pre-test post-test, non-equivalent control group research design was implemented. The treatment group (n = 38) used LOC module, while the control group (n = 35) used conventional module in teaching science. Academic achievement evaluates using Science Achievement Test (SAT), whereas intrinsic motivation evaluates using Intrinsic Motivation Questionnaire (IMQ). Data obtained from AT and IMQ were analysed using independent-sample T-test and MANOVA repeated measures. The results showed non-significant increase in SAT mean scores in the treatment group. The findings also indicate that there is no significant main effect and interaction effect between group and time towards intrinsic motivation. As a result, the two teaching methods do not have significant and positive impact on intrinsic motivation among marginalised learners.

Keywords: academic achievement, intrinsic motivation, learning outside the classroom (LOC), marginalised children, primary science module

1. Introduction

In the twenty-first century, the demand for large scale human capital workforce based on scientific knowledge is rising especially in Science, Technology, Engineering and Mathematics

(STEM)-related carriers. Innovative societies need people who are equipped with scientific knowledge and competencies. Therefore, STEM education has become extremely important in today's world in order to produce STEM literate students who are capable of identifying, applying and integrating STEM concept in understanding complex problems and able to generate innovation to solve the problems [1].

All societies in the world have ways to educate their people because education has always played a very important role in the development of a society, in which it can affect self-development, can improve living standards, shape the future and also develop human capital. Moreover, the importance of educational qualifications increases drastically as the number of low-skilled jobs in the employment market nowadays decreases. Malaysia, a developing country in the twenty-first century, is constantly working to improve the level of STEM education among its people including marginalised students. Efforts to raise the level of education among marginalised children in Malaysia have always been given serious consideration. This is to ensure they become full participants that are capable of utilising the knowledge and skills that can contribute to the society. Through education, individual's gap can be reduced and the level of competence among students can also be increased [2].

The rapid development taking place in Malaysia has opened up opportunities to the process of modernization and also access to education, especially for marginalised groups that are still considered backward. Therefore, marginalised children should move forward and adapt themselves in this new era through STEM education so that they will not be left behind when compared with other communities. In addition, it also provides marginalised children for a future that requires knowledge and application skills in a highly competitive job [3] in STEM-related carriers. Hence, factors that affect and contribute to learning process among marginalised children especially in science learning should be identified and studied so that a nation of high competence and high achievers in the field of STEM can be realised.

In recent years, studies have conducted on the affective domain in learning such as motivation as well as cognitive domain that focuses on knowledge learned in school [4]. Motivation is a pre-requisite and co-requisite for effective learning [5] and is said to have influence and impact on children learning outcomes [6]. Furthermore, the importance of motivation in learning has been studied extensively in education [4, 6–12] and has been widely recognised. This research focuses on intrinsic motivation because it was found to be very relevant and also one of the main factors affecting the academic achievement of learners [13–15] and regularly reviewed in academic achievement [16, 17]. According to Ref. [18], intrinsic motivation arises from the individual needs to achieve a certain level of competence. In addition, it involves fun in the learning process at school [13].

In addition to intrinsic motivation, conducive learning environment is also a very important factor in ensuring effective learning process among marginalised children. According to Ref. [19], marginalised children love learning activities that involve environment as they have deep feeling for the environment. Conducive and comfortable learning environment in school will lead to the enactment of meaningful learning among them. Therefore, the authors have initiated an innovation instructional strategy with the application and implementation of activities based on the environment in the process of the teaching and learning (T&L) science. Intervention that can enhance the level of science achievement and intrinsic motivation of marginalised children in primary schools in needed. With this, Learning Outside Classroom (LOC) primary science module has been developed as a mechanism to accomplish the desired goals. The purpose of this research is to determine the impact of LOC primary science module in enhancing science academic achievement and intrinsic motivation of marginalised children.

2. Education achievement and intrinsic motivation of marginalised children

Despite the importance of science nowadays in STEM education, science education has tended to be perceived as irrelevant and not interested by marginalised children. As Brianzoni and Cardellini [20] stated, many learners are often not interested in school science. Although various efforts and programmes has been taken by the Ministry of Education (MOE), marginalised children in Malaysia still showed low and unsatisfactory level in science performance [21, 22]. The level of science education among marginalised children still lags behind as compared to mainstream children. This is because marginalised children often associated with lower academic achievement when compared with children in the mainstream flow This situation not only happen in Malaysia but also faced by other countries such as Canada, Taiwan and New Zealand [23–28]. This is consistent with [29] which states that there are differences exist globally between the education level of native learners and non-native learners in their respective countries.

Overall, the motivation level to learn in school among marginalised children in Malaysia still consider low and has been reported to be at unsatisfactory level [30, 31]. This is further strengthened by Refs. [9, 32] which showed that Malaysian learners have low motivation in learning science. According to Mohammad and Abdul [33], the lack of motivation in learning has contributed to the occurrence of dropout and truancy from school that directly affects their academic achievement. Therefore, it is very important to raise the level of intrinsic motivation among marginalised children in Malaysia. With the increasing level of intrinsic motivation, hopefully, it can have a positive impact on the academic achievement of marginalised children.

Many studies conducted show there is a significant positive relationship between intrinsic motivation and academic achievement [6, 8, 11, 12, 34]. This relationship leads to the conclusion that the motivation can be used to predict the academic achievement of learners [35]. Therefore, we as educators are obliged to increase efforts to ensure that marginalised children have access not only to appropriate education but also to a scientific culture.

Hence, a form of science education that is holistic needs to be created to produce marginalised children who are science literate capable of applying science and technology to overcome the challenges of life now and in the future. Implementing new instructional strategies and pedagogies in science education for marginalised children is extremely important to drastically improve the scientific literacy by giving value and enjoyment in learning science. New strategies needed to create opportunities for marginalised children to be motivated and actively involved in learning science, not only in the classroom, but also outside of traditional classroom. LOC primary science module requires teachers take children out of the classroom during the science T&L process. Hence, the learning process will occur in locations that are close to the environment. Marginalised children need to see its relevance in a societal sense to have the opportunity to be engaged in meaningful learning. This is because forest and the environment are important elements in their daily life. This fun and enjoyable situation will have positive impact and effect on their learning process and intrinsic motivation. Furthermore, Ref. [36] mentioned that LOC approach will be able to build dynamic knowledge and subsequently can explore the skills and abilities of the children. This is to prepare them to face the future when pursuing STEM careers that are highly competitive in the twenty-first century.

3. Conceptual framework of LOC primary science module

This LOC primary science module applied several theories of learning, namely behaviourist learning theory, cognitivist learning theory and constructivist learning theory. Behaviourist learning theory emphasises behavioural changes that can be observed and measured. The principles in Thorndike Theory [37] such as Law of Readiness (pupils readiness to learn), Law of Exercise (the importance of practice and repetition) and Law of Effect (the impact or effect which is obtained by pupils when doing an action) are taken into consideration. Additionally, the principle of reinforcement in Skinner's Operant Conditioning Theory [38] also applied together. Meanwhile, the cognitivist learning theory based on Ref. [39] which emphasises information processing in the mind also included in this module. Ausubel [39] emphasises meaningful learning and the use of advance organiser in the T&L process.

In addition, contextual approach based on constructivist theory that stimulates a person's mind to find meaning in context by making meaningful and relevant relationship to their environment also applied. The learning materials used are readily available from the environment in which these marginalised children are already familiar with these materials. This can make it easier for the children and enhance further the process of understanding the learning that takes place where the children can process new knowledge in a way that is meaningful to them. The sequence of information presentation during the science T&L process is based on Needham's Five Phase Constructivist Learning Theory [40] that is able to create learning environment that stimulates and motivates marginalised pupils. Needham's Five Phase Constructivist Model [40] involves the orientation phase, eliciting ideas, restructuring of ideas, application of ideas and reflection as shown in **Table 1**.

Apart from the learning theories above, the construction of the LOC module will also take into account the Cognitive Load Theory (CLT), which aims to reduce the learning load experienced

Phase	Purpose	Examples of activities
Orientation	To attract students attention and interest	Experiment, video and film show, demonstration, problem-solving, song
Eliciting ideas	To be aware of the student's prior knowledge	Experiment, small group discussion, concept mapping and presentation
Restructuring of ideas • Explanation and exchanging ideas • Exposure to conflict ideas • Development of new ideas • Evaluation	To realise the existence of alternative ideas, ideas need to be improved, to be developed or to be replaced with scientific ideas To determine the alternative ideas and critically assess the present ideas To test the validity of the present ideas To improvise, develop or to replace with new ideas To test the validity of new ideas	Small group discussion and presentation Discussion, reading and teacher's input Experiment, project and demonstration
Application of ideas	To apply the new ideas to a different situation	Writing of individual's report on the project work
Reflection	To accommodate ones idea to the scientific ideas	Writing of individual's report on the project work, group discussion, personal notes

Table 1. Needham's five phase constructivist model.

by the students so that the learning process can occur easily, simply, and smoothly. CLT emphasises on the role played by short-term memory and long-term memory in a learning process. The load in short-term memory should be considered and given attention so that it does not exceed the capacity or limitations that can be processed. Hence, all three effects in this theory, namely the Split-Attention Effect, Modality Effect and Redundancy Effect taken into account and considered during the development of the module.

The instructional design model used is based on the Morrison, Ross, Kalman, and Kemp Model (MRKK) [41]. This model is the basis for the development of the module that will be prepared by the researcher in this study. It has nine major elements arranged in an oval-shaped cycle and is not linear. This means that the instruction can start anywhere that is considered appropriate. The cycle has no starting point or ending point. The process of review and evaluation will take place on an on-going basis to improve instruction. The MRKK Model is shown in **Figure 1**.

Motivation is said to have a significant positive relationship with academic achievement [7, 12–14]. Such relationship leads to the conclusion that motivation can be used as a predictor of academic performance. When marginalised children go through the T&L process based on this module, it is believed that positive changes in the aspect of intrinsic motivation can be demonstrated. This will also simultaneously influence and have positive impact on academic achievement in science. The conceptual framework discussed can be visualised in **Figure 2**.

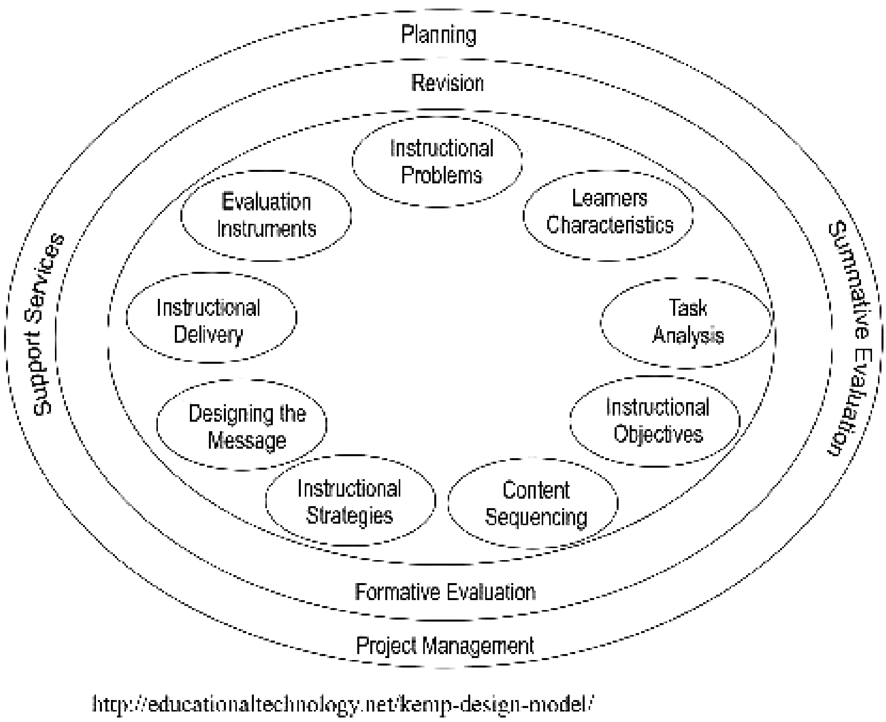

Figure 1. MRKK model.

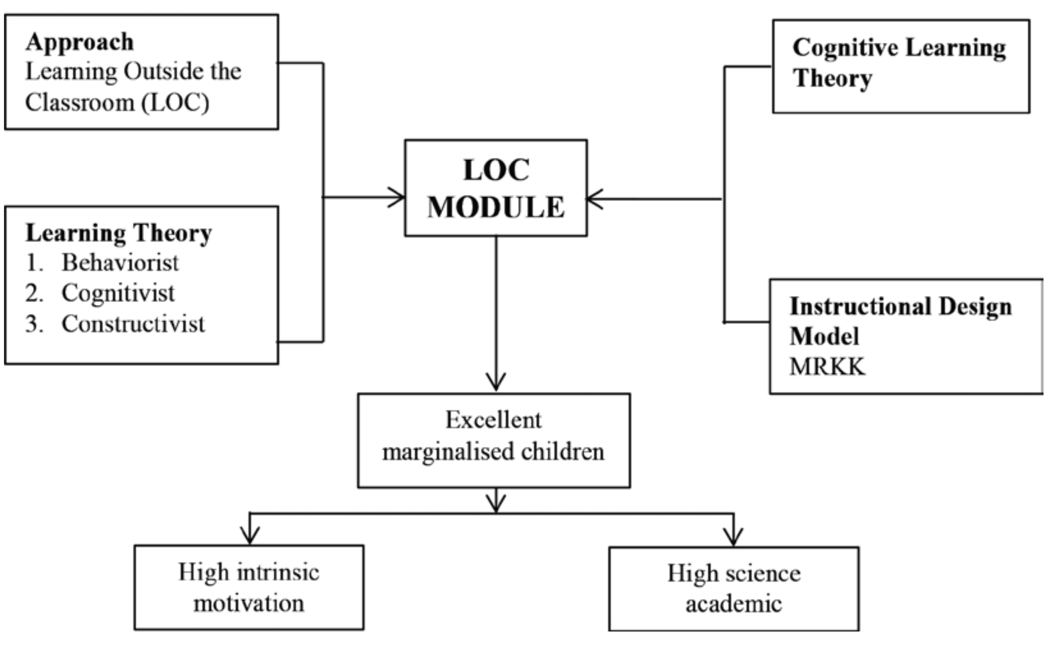

Figure 2. Conceptual framework.

4. Application of theories in LOC primary science module

The sequence of information presentation during the T&L process is according to Needham's Five Phase Constructivist Theory (1987) [40] which involves the phases such as orientation, eliciting ideas, restructuring of ideas, application of ideas and reflection as shown in **Table 1**. The application of these learning theories is implemented in phases deemed appropriate during the science T&L process. In the orientation phase, the Law of Readiness in Thorndike's theory will be implemented. The learning objectives and the teacher's expectations of learners will be communicated to the learners at the beginning of the T&L session. In addition, the contents in the form of a mind map will also be presented to the learners. This is also appropriate with Ausubel's theory of learning [39] which emphasises advance organiser in which the conceptual relationship in the form of a mind map will be applied. The purpose is for the learners to prepare themselves to cope with and receive information that will be presented by the teacher.

During the eliciting ideas phase, learners are stimulated to review and be aware of their original idea of the concepts relevant to the topic to be presented. The discussion and questioning strategy can be used to trigger or elicit learners' original idea. Motivation in the form of encouragement and guidance can be used by teachers so that the learners feel comfortable in giving their answers or their views. This is as described by the Law of Effect in Thorndike's theory and also in Skinner's theory of conditioning that emphasise positive reinforcement and negative reinforcement.

The next phase is the restructuring of idea phase, where learners are aware of the existence of alternative ideas in the form of scientific ideas. In this phase, the pupils realise that the existing ideas that they have before this need to be modified or expanded to ideas that are more scientific. The outside of the classroom contextual approach that is implemented will be more meaningful to the learners. Meaningful learning is emphasised by Ausubel in his theory. Appropriate strategies and teaching techniques can be applied to allow an increase in learners' knowledge.

In the application of ideas phase, the process of consolidation of scientific ideas that was newly developed and established during the restructuring phase will be applied in other circumstances and situations. Repetition process in the form of exercises and drills can be carried out so that the newly acquired knowledge can be reinforced and applied in daily life. This coincides with the Law of Exercise in Thorndike's theory which emphasises on practice and repetition. Exercises will be given to the learners after the completion of each learning session in each subtopic taught by the teacher. This allows learners to master topics taught before proceeding to another subtopic.

The last phase is the phase of reflection. In this phase, learners are aware of the changes of the original idea to new ideas developed during the process of T&L. Comparison of original ideas with the new ideas is done by the learners and the learners will also reflect on the learning process that has resulted in the changes to the ideas to occur.

The contextual-based LOC approach that is implemented in this research is expected to increase the enthusiasm and interests of the learners to learn. The process of learning outside the classroom (LOC) brings learners out from the traditional classroom to the natural environment where they would feel comfortable and familiar as their daily lives are surrounded by flora and fauna. The activities undertaken and the examples given will use materials that are familiar and enjoyable to the pupils. This is to encourage more meaningful learning so that they can associate it with the phenomenon around them or their daily life. Parts of lesson plan in LOC module are shown in **Figure 3**.

Application of ideas (25 minutes)	**Activity 2.3** *Hands-on activity*: **Plants need air to live.** Teacher tells students that they are going to conduct an investigation about the basic needs of plants that will involve air. Teacher elicits students' prior knowledge about control breathing: *T: Who can show teacher how to stop humans and animals from breathing?* *S: Cover your nose* *T: What will happen if you stop breathing or there is no air for you to breathe?* *S: Die / Fainted / Fainting* *T: Then, how to stop plant from breathing?* *S: Close the hole / Don't know* Teacher explains to students that if they cover the leaves with nail varnish, the holes on the leaves will be filled and this prevents leaves from getting air. *T: What will happen if the plant does not get air?* *S: Die* *T: You will carry out an investigation to see what will happen if the plant does not get enough air.* *S: Yes, teacher.* Teacher divides students into groups of 2-3 or at the discretion of the teacher. Each group appoints a team leader. Teacher shows students the materials / equipment needed to carry out the investigation for each group. Students start the investigation activity.	Contextual Early preparation: • Germinate the seeds into seedlings (1-2 weeks before the activity). • Place soil in a container.

Figure 3. Parts of lesson plan in LOC primary science module.

5. Objectives

This research aimed to develop and determine the impact of learning outside the classroom (LOC) primary science module in enhancing science academic achievement and intrinsic motivation of marginalised children in remote area of Malaysia. With this, alternative T&L approach will be introduced beside the conventional teaching strategies practiced in rural schools in Malaysia.

6. Methodology

6.1. Research design

This research employed quasi-experimental of the type pre-test, post-test and non-equivalent control group design. Both the treatment and control group were tested with pre-test and post-test before and after the intervention implemented as shown in **Table 2**.

This research was conducted in four out of six marginalised primary schools in a remote area of Malaysia. Control group and treatment group comprised of two schools each in order to make sure that the number of respondents are more than 30 for each group. Control group used conventional module, while treatment group used LOC primary science module during T&L of science. The independent variable in this research is the study group, namely control and treatment group, while two dependent variables are science academic achievement and intrinsic motivation.

6.2. Respondent

Year 2 learners from four primary schools in interior part of Malaysia served as respondent in this research. A total of 73 respondents involved in this research in which the treatment group consisted of 38 Year 2 learners and the control group consisted of 35 Year 2 learners.

6.3. Instrument

Two instruments were used in this research which is Science Achievement Test (SAT) and Intrinsic Motivation Questionnaire (IMQ). Authors created two sets of SAT, namely pre-test and post-test which are equivalent in the aspect of number of items, level of difficulty,

Group	Test	Intervention	Test
Control	Pre-test	Conventional	Post-test
Treatment	Pre-test	LOC primary science module	Post-test

Table 2. Pre-test, post-test, non-equivalent control group design.

the format and the scope to test learners' knowledge in the topic "Plant", while IMQ was taken from Ref. [42], adapted from the Youth Children's Academic Intrinsic Motivation Inventory (Y-CAIMI) instrument in Ref. [14]. However, only two categories in IMQ were selected for this research, namely general construct and science construct. After the verification process by experts and pilot test was conducted, SAT contains 10 items, whereas IMQ contains 18 items which consists of 11 items from general constructs and 7 items from science constructs in the form of a 3-point Likert scale of "1 = Not True", "2 = Not Sure", and "3 = True". The reliability for SAT in this study showed a value of 0.711 using the Kuder Richardson approach and IMQ showed value more than 0.70 with Cronbach alpha coefficient.

6.4. Procedure

After pilot test, correction and improvements was done to the module and instruments before administered them in the actual research. SAT and IMQ were administered to respondents in both groups before the T&L on plants as pre-test to determine the homogeneity level of academic achievement and intrinsic motivation between the control and treatment groups. Control group used conventional module, while treatment group used LOC module during T&L session. At the end of the T&L session, SAT and IMQ administered again to the same respondents in both groups as post-test. Both SAT and IMQ administered by the provisions of the same time taken before and after the T&L session on "Plants" topic in both control and treatment groups.

6.5. Analysis

Quantitative data obtained through SAT and IMQ before and after the T&L session in both the control and treatment groups were analysed using descriptive statistics and inferential statistics. Independent samples T-test was conducted on the data collected during the pre-test to determine the level of homogeneity of the academic achievement and intrinsic motivation between the two groups involved. Independent samples T-test also performed on post-test to determine the effect of LOC primary science module in enhancing marginalised learners' academic achievement in science. In addition, MANOVA 2 × 2 × 2 repeated measures analysis was used to determine the effect of LOC primary science module in enhancing intrinsic motivation. Repeated measures involves two study groups (control and treatment), two time (pre-test and post-test) and two constructs of intrinsic motivation (general and science).

7. Research findings

7.1. Homogeneity of academic achievement and intrinsic motivation

Homogeneity analysis using T-test independent samples at 0.05 significant levels found that there were no significant difference between control and treatment groups in term of academic achievement and intrinsic motivation. **Table 3** shows pre-test mean score of academic

Dependent variable	t	df	p	Mean difference
Pre-test academic achievement	−0.085	63.95	−0.932	−0.293
Pre-test intrinsic motivation	1.617	71	0.110	0.086

Table 3. Independent T-test pre-test mean score of academic achievement and intrinsic motivation according to groups.

achievement, $t = -0.085$ and $df = 63.95$, $p > 0.05$, and pre-test mean score of intrinsic motivation, $t = 1.617$ and $df = 71$, $p > 0.05$. The findings show that before the intervention, both the academic achievement and intrinsic motivation in the control and treatment groups were homogeneous. This allows comparison to be performed on the impact of LOC primary science module in the learning of "Plants" topic among marginalised children.

7.2. Science Achievement Test (SAT)

Before intervention, descriptive analysis found the pre-test mean score of SAT in control group, M = 46.29 (SD = 11:40), while pre-test mean score of SAT in treatment group, M = 46.58 (SD = 17.60). After intervention, descriptive analysis found the post-test mean scores of SAT in control group, M = 73.14 (SD = 21.11), while post-test mean scores of SAT in treatment group, M = 76.84 (SD = 14.91). Control group showed an increase mean score of 26.85, and treatment group showed an increase mean score of 30.26. Post-test mean scores of treatment group exceeds the control group by 3.70. **Table 4** shows the descriptive statistic of pre-test and post-test mean scores of AT according to groups.

Table 5 shows the analysis of the independent samples T-test of post-test mean score for academic achievement according to group. Results in **Table 5** showed that there is no significant differences in the post-test mean score of SAT between the control and the treatment groups, $t = -0.870$ and $df = 71$, $p > 0.05$.

7.3. Intrinsic motivation

MANOVA repeated measures 2 × 2 × 2 analysis was used to determine the impact of LOC primary science module in enhancing intrinsic motivation among marginalised children

Group	N	Test	Mean (M)	Standard deviation (SD)
Control	35	Pre	46.29	11.40
		Post	73.14	21.11
Treatment	38	Pre	46.58	17.60
		Post	76.84	14.90

Table 4. Descriptive statistics pre-test and post-test mean score of achievement test according to groups.

in this research. The findings in **Table 6** showed that there is no significant main effect of group on intrinsic motivation [$F(2, 70) = 0.273$, $p > 0.05$]. Data also showed that there is no significant main effect of time on intrinsic motivation [$F(2, 70) = 2.574$, $p > 0.05$]. The effect of the interaction between time with the group is also not significant to the intrinsic motivation [$F(2, 70) = 3.039$, $p < 0.05$].

However, further analyses as shown in **Table 7** found that there is a significant main effect of the time on the general construct of intrinsic motivation [$F(1, 71) = 5.054$, $p < 0.05$]. Further descriptive analysis found that the pre-test mean score of general construct ($M = 2.633$, $SD = 0.282$) exceeds the post-test mean score of general construct ($M = 2.526$, $SD = 0.369$). This means that the level of intrinsic motivation among marginalised children generally has not been increased, but it decreased significantly across time.

The results in **Table 7** also found that there is a significant interaction effect between time and group on general construct of intrinsic motivation [$F(1, 71) = 4,423$, $p < 0.05$]. Further analysis using a paired T-test for control group general construct of intrinsic motivation was significant ($t = 2.600$, $df = 34$, $p < 0.05$), while the paired T-test results for the treatment group general construct of intrinsic motivation were not significant ($t = 0.127$, $df = 37$, $p > 0.05$). **Table 8** shows the results of paired t-test.

Dependent variable	t	df	p	Mean difference
Post-test academic achievement	−0.870	71	0.387	3.699

Table 5. Independent T-test post-test mean score of academic achievement according to groups.

Effect	Pillai's trace value	F	df1	df2	p	Partial eta squared
Group	0.008	0.273	2	70	0.762	0.008
Time	0.069	2.574	2	70	0.083	0.069
Group × time	0.080	3.039	2	70	0.054	0.080

Table 6. Multivariate test.

Effect	Construct	Squared total	df	Mean squared	F	p	Partial eta squared
Time	General	0.452	1	0.452	5.054	0.028	0.066
	Science	0.129	1	0.129	0.911	0.343	0.013
Time × group	General	0.396	1	0.396	4.423	0.039	0.059
	Science	0.457	1	0.457	3.239	0.076	0.044

Table 7. Effect within subjects test.

Construct	Group	Test	Mean (M)	Standard deviation (SD)	t	df	p
General	Control	Pre	0.214	0.491	2.600	34	0.014
		Post					
	Treatment	Pre	0.007	0.349	0.127	37	0.900
		Post					

Table 8. Results of paired T-test for general construct of intrinsic motivation according to time and group.

8. Discussion

The findings in this research showed that both LOC primary science module used in treatment group and conventional module used in control group give equal or similar impact in improving the academic achievement of marginalised children. This result directly indicated that the LOC module is not very effective as compare to conventional module in improving the academic achievement of Year 2 marginalised children in Malaysia. In this research, information still effectively conveys to marginalised children although conventional module was used. This may be due to the fact that marginalised children live in surroundings full of wide variety of flora and fauna. According to Ref. [43], knowledge of plants is unique among marginalised people around the world. With the familiarity of plants among marginalised children, it does not make any significant difference between using conventional module or LOC module during T&L science in school.

Nevertheless, there is an increase in the mean score of 3.70, when LOC primary science module was used. In comparison, it can be said that LOC module has more positive impact than the conventional module although it does not show any significant difference. In the LOC module, teacher requires to bring children out from the traditional classroom for the T&L session. This situation led the children near to the environment and close to the natural flora and fauna. This provides an opportunity for children to learn science in a new environment that is conducive and comfortable for them. A conducive learning environment coupled with fun may be a contributor to the slightly higher mean score in the LOC module compare to the conventional module.

The findings also indicated that the LOC primary science module is ineffective in enhancing intrinsic motivation among marginalised children as a whole. Although there are significant main effects of the time and significant interaction effect between time and group on the general construct of intrinsic motivation, but both, respectively, showed a decrease over time. The significant decrease in the mean score on general construct of intrinsic motivation in the control group showed that conventional module has a significant negative impact on intrinsic motivation among marginalised children. For comparison purposes, it can be said that LOC primary science module is better than the conventional module, although both modules did not bring positive impact on the general construct of intrinsic motivation among marginalised children.

Although LOC primary science module did not significantly increase academic achievement and intrinsic motivation among marginalised children, it does not necessary indicate that this module is not good. Such declines can be due to several reasons. One of the reasons may likely due to the change of strategy or approach to T&L used by teachers in the treatment schools that create a negative impact on the achievement and motivation of these marginalised children. From the conventional approach that is more teacher-centred to the implementation of learner-centred activities in LOC primary science module has brought drastic change to the marginalised children. This change causes something unusual to them. As reported by Ayla [4], this drastic change causes negative impact among marginalised children in Turkey.

Another reason of ineffective LOC primary science module may relate to the existing level of marginalised children's achievement and motivation for learning as a whole. Many studies reported that these marginalised children are weak in their studies and show lower cognitive level compared to mainstream learners. Refs. [30, 31] also reported that marginalised children do not show enthusiasm and high motivation in the process of learning. The learning process among marginalised children only occurred when they are in school. They do not study at home because of parents are not interested in education, and moreover, they cannot see the importance of education for their children. This directly affects the academic achievement and intrinsic motivation of marginalised children.

These findings bring us to suggest a few proposals in order to enhance the academic achievement and intrinsic motivation among marginalised children in Malaysia. The curriculum used for this marginalised children should be revised and updated. As reported by Ayla [4], review of science curriculum that is more focused on matters relating to life will directly affect the environment in the classroom and in turn have a positive impact on children's learning in Turkey. In addition, shifting the focus from cognitive aspect to psychomotor and affective aspects of the learning process of the marginalised children in the curriculum can be considered. This is because marginalised children are poor in cognitive aspect and the attention span of these children is limited.

Besides that, integration of local culture and environment in the new curriculum may help to make the curriculum more relevant to the marginalised children. This modification or integration in accordance with the culture and environment of marginalised or indigenous communities have occurred in other countries such as Canada [44, 45] and New Zealand [46]. With this integration, marginalised children can relate what they have learned in science to their daily lives. Marginalised children can see the relevance of education and science in their daily lives and in turn can increase their intrinsic motivation towards learning science. According to Ref. [47], it is not enough to introduce learners to new and updated developments in science, but they need to see its relevance in a societal sense to have the opportunity to be actively involved in the process of learning.

Modification and improvement can be conceived to overcome the weaknesses of the LOC module in order to give more significant and positive impact. The blending of suitable strategies and pedagogies with curriculum that integrates culture and environment of the indigenous community in the new module can and should have more positive effect compared to the module used in this research. All these are in hope that the level of motivation among indigenous learners can be raised to a higher point. As stated in Refs. [48, 49], modules that use suitable strategies and pedagogies with curriculum that integrates community's culture and environment can give more positive impact in the process of T&L.

9. Conclusions

Although LOC primary science module in this research did not give favourable effect towards achievement and intrinsic motivation, but it has implications especially to T&L practices and marginalised children. Lesson plan in the module helped teachers to conduct the T&L in a more systematic manner besides enhancing their higher order questioning skills. The group activity created more fun learning and hence contributed towards active participation, which ultimately enlightened the marginalised children about the importance of studying science. This instructional strategy introduced in LOC module also allows children to learn science in a meaningful way. The aim is to produce human capital among marginalised communities in the twenty-first century for a future that requires knowledge and skills in a job application that is highly competitive.

With the limitations in our research, we also encountered questions in need of further research. T&L science module which integrates local culture and environment of indigenous knowledge that are suitable and practical for marginalised children should be carried out. The module created can be a way to guide novice teachers especially in teaching science to marginalised children too. In addition, using indigenous language in the process of T&L science for marginalised can be studied too. This method has been carried out successfully in Canada for First Nation's community and in New Zealand for Maori community. Further research is also needed to effectively blend learning experiences in formal and informal learning in order to significantly enhance the academic achievement and motivation in learning science for marginalised children. In conclusion, several efforts to improve the T&L process need to be taken seriously in the hope of enhancing motivation towards learning science among the indigenous learners. Various teaching issues and challenges in marginalised schools need to be solved so that the T&L process can be implemented effectively towards marginalised children. With this, they too can contribute to achieving a high level of scientific literacy and STEM literate community.

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References

[1] Chew CM, Noraini I, Leong KE, Mohd Fadzil D. Secondary school assessment practices in science, technology, engineering and mathematics (STEM) related subjects. Journal of Mathematics Education. 2013;**6**(2):58-69

[2] Min KK, Mi KC. Design and implementation of integrated instruction of mathematics and science in Korea. Eurasia Journal of Mathematics, Science & Technology Education. 2015;**11**(1):3-15

[3] Trilling B, Fadel C. 21st Century Skills: Learning for Life in Our Times. San Francisco, CA: Jossey-Bass; 2009

[4] Ayla C. Student motivation in constructivist learning environment. Eurasia Journal of Mathematics, Science & Technology Education. 2016;**12**(2):233-247

[5] Palmer D. A motivational view of constructivist-informed teaching. International Journal of Science Education. 2005;**27**(15):1853-1881

[6] Li JY, Shieh C. A study on the effects of multiple goal orientation on learning motivation and learning behaviours. Eurasia Journal of Mathematics, Science & Technology Education. 2016;**12**(1):161172

[7] Eccles JS, Wigfield A. Motivational beliefs, values, and goals. Annual Review of Psychology. 2002;**53**:109-132

[8] Hirst G, Van Knippenberg D, Chen CH, Sacramento CA. How does bureaucracy impact individual creativity? A cross-level investigation of team contextual influences on goal orientation–creativity relationships. Academy of Management Journal. 2011;**54**:624-641

[9] Kamisah O, Zanaton HI, Lilia H. Sikap terhadap Sains dan sikap saintifik di kalangan pelajar Sains (Attitudes toward science and scientific attitudes among Science students). Jurnal Pendidikan. 2007;**32**:39-60

[10] Lee TT. Pembinaan dan keberkesanan modul multimedia interaktif dengan agen pedagogi dalam pembelajaran elektrokimia (Construction and effectiveness of interactive multimedia modules with pedagogical agents in the learning of electrochemical) [thesis]. Universiti Kebangsaan Malaysia, Malaysia; 2013

[11] Zhu Y, Leung FKS. Motivation and achievement: Is there an east asian model? International Journal of Science and Mathematics Education. 2011;**9**:1189-1212

[12] Zimmerman BJ. Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. American Educational Research Journal. 2008;**45**:166-183

[13] Gottfried AE. Academic intrinsic motivation in elementary and junior high school students. Journal of Educational Psychology. 1985;**77**:631-645

[14] Gottfried AE. Academic intrinsic motivation in young elementary school children. Journal of Educational Psychology. 1990;**82**(3):525-538

[15] Gottfried AE, Gottfried AW. A longitudinal study of academic intrinsic motivation in intellectually gifted children: Childhood through early adolescence. Gifted Child Quarterly. 1996;**40**:179-183

[16] Schiefele U. Interest, learning and motivation. Educational Psychologist. 1991;**26**:299-323

[17] Steinmayr R, Spinath B. The importance of motivation as a predictor of school achievement. Learning and Individual Differences. 2009;**19**:80-90

[18] Deci EL, Ryan RM. The support of autonomy and the control of behavior. Journal of Personality & Social Psychology. 1987;**53**:1024-1037

[19] Márof R, Sarjit S, Orang A: Isu, Transformasi dan Cabaran. Selangor: Penerbit Universiti Putra Malaysia; 2008

[20] Brianzoni V, Cardellini L. Science education in Italy: Critical and desirable aspect of learning environments. Journal of Baltic Science Education. 2015;**14**(5):685-696

[21] Subahan MM. Overcoming marginalized children learning through professional development of teachers. Procedia Social and Behavioral Sciences. 2009;**I**:1759-1762

[22] Subahan MM, Lilia H, Saemah AR, Halimah H, Rozlina TA. Teaching marginalized children at primary schools: Teachers' professional development through collaborative action research. Cypriot Journal of Educational Sciences. 2011;**2**:49-60

[23] Bamhardt R, Kawagley AO, Hill F. Cultural standards and test scores. Sharing Our Pathways. 2000;**5**(4):1-4

[24] Canadian Council on Learning (CCL). The Cultural Divide in Science Education for Aboriginal learners. [Internet]. 2007. Available from: http://www.cclcca.ca/pdfs/LessonslnLearning/. [Accessed: 25-10-2015]

[25] Kidman J, Chiung FY, Abrams E. Indigenous students' experiences of the hidden curriculum in science education: A cross-national study in New Zealand and Taiwan. International Journal of Science and Mathematics Education. 2013;**11**:43-64

[26] Kuo LTW. A cooperative action research project in achieving the science curriculum goals with community-based approach. Journal of Australian Indigenous Issues. 2008;**12**:219-228

[27] Meyer X, Crawford BA. Teaching science as a cultural way of knowing: Merging authentic inquiry, nature of science, and multicultural strategies. Cultural Studies of Science Education. 2011;**6**(3):525-547

[28] Stewart GM. Science in the Maori-medium Curriculum: Assessment of Policy Outcomes in Putaiao Education. Educational Philosophy and Theory. NZ: University of Waikato; 2009

[29] Prout S, Hill A. Situating indigenous student mobility within the global education research agenda. International Journal of Educational Research. 2012;**54**:60-68

[30] Abdull SS, Nuraini Y, Mohd IG, Mohd HD. Kanak-kanak minoriti orang asli di Malaysia: Menggapai literasi bahasa melayu (Aboriginal minority children in Malaysia: Achieve malay language literacy). Jurnal Pendidikan Bahasa Melayu. 2011;**1**(2):59-70

[31] Asnarulkhadi AS, Maria M, Zahid E, Mariani M, Hanina HH. Kurikulum Bersepadu Orang Asli/Penan (KAP) – Satu Pendekatan Baru dalam pembangunan Pendidikan Komuniti Orang Asli/Penan (Integrated Curriculum for Aboriginal/Penan (KAP) – A New Approach in the Development of Aboriginal Community Education/Penan). In: Seminar Kebangsaan Sains Sosial: Sains Sosial Teras Pembangunan Modal Insan (National Seminar on Social Sciences: Social Science Core Human Capital Development); 20-21 May 2007; Kuala Lumpur; 2007

[32] Zanaton HI, Lilia H, Kamisah O. Sikap terhadap Sains dalam kalangan pelajar Sains di peringkat menengah dan matrikulasi (Attitudes toward Science among Science students at the secondary and matriculation). Pertanika Journal of Social Science & Humanities. 2006;**14**(2):131-147

[33] Mohammad JS, Abdul RA. Kesedaran pendidikan dalam kalangan masyarakat orang asli (Education awareness among indigenous communities). In: Abdul Razaq Ahmad & Zalizan Mohd. Jelas (Pnys). Masyarakat Orang Asli: Perspektif Pendidikan dan Sosiobudaya (Aboriginal Community: Education and Socio-Cultural Perspective). Bangi: Fakulti Pendidikan, Universiti Kebangsaan Malaysia; 2009; pp. 47-58

[34] Delmas MA, Lessem N. Saving power to conserve your reputation? The effectiveness of private versus public information. Journal of Environmental Economics and Management. 2014;**67**(3):353-370

[35] Henman K. The correlation between academic achievements, self-esteem and motivation of female seventh grade students: A mixed methods approach [dissertation]. Indiana State University, Indiana; 2010

[36] Smith G, Sobel D. Place and Community Based Education in School. United Kingdom, Routledge: Taylor & Francis; 2010

[37] Thorndike EL. Animal intelligence: An experimental study of the associative processes in animals. Psychological Review. 1898;**2**(81):551-553

[38] Skinner BF. Science and Human Behavior. New York: The Macmillan Company; 1953

[39] Ausubel DP. The Psychology of Meaningful Verbal Learning. New York & London: Grune & Stratton; 1963

[40] Needham R. CLIS in the Classroom: Teaching Strategies for Developing Understanding in Science. Leeds: University of Leeds; 1987

[41] Morrison GR, Ross SM, Kalman HK, Kemp JE. Designing Effective Instruction. 7th ed. NJ: John Wiley & Sons, Inc; 2013

[42] Leibham ME. The impact of interest on elementary school children's selfconcepts, intrinsic motivation, academic achievement, and willingness to broaden knowledge [dissertation]. Indiana State University, Indiana; 2005

[43] Fatan HY, Nursuhana AH, Abbas. (Masyarakat pribumi dan perburuan haiwan liar (Indigenous people and hunting of wild animals). In: Abdul Razaq Ahmad dan Zalizan

Mohd. Jelas (Pnys), Masyarakat Orang Asli: Perspektif Pendidikan dan Sosiobudaya (Aboriginal Community: Education and Socio-Cultural Perspective). Bangi: Fakulti Pendidikan, Universiti Kebangsaan Malaysia; 2009. pp. 33-40

[44] Lewthwaite BE, Owen T, Doiron A. Curriculum change and self-governing agreements: A Yukon First Nation case study. International Journal of Multicultural Education. 2015;**17**(3):37-55

[45] St GG, Dyck LE. Reforming First Nations Education: From Crisis to Hope. In Report of the Standing Senate Committee on Aboriginal Peoples. Senate of Canada, Ottawa, ON; 2011

[46] Colleen M. Indigenous people: Emancipatory possibilities in curriculum development. Canadian Journal of Education. 2008;**31**(3):614-638

[47] Rannikmae M. Some crucial areas in science education research corresponding to the needs of the contemporary society. Journal of Baltic Science Education. 2016;**15**(1):4-6

[48] Cindy WCC, Kamisah O. The effect of *Kayeu* learning outside the classroom primary science module on intrinsic motivation of indigenous learners. Journal of Baltic Science Education. 2016;**15**(3):360-370

[49] Cindy WCC, Kamisah O. Cultivating marginalized children's scientific literacy in facing the challenges of the 21st century. K-12 STEM Education. 2017;**3**(1):167-177

Chapter 5

Discussing Socioscientific Controversies in Primary and Secondary Education: Potentials and Constraints in Science Lessons

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Additional information is available at the end of the chapter

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Abstract

This chapter presents the results of an investigation conducted with the objective of understanding the socioscientific controversies approach in science teaching from the perspective of curricular integration, against the background of the new social and environmental challenges currently faced by science education. The research was conducted as a case study, and the data presented here were collected using questionnaires and interviews and were analyzed using the discursive text analysis method. The approach is predominantly qualitative and descriptive. The results of these analyses indicate the potential of the socioscientific controversies approach combined with integrated projects, fostering debate between different subject areas in discussions of subjects that are considered controversial.

Keywords: socioscientific controversies, curricular integration, science education

1. Introduction

This chapter is intended to contribute to the academic debate around discussion of socioscientific controversies (SSCs) in science teaching from an integrative perspective.

This study of SSC is situated within the context of a century in which, according to Silva and Cicilini [1], we are witnessing scientific and technological achievements that have been predicted in the past, but more in a tone of science fiction than of reality. These developments have had impacts on society, communication media, and education. The traditional way that Biology is taught has undergone changes and new issues have emerged for discussion, both within schools and in other spheres of society. Social debate is definitively attracted by problems related to the promises, challenges, and controversies of subjects related to life sciences and technology.

Within this context, Schramm [2] has claimed that we are witnessing a Biological Revolution, some examples of which are already part of citizens' lives, such as in vitro fertilization and implantation of embryos; cloning; the medicines produced by application of biotechnological knowledge; treatments for cancer, for AIDS, and for other pathologies; modification of plants and animals by manipulating and reprogramming their genes; and the fight against the major endemic diseases, hunger, and so on.

As part of this veritable revolution, new scientific capabilities have been acquired, such as, for example, treatment of the genetic information of living beings. This Biological Revolution has not only made it possible to describe and understand life but has also enabled its modification, resulting from a new form of applied knowledge that has resulted from an alliance between the technical sciences of language and the technical sciences of biology [2].

Galvão and Reis [3] argue that nowadays the objective is to integrate scientific knowledge into the students' world, in order to help them understand the objects and events which they encounter every day, attempting to increase their interest in science and scientific activities and to encourage their involvement in processes of discussion and evaluation of socioscientific issues.

These authors state that it is the responsibility of the school and, consequently, the teacher to provide opportunities for discussion of the socioscientific issues that are increasingly part of everyday life. Schools must foster a scientific education that problematizes scientific developments, because, in addition to being necessary, it is an indispensable social duty to present students with science that is more up-to-date, historical, social, critical, and human.

Galvão and Reis [3] also point out that the teacher's role includes encouraging students to research and select reliable sources of information; contrast different points of view; seek the knowledge needed to understand a given issue; familiarize themselves with the practices, techniques, and theories of scientists, so that they can be related to their daily lives; to discuss the subjects; to study the benefits they can offer and the harm they can cause; and to critically assess and express opinions on socioscientific issues.

Therefore, the classroom should become a venue for discussion, where the students can participate actively, expressing their interest in and knowledge about the widest variety of subjects, which can be dealt with not merely in relation to scientific knowledge but also in terms of their social meaning and impact. This experience can be accomplished in a variety of different ways and should involve the points of view of distinct social groups, thereby providing a platform for discussion of the constraints on and potentials of participation in socioscientific controversies.

Within the scope of science teaching, the space occupied by this debate has been growing as a result of certain issues that have already attracted the interest of teachers and their students, such as cloning and assisted reproductive techniques. There appears to be the space and opportunity, and even a need, to design a form of science education that is able to, effectively, foster in-depth discussion of these issues. Working from the objectives of school-based education in the sciences, we should be developing scientific literacy, in other words, providing training in the sciences that "[…] provides the tools that make it possible to better understand the society in which we live" [4],[1] to enable students to take decisions consciously.

This chapter is derived from a doctoral thesis, and its overall objective is "to present the constraints on and potentials of the socioscientific controversies approach, by means of a case study of use of the integrated project teaching method in Science lessons."

2. Socioscientific controversies in science teaching

We live in a world in which new scientific discoveries and technologies are directly connected with our lives, interfering at greater or lesser intensities in our everyday society. On this basis, Delizoicov and Auler [5] refute the assumption that scientific enterprises and their agenda are neutral, pointing out that the questions that science asks, the phenomena that are selected for investigation and the problems chosen for solution, the research avenues opened and, as a consequence, the advances achieved in one or another field are all directly linked to the values of a specific spatiotemporal context and to the demands located within it.

We live in a society in which the technology clearly impacts on everyday affairs. This is why we must prepare our students to build the skills to evaluate and intervene intelligently in technological and scientific activities. In the current context, this role falls to science teachers.

The use of socioscientific controversies (SSCs) for teaching science and technology is increasingly emphasized in curricula and in research into science teaching. Certain elements of the science, technology, and society movement [6–8] refer to these subjects as socioscientific issues, which are an expression of the application of this movement's assumptions in the classroom. It is therefore more important to educate the population to take a position with relation to the scientific and technological revolution than it is to instruct and inform it.

2.1. Socioscientific controversies (SSCs)

In attempt to situate the reader, it is worthwhile to start by discussing what is meant by SSC, basing the discussion on the literature. The terms "controversial subjects," "scientific dilemmas," "socioscientific controversies," "socioscientific issues," and "contentious subjects" are all used to designate elements in common.

According to Rudduck [9], an issue is defined as controversial if it divides people and involves value-judgments that prevent it from being settled solely on the basis of analysis of evidence or by experiment. A controversy cannot be settled by an appeal to facts, empirical data, or experience alone, because it involves both facts and issues of values.

[1]This and all subsequent quotations from work published in languages other than English have been translated by the author.

According to Nelkin [10, 11], scientific controversies can be caused by: (a) the social, moral, or religious implications of a scientific theory or practice (e.g., issues related to cloning and genetic modification of living beings); (b) social tensions between individual rights and social objectives, political priorities and environmental values, economic interests, and health-related concerns that result from the application of technology; (c) by use of public financial resources for major scientific and technological projects to the detriment of other projects, such as, for example, for social ends. These controversies can also be referred to as socioscientific issues, that is, social issues provoked by scientific and technological developments.

Ramsey [12] defined three criteria for selection of controversial socioscientific subjects: (i) whether there are differences of opinion in relation to them; (ii) whether the subject has social significance; and (iii) whether the subject, to some extent, is related to science and technology.

According to Para Reis [13], controversial socioscientific issues (CSIs) are social issues with a considerable scientific and technological dimension, such as, for example, manipulation of the genomes of living beings, in vitro fertilization, and cloning; release into the atmosphere of substances with effects on public health, on the greenhouse effect, and on destruction of the ozone layer; use of hormones and antibiotics in animal production; environmental and public health issues.

Pérez and Carvalho [14] state that CSIs encompass debates, controversies, or subjects directly related to scientific and/or technological knowledge that have a major impact on society. According to Abd-El-Khalick [15], these issues are markedly different from the exercises or "problems" that appear at the ends of chapters of the text books used in the classroom. Such exercises are generally defined and cover multidisciplinary aspects that are very often loaded with ethical, esthetic, ecological, moral, educational, cultural, and religious values.

These authors argue that the characteristics generally observed in socioscientific issues are: (a) knowledge of a scientific nature; (b) formation of opinions and choosing between options; (c) frequent appearances in the news media; (d) local scope; (e) analysis in terms of cost versus benefit and of values; (f) awareness of sustainability; (g) permeation by ethical and moral rationales; (h) permeated by understanding of risks; and (i) normally, part of people's everyday lives.

We can see that even the definition of a controversy is a controversial issue. According to Velho and Velho [16], some authors consider a controversy to be a discussion between two parties about a particular subject in which their beliefs and arguments are at stake, which is a view that places controversy on a more cognitive or psychological plane. I therefore believe that controversies cannot be separated from a wider cultural context and are, therefore, social phenomena that are historically determined.

Faced with such a diversity of definitions, I have chosen to use the term "socioscientific controversies" and have adopted the following criteria for selection of the articles that make up our corpus for analysis:

(i) controversies that are provoked by the social impacts of scientific and technological innovations and divide both the scientific community and society in general;

(ii) that which allows discussion between two or more involved parties on a given controversy, in which their beliefs and arguments are at stake;

(iii) whether, in relation to the controversy being discussed, people are divided because this reflection involves value-judgments that prevent it from being settled solely on the basis of analysis of evidence or by experiment.

2.2. Socioscientific controversies in Brazil

The proposal of working with the SSC in the classroom is relatively new and has received little publicity. For Brazil, searching with the dates 2001 to 2014, a total of 44 publications were identified in online periodicals dealing with science teaching, which suggested this type of approach [17]. Some studies list the educational potentials that discussing SSC in the classroom can leverage, not only for learning curricula content but also for learning about processes of a scientific and technological nature and for students' cognitive, social, political, moral, and ethical development [3, 13, 18–23].

Reis [13] conducted a series of studies investigating the educational impact of conflict and controversy in the classroom, finding that their use resulted in motivation, research, and interchange of information. Reassessment of individual positions, supportive relationships between the students, and appreciation of content and of the learning experience enabled development of logical and moral reasoning skills and a deeper understanding of the important aspects of the nature of science.

Reis and Galvão [19] believe that use of socioscientific issues can be important for the establishment of a link between the scientific culture (in which the scientific community participate) and science teaching.

Ramos and Silva [20] claim that discussion of controversial subjects allows students to acquire knowledge about the type of reasoning that motivates governments, scientists, and protest movements, and also a more realistic understanding of scientific and technological development, within its social and political context, and of its impact on the general public or on specific communities. They state that it is the school's and, therefore, the teacher's responsibility to create opportunities for discussion of controversial subjects, which are an ever growing part of daily life. Schools should provide science education that informs students of scientific developments since, in addition to being necessary, it is an indispensable social duty to provide them with science that is up-to-date, historical, social, critical, and human.

Galvão and Reis [3] add that it is the science teacher's job to encourage students to: research and select reliable sources of information; contrast different points of views with each other; search for necessary knowledge; familiarize themselves with scientists' practices, techniques, and theories, creating opportunities to relate this knowledge to their daily lives; debate the subjects; determine the benefits and harm that could result; and critically assess and form an opinion on controversial issues.

Vieira and Bazzo [21] state that discussing controversial socioscientific situations can offer students a more realistic image of science, whereas not including them in science teaching contributes to transmission of distorted ideas that often describe science as non-controversial, neutral, and disinterested.

Zuin and Freitas [22] describe how socioscientific controversies are not resolved by analysis of evidence such as empirical data. They state that we must pay special attention to considerations of ethics, morals, and values with relation to social elements and to conceptual, methodological, and technological elements related to science. Within this perspective, learning opportunities provided by teaching based on discussion of socioscientific problems have shown great potential for construction of a more realistic view of scientific development and for promotion of responsible citizenship.

Forgiarini and Auler [23] claim that another of the characteristics of controversial subjects is that they are given prominence in the press, on television, and in films, which may relate them to stereotypical ideas of science and technology and of the activity of scientists. It is accepted that both schools and the media can contribute to construction of misleading conceptions with relation to scientific and technological endeavors.

Forgiarini and Auler [23] also state that controversial subjects are still studied little in the classroom and highlight the reasons that lead many teachers to avoid them. According to Reis [13], one of the factors behind this absence could be: "[…] concerns about a possible failure of control during discussions, since there may not be correct answers, rather a diversity of value judgments" [13]. He recommends that the teacher should maintain a neutral position, that of a mediator, with relation to discussion of these subjects, in order to avoid revealing personal positions that the students might assume are correct. He states that the teacher's neutrality is of fundamental importance, because the students must be given the right to form their own opinions, and, therefore, the teacher should opt for neutrality during these discussions.

In addition to contribution to demystification of misleading ideas with relation to scientific endeavor, discussion of socioscientific controversies can also motivate students to express their opinions, to learn to construct arguments, and to take well-founded decisions with respect to scientific and technological development and its implications for society.

Reis also raises the suggestion that by using socioscientific controversies in science teaching, we can cover a range of different curricular content. This process can be conducted in an interdisciplinary manner, in the form of a collaborative effort involving teachers from several different subjects (general science, history, geography, chemistry, physics, and biology, among others).

2.3. Constraints on and potentials of socioscientific controversies in Brazil

A study conducted by Duso [17] identified work that focused on socioscientific controversies published from 2001 to 2014 in Brazilian periodicals dealing with science, available on-line, and indexed with the terms "controversial subjects," "contentious subjects," "socioscientific controversies," "contemporary subjects," or "socioscientific issues" in their subtitles, titles, abstracts, or keywords. The study located 44 papers published in the journals selected.

The authors of these articles pointed out the difficulties faced by teachers who, in general, do not have the skills to manage and direct classroom discussions nor the knowledge needed for discussion of socioscientific issues with relation to the nature of science and the sociological, political, ethical, and economic elements of the subjects being discussed. Additionally, they also deal with the difficulties involved in assessing activities involving discussion of socioscientific controversies and/or the pressure exerted by national assessment systems that do not place value on this type of discussion, creating barriers to effective adoption of this approach.

One of the major problems of teaching, highlighted by Shulman [24], Carr and Kemmis [25], and Tardif [26], has been the lack of individual and collective systematization of teachers' experiences, which has resulted in a real absence of history and practice, without which it is difficult to conduct an analysis of its principles. This is why Lee Shulman's studies are important, because they follow teachers at different levels of education and constitute a considerable number of cases, in which their reasoning and actions while in service were recorded.

Shulman's contributions with relation to teacher's knowledge of their subjects' content are of interest in teacher training, because I consider that this knowledge helps to construct teachers' autonomy. Nevertheless, it is important to point out that achieving autonomy is not limited to teachers knowing their subjects' content, which is still in the personal dimension of a teacher's professional development, since it is also necessary to cultivate the social dimension, because teachers' autonomy is an especially collective process and not only an individual process.

Content is no longer discussed, it is simply replicated and derived. In contrast, training is a concept that must be problematized and reformulated, working from the concepts and the objectives of science teaching.

According to Fourez [27], there are divergent positions on the utility of training in epistemology, history of science, and interdisciplinary approaches, because of the complex situations or the fundamental questions provoked by scientific models. The collective dimensions of scientific work should be fostered, organizing interdisciplinary working groups and facilitating interaction between different groups of teachers from different subject areas and the scientific community.

Along the same lines, Forgiarini and Auler [23] state that teacher training that is excessively fragmented and disconnected from the social context exacerbates the extent to which the true situation is different from the ideal. They point out that the great majority of teachers suffer from knowledge gaps, from a lack of information related to controversial subjects, because controversial socioscientific issues are considerably different from the types of problems that are generally dealt with in science lessons.

However, in some of the articles analyzed, while the importance of collective working is highlighted, teachers from subjects in the humanities are not considered to have so many obligations with relation to the circumstances of controversies related to scientific subjects. The most excessive criticisms are leveled at biology teachers, possibly because of the specificity of the curricula content linked with this science.

Levinson [18] considers that science and humanities teachers have complementary strengths and weaknesses. While teachers from humanities subjects are more at home with controversy, Science teachers have greater knowledge of scientific concepts. Collaboration has useful contributions to make, but, unfortunately, the teachers from these different spheres rarely work in cooperation.

If collaboration between teachers can be fostered, the classroom can become a forum for discussions in which the students participate actively, demonstrating their interests and knowledge about the most varied range of subjects, which can be dealt with not only with regard to scientific knowledge but also in relation to their social significance and impact. This will give them the opportunity to experiment in a variety of forms or from different perspectives with the points of view of different social groups, which in turn makes dialogue over the limitations to and possibilities for debates about controversial socioscientific subjects possible.

I understand that it is not feasible to work with controversial subjects by exclusively drawing on subject knowledge. Contributions are needed from multiple fields of knowledge. This is why cooperative work is extremely necessary, so that all participants can make contributions from their own area of expertise to analyze the many different dimensions involved.

It is also indispensable to conduct in-depth studies with relation to controversial subjects, in order to avoid simplification of complex issues, and it is necessary to engage in coherent epistemological reflection on science and technology, acknowledging the impossibility of obtaining answers to all questions exclusively on the basis of technical and scientific knowledge [19], choosing working methods that are appropriate to the objectives that discussion of controversial issues in the classroom is intended to achieve.

2.4. The project teaching method as an option for integrated teaching practices

The project teaching method was pioneered by John Dewey and Kilpatrick in Chicago at the start of the twentieth century with the objective of resignifying the school environment to make it more open to real life. This approach was taken up and championed by Freinet, in France, in the 1920s and 1930s.

Kilpatrick believed that the foundation of all education is guided and decided activity. In other words, all school activities could be conducted in the form of projects, with no need for special organization.

In turn, Freinet [28] did not explicitly propose using this method, but did vehemently argue in favor of the idea of work as a vital function of each and every individual. This is the school of work that becomes the school of life, and each will become the other.

Jolibert and colleagues were influenced by Freinet's ideas and constructed a proposal based on working with projects. They proposed organizing work on the basis of principles such as the collaborative life, students' appropriation of their own school lives, and organization of teaching into projects. Jolibert [29] believed that the project teaching method allows school life to be founded on the real, open to multiple relationships with the exterior, and in which the students take an active part in their own learning.

This concept is founded on a globalizing and interdisciplinary view of organization of schools' curricular content. Within this proposal, it is possible to combine study of significant contemporary problems by groups of students and teachers with the content of school subjects, respecting their interests and their requirements and taking students' concepts, hypotheses, and knowledge as a starting point.

There are many different approaches to working with projects, following different methodological paths. The approach that is advocated in this text is the result of certain reflections on and experiments with implementation of integrated projects in a secondary school.

Working with the project teaching method proposes changes in the teacher's role, which becomes that of a guide and a researcher who both challenges and learns. The objective is to foster in the students an understanding of the problems investigated, going beyond the information provided and recognizing the different versions of a fact, proposing explanations and hypotheses and engaging in dialogue on different points of view.

Secondary education is possibly the most appropriate time to work with interdisciplinary projects, since it is a period during which young people are going through a process of transition between childhood and adulthood and is therefore a stage in which they are defining their future roles in society. As Hernández [30] puts it, "[…] the school culture takes on a function of remaking and renaming the world and of teaching students to interpret the changeable meanings with which people in different cultures and historical periods give meaning to reality."

When working with integrated projects, the activities are organized on the basis of students' experiences, motivations, expectations, and interests, and it is assumed that working groups will be formed that enrich through meaningful collaboration. The subject matter is not predetermined, because it is the result of an open process, and is explored in relation to the students' everyday lives, so that they gain a cognitive, emotional, and relational understanding of the phenomena of the world that surrounds them.

2.5. The constraints on and the potentials of the project teaching method

According to Santomé [31], certain constraints are because of a lack of adequate planning, of work in small groups, and a lack of motivation for work that is not appropriately remunerated. Compounding these elements is the prejudice against using projects because of ignorance of their meaning and lack of professional preparedness.

We should take into account the way teachers are trained by specific subject area. According to Schor [32], as a result of the specialization of scientific knowledge, certain problems emerge that demand a collaborative approach, that is, it is necessary that specialists work together collectively. We cannot expect that subject teachers will engage in integrated work if it does not fit in with their specialties. A lack of experience during training, both initial qualification and ongoing education, with an integrative curriculum approach can create constraints.

However, according to some authors, what is reported is that working with project teaching method is a challenge for teachers, since this dynamic implies that they must take on the roles of teachers, researchers, and mediators, leaving aside their roles as transmitters of knowledge to become mediators of learning, encouraging the formation of autonomous students, capable of acting and interacting in the world in which they live. The project teaching methodology, with activities conducted within the project, leads to considerable changes in students' behavior, interest, and motivation with relation to learning the subject.

One of the potentials of using integrated projects is the students' involvement in the process of construction of knowledge and of seeking solutions to problematic situations, in addition to positive changes in relation to day-to-day attitudes and greater motivation and involvement in the learning process.

Although it is difficult for teachers to achieve a good balance between the elements of the triad "subject matter," "activities," and "assessment" in the classroom, students are able to demonstrate and re-elaborate earlier concepts, which I consider to be of great importance in the construction of knowledge.

Beane [33] sees curricular integration as a concept that is concerned with the possibilities for personal and social integration through a curriculum that is organized around significant problems and questions, identified in a collaborative manner by the teachers and students, irrespective of the demarcations that separate subjects.

However, difficulties are encountered, especially with relation to the issue of bringing the humanities closer to the sciences. In the majority of cases, integration between these different groups of subjects proves to be a practical problem that is difficult to solve. The difficulty lies in establishing a set of common repertoires that will enable dialogue.

In view of the above, the SSC approach can be considered an ideal way to achieve curricular integration in teaching, since all of the different subject areas will get the opportunity to contribute a great deal of subject matter to the discussion.

3. Methodology

In order to understand the SSC approach using the project teaching method, I observed the planning of some of these projects in real teaching situations, thereby delineating their limits and possibilities in this area.

The SSC approach used in combination with integrated projects was observed in a private school that provides both Secondary and Technical Vocational education and is located in the state of Rio Grande do Sul, Brazil.

Data were collected by administering questionnaires containing open-ended questions to the 42 teachers with the objective of obtaining information on the conception that these teachers had of SSC, and of their constraints and potentials for teaching. This questionnaire was also designed to provide an understanding of teachers' concepts with regard to organization and application of projects conducted in the school and the constraints and potentials for using them in teaching. Fourteen teachers completed the questionnaires.

After collecting the teachers' responses to the questionnaire, it was necessary to conduct unstructured interviews [34] with the objective of probing in greater depth the research participants' thoughts with relation to use of SSC and the way the projects are organized at the school.

These interviews were conducted with the school's Principal, the Vice-principal responsible for teaching and three teachers, one from each subject area (languages, humanities, and sciences), selected using the criterion of longest time teaching at the school.

The data collected were analyzed using Discursive Text Analysis [35]. This analytical resource was used to systematize information from the questionnaires and to construct an interpretation of the subject in question from the point of view of the research participants. This analysis, which is coherent with the qualitative approach chosen, facilitates comprehension of the phenomenon investigated with no intention of generalizing or explaining it.

During this analysis, the questionnaires were read and organized into units and assigned to a system of categories that provide the basis for construction of descriptive texts (metatexts) that would be used to interpret the phenomenon studied.

In order to organize these units, a labeling system was adopted in which units from questionnaires were marked with a "Q" and those from teachers with a "T." The units were numbered from 1 to 14 to represent the respondents, with no relationship between the number and the respondent. Finally, units were also labeled with the number of the questionnaire item, separated from the number of the respondent by an underscore character (_).

Next, the interviews were transcribed but were not categorized, rather they were used as a basis for in-depth discussion of the constraints and potentials identified in the data from the questionnaires. Data from the questionnaires and the interviews were combined to construct a metatext. To identify the teachers interviewed, I used the same numbers as for the questionnaires, adding the letter "I" to indicate interview data. The Principal is identified with the label "Prin," and the Vice-principal responsible for teaching is identified with the label "VPT."

4. The constraints on and potentials of projects in the school

The principal constraint, mentioned both by the Vice-principal for teaching and by the teachers, was the time allotted by the school for planning projects, as can be observed in the following extract: "[…] we should have more time for discussion" (IT14). This time could be apportioned during the school's teachers' meetings, since this is an activity that goes beyond the teachers' normal classroom activity. The same constraint was also identified by the Principal.

> *[…] the obstacles to them having more time to plan are administrative, teachers should nowadays have "teacher's time" and be paid for it, teachers do it on their own time, just like they grade tests, they do it as part of their jobs, but if we look at it properly, it would be more time for planning than, including paid time, perhaps more meetings. (IPrin)*

Another constraint, highlighted by the Vice-principal, is related to teachers who also work for other educational institutions: "[…] also considering the teachers' working hours, considering their involvement, sometimes, with more than one institution, well this caused some difficulties" (IVPT). This constraint, compounded by the lack of time, means that the teacher also needs to make more time available outside of the school.

> *It's obvious that there are certain barriers to this approach, but it demands that the teachers make themselves available beyond their involvement with the school. It requires teachers to talk to their peers both inside and outside of the school environment. (IVPT)*

However, despite the existence of these constraints, it is clear, in what was said by the history teacher, for example, that: "[…] we integrate and I loved meeting up to plan and grade the projects and we grew together with others who have different points of view, because we also have to negotiate" (IT4). This situation of integration and discussion of the debate encourages reflection within the group that is already working with projects.

It should not be forgotten that there is turnover among the school's teaching staff, that is, new teachers are contracted who had not taken part in the discussions about the projects. Therefore, new teaching concepts should be expected and also that teachers will be contracted who do not have this understanding of what working with projects is or how it is done.

> *Obviously, some people were not disposed, obviously they could not continue to work here because they were unable to work within this system. This is perfectly understandable, without detracting from, without considering that there is any lack of merit in these teachers' professional activity. They have to be respected, within their own concepts of education. (IVPT)*

In addition to the constraints reported above, issues related to paperwork and training also stand out in the interviews, such as, for example, personal issues, as illustrated in the following excerpt from the interview with the Portuguese language teacher: "I think that today the barriers are, on my part, overly optimistic expectations with relation to the presentation of projects; I always expect much more than the students produce" (IT13).

This constraint related to the expectations of a languages teacher was not observed in the transcripts from the humanities teacher. Here it is clear that when they are working with projects, the students tend to become more involved in the teamwork dynamic, which provides openings for exchange of ideas, which are sometimes different from the teacher's ideas.

> *[…] when we do an integrated project, we automatically involve the students and the students integrate and the students get a feel for the school, they work within a different perspective in which evidently the subjects don't matter, but they do matter, you know? But there is a type of socialization, of knowledge between all of the teachers, and with the students, and it becomes clear that many things, for example, what it means to work in a team; I think that the students take this experience away with them, because they end up, respect for human beings, because they are discussed, they're not imposed, so I have to accept that, very often, it's not how I think, so it is an exercise in democracy. (IT14)*

As the Vice-principal pointed out, when the theme is based on subjects that are more significant to the students, there is an observable increase in their involvement in the project.

> *[…] the advantages are obvious, to the extent that the students were involved in executing these projects, and they became more relevant each time, as we managed to focus on subjects that were significant to the students, as well. So, to the extent that we improved or perfected these subjects, the students' involvement with this is huge, in relation to this. (IVPT)*

We can also see that the projects approach employed at the school enabled greater integration not only among the students but also between them and the teachers. This multiple integration is superior to pure memorization of curricula content with little meaning and depends upon a dialogue between different points of view. The result is an amplified view of the world and makes it possible to "[…] form a critical and creative person, at one with their times, who can collaborate in construction of a better society, you know? You see lots of all of this in the integrated projects, you see it in action, they have thousands of ideas" (IPrin). The teacher (IT13) confirms this:

> *[…] they (the students) have a much richer view of the world, […] a completely different reality, including to me, because I was also unaware, so you realize that we live in a much larger world, with those we live with. (IT13)*

We can see, in the interviews with the management team and with the teachers, that they have a number of different conceptions with relation to the nature of the projects that are run at this school, their planning, and the possible ways of implementing them. Their expectations are primarily linked to issues with the time available for planning and discussion with groups of teachers and are associated with a lack of teachers' meetings at the school.

Therefore, analyzing the interviews with my interlocutors, I was able to identify the many constraints that could make use of projects impossible, and I was also able to reflect on other spaces in the school dynamic where it would be opportune to expand this discussion.

5. The SSC approach in the school

Within this universe of reflection about integrated projects and their relationship with the school, I consider that it is opportune to discuss SSC and consider the possible contributions that this approach can make to enhance the project teaching method.

Socioscientific controversies emerge from the social impacts of scientific and technological innovations that cause controversy in both the scientific community and society in general. I talked to the management team and to the teachers, attempting to understand the concepts that underpin their points of view with respect to SSC.

During the years that the school used projects, there were times when controversial subjects were covered, but this was not explicit. Approaching and dealing with SSC in the school context can encourage discussion of different points of view on the same subject and contribute to students' and teachers' moral development and to building their argument skills and can also contribute to an improved understanding of the scientific process as a whole.

5.1. The constraints on and potentials of SSC

The responses to the questionnaire and my conversations with the interviewees brought up certain constraints that are unfavorable to adoption of the SSC approach. Among these constraints, I highlight "Curricular planning and time" and also "Insecurity with discussion of the subject." It will be noted that the time available and the space dedicated by the school to discussion between teachers once more figure as constraints, because, as one teacher pointed out, it is important "[…] that we discuss this among the teachers, isn't it? And everyone thinks along the same lines, you know? I think it's a good idea for us to approach it as a group […]" (IT14) to plan the project. This particular excerpt underscores the concern that all the teachers should think along the same lines with relation to the controversy to be dealt with. For this reason, this constraint can be linked to insecurity with discussion, with epistemological reflection, and with the treatment needed for use in projects.

> *[…] there are people who are in favor and people who are against, but that's it, the maturity, that the teacher's nakedness to, to be able to reach closure in each of these subjects, without giving his own opinion, agreeing or disagreeing, but then it is the adult's point of view, that has to end it. (IT13)*

The same teacher (T13) refers to the issue of neutrality in the discussion process "[…] because if the teacher also more or less sits on the fence, then he doesn't know and then the student realizes this, particularly adolescents, they will realize this […]" (IT13), thereby creating an obstacle to mediation of the subject being discussed.

> *[…] the teacher has to be very adult and take this position, of an adult, he can't give an opinion that he agrees, disagrees, I accept, don't accept, that's not it, he has to play the role of someone who is mature for power, provide a compass, you know? I think that's the teacher's job. (IT13)*

Other constraints are related to "teaching materials and supporting materials," as seen in an excerpt from another teacher: "These controversies, sometimes, are not covered in the teaching materials" (I14). This element is also highlighted in articles and by researchers [13, 21, 23] who use the SSC approach.

Another of the constraints that was cited was "assessment," and there were no comments specifically related to learning during the interviews. I therefore conclude that this may be related to insecurity with dealing with the subject, since, when assessing a discussion of controversial subjects, the teacher cannot only consider one point of view to be correct.

When asked about the potentials of using the SSC approach in lessons, the teachers considered that they provide motivation for the students to seek information on current issues. Taking into consideration the concepts involved in dealing with controversies, one teacher (T1) answered a questionnaire item as follows: "I think that this approach is always motivating and provoking, because it drives me to seek more information and greater precision with relation to the concepts covered" (QT1_5).

Other teachers stated that the controversies approach promotes better understanding of reality; as follows: "[…] it helps with development of critical reasoning and position-taking, helping students to think like a citizen and see beyond appearances[…]" (QT3_5), providing "[…] awareness of the facts and changes that are a part of learning […]" (QT4_5) and, therefore, "[…] gives significance to the students' reality" (QT14_5). A different point of view on potentials is revealed in another teacher's response: "It is important since they are who will continue scientific and technological develoxpment and presenting them with these controversies is a way of making them reflect so that in the future we can achieve better solutions than the current ones" (QT10_5).

My understanding is that including SSC among the subjects of the projects run at the school is relevant, since it provides an opportunity to discuss controversial subjects in society. Nevertheless, this challenge should be accepted in an integrated manner across the curriculum and within organization of the subjects and not delegated to just one subject department, because of the complexity of the subjects involved and their didactic organization. The school's Vice-principal responsible for teaching argues along the same lines:

> *Nowadays, I don't think it is conceivable any longer to analyze any controversy from the point of view of just one subject. I think it would be almost impossible. Perhaps, in my view, it is almost impossible, or such an analysis would be very prejudiced, or it would not be sufficiently enriched to even merit analysis of its results because of the bias introduced by the concepts of a specific subject. (IVPT)*

This perspective is shared by teachers from the different subjects themselves.

> *[…] that is exactly what the project is for, we identify certain issues which, after the curiosity, the asking of questions, these specific issues will be discussed with each student in the classroom, so perhaps, in Sociology they will discuss (one angle), and in History another, and in Geography they'll discuss another, I think it's more or less like that. (IT14)*

These contributions from the management team and the subject teachers show that some of the constraints are related both to planning the projects and to the way that SSCs are approached. Time is one of the most important elements to be considered in this context, followed by the challenge of directing discussions when there are differing positions on a given subject. Divergent points of view can arise among the group of teachers who are planning and organizing the project as well as among the students during lessons.

Despite these constraints, we can see that implementation of this approach in a school that is already methodologically committed to a perspective that values curricular integration appear to be appropriate and could potentialize this integration even further. The school understands that current issues that cause controversies should be dealt with through projects in several different subject areas, rather than be focused on just one branch of knowledge. In this chapter, I defend the claim that the SSC approach can potentialize this integration, not only by bringing the subjects together but also by encouraging wider curricular integration.

6. Some considerations

It is our belief that it is not enough to rely on traditional subject-based teaching alone, in which information considered relevant is provided by the teacher, with content isolated from its context. Rather, it is necessary to use methodologies that enable the integration of concepts across different subjects to be perceived in a clear and objective manner, taking advantage of the experiences provided by the environment of which the students are part, combined with an approach using socioscientific controversies to provide opportunities for discussions that are not restricted to scientific knowledge.

However, I have also shown some of the limitations of this type of activity, many related to planning its use within the daily routine of the school, describing a series of factors that are impediments to its effective implementation. These factors are linked to issues from a range of different domains, including of a political, emotional, and structural nature, in addition to elements related to training and qualifications. However, these limitations could be resolved if the teaching staff involved in a collective project were able to discuss strategies to overcome them. It is clear that some factors are not easy to resolve and, in some cases, are under the control of the school's Principal and Vice-principal, such as allocating space and time for more effective discussions to take place, in addition to more adequate remuneration for the teachers.

The analyses of questionnaires and interview transcripts enabled us to identify the principal factors that interfere with using controversial subjects in the classroom. One of these aspects is emphasis on memorization and the little attention given to aspects related to the process of construction of scientific knowledge or to the epistemological aspects of science. This is strongly linked to teachers' initial training, where the emphasis is on depositing the subject content learnt, passing it on to the students so they are instrumentalized to pass external assessment exams and university entrance exams, ignoring the context and the reality of society.

Another factor is the teachers' lack of experience and, consequently, the students' lack of experience with discussions in the classroom, which means they do not have the necessary skills for this type of activity. Of particular importance is a lack of knowledge about how to design and manage classroom discussion activities, obviously in relation to controversial subjects. Although they did use a space for, for example, simulation of a jury, the teachers had concerns with relation to mediating these activities. This insecurity, related to a lack of experience, demonstrates the extent to which theory and practice are separated in the classroom. Both initial training and ongoing education explore the importance of group activities and of discussion, but teachers do not have experience with these activities, making it less likely that they will employ them.

Other constraints are related to the large quantity of curricular content in science subjects; the teachers' concepts of science teaching and the socioscientific issues approach; and a lack of educational resources. These teachers end up opting for direct presentation as teaching strategy and concern themselves with transmission of knowledge, filling their lessons with fragmented elements from the curriculum, when they could be utilizing aspects of knowledge production and the epistemology of science, with the result that they create an idea of science as pre-established content that the students must master.

It is our understanding that using the SSC approach within the sciences alone will not achieve integration between the different subjects. Along the same lines, taking this approach to teaching the humanities or languages, in isolation, will also fail to achieve this success. The project teaching method is one means of bringing these subjects together, because it works, organizes, and teaches in a way that is collective and integrative, making the social dynamics of working groups explicit and providing opportunities for integration.

In addition to integration, which is fostered by the project teaching method, we need to go further, by planning projects with the SSC approach, since, in order to develop citizenship, we cannot limit ourselves to discussion but must provide opportunities for the students to act on their discussions, that is, enable them to go beyond the school walls and into society, motivating them to exercise their citizenship.

Analysis of the teachers' responses showed that, in general, the staff are open to new ways of working, including the strategy proposed, involving use of socioscientific controversies in an integrative manner. Many of them pointed out that they already include different ways of working in their practices, albeit in an isolated manner, which reveals a fresh view on their conceptualizations of teaching, students, and education. Working from the constraints on and potentials of discussion of socioscientific controversies within an integrative approach, I believe that we need to rethink the way that initial teacher training and ongoing education are constituted. It is important to help them to internalize the educational relevance of this type of educational experience and to develop the teaching knowledge necessary to implement it in the classroom setting.

I believe that the constraints and potentials raised by the teachers with relation to this type of practice in the school are potentialized by explanation of the contradictions between what is possible and what limits effective use. From this perspective, it is possible to understand what the "constraints" are and how they operate and how, sometimes, they can be overcome. Taking them as a basis, it is necessary to undertake planned actions to ensure that this type of discussion is included as part of teachers' training, going beyond identification of limiting factors, in the direction of achieving better knowledge of and interaction with reality.

When faced with difficulties, teachers should attempt to evaluate the reasons behind the success or failure of the approach adopted. It is likely that they will not be inherent to the methodology proposed but to the way it has been conceived and managed. Particular attention must be paid to the subject and structure of the task, to the composition of groups, and to the social skills that are needed to complete the activities that follow.

Another concern related to using discussion of socioscientific controversies in an integrative model is that this approach could tend to be transformed into just another teaching resource for convincing students that scientific knowledge, because it is different, has greater validity than other types, or that it is the only knowledge that should be taken into account for decision-making. I believe that this can often lead to discussion of controversies being seen as an instrument exclusively for learning scientific knowledge, reducing a debate that could be much wider-ranging, because scientific discourse is seen as an instrument for understanding human controversies.

Teaching with Integrated Projects, allied to the SSC approach, can enable an expansion of horizons and lead to perception of the implications for understanding the reality of the curricular content of each of the subjects. In addition to this advantage, the practice can help students and teachers to perceive the importance of an integrative view of knowledge, stimulating them to advance beyond education bound by the domains of the content of a single subject. This study appears to show that the project teaching strategy is a promising way to transform the student-student, student-teacher, and teacher-teacher relationships in the classroom.

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References

[1] Silva MO, Cicillini GA. O potencial das discussões polêmicas nas aulas de biologia. In: Semana Acadêmica. Uberlândia: Universidade Federal de Uberlândia; 2008. Available from: https://ssl4799.websiteseguro.com/swge5/seg/cd2008/PDF/SA08-20377.PDF [accessed:2017-02-12].

[2] Schramm FR. Paradigma biotecnocientífico e paradigma bioético. In: Oda LM, editor. Biosafety of transgenic organisms in human health products. Rio de Janeiro: Fiocruz; 1996. pp. 109-127.

[3] Galvão C, Reis P. A promoção do interesse e da relevância do ensino da ciência através da discussão de controvérsias sociocientíficas. In: Vieira RM, editor. Ciência-tecnologia-sociedade no ensino das ciências: educação científica e desenvolvimento sustentável. Aveiro: Universidade de Aveiro; 2008; pp. 131-135.

[4] Delizoicov D, Angotti JL. Metodologia do Ensino de Ciências. São Paulo: Cortez; 2011. p. 207.

[5] Delizoicov D, Auler D. Ciência, tecnologia e Formação Social do Espaço: questões sobre a não-neutralidade. Alexandria – Revista de Educação em Ciência e Tecnologia. 2011;4(2):247-273.

[6] Ratcliffe M, Grace M. Science education for citizenship: teaching socio-scientific issues. Maidenhead: Open University Press; 2003.

[7] Pedretti E. Teaching science, technology, society and Environment (STSE) education: Preservice Teachers' philosophical and pedagogical landscapes. In: Zeidler D, editor. The role of moral reasoning on socioscientific issues and discourse in science education. The Netherlands: Kluwer Academic Publishers; 2003; pp. 219-239.

[8] Zeidler DL. Tangled up in views: Beliefs in the nature of science and responses to socio-scientific dilemmas. Science Education. 2002;86:343-367.

[9] Rudduck J. A strategy for handling controversial issues in the secondary school. In: Wellington JJ, editor. Controversial issues in the curriculum. Oxford: Basil Blackwell; 1986. pp. 6-18.

[10] Nelkin D. Controversy: politics of technical decisions. London: Sage Publications; 1992.

[11] Nelkin D. Science controversies: The dynamics of public disputes in the US. In: Jasanoff S, Markle G, Petersen J, Pinch T, editors. Handbook of science and technology studies. Thousand Oaks: Sage; 1995. pp. 444-456.

[12] Ramsey J. The science education reform movement: implications for social responsibility. Science Education. 1993;77(2):235-258.

[13] Reis P. A discussão de assuntos controversos no ensino das ciências. Inovação. 1999; 12:107-112.

[14] Pérez LFM, Carvalho WLP. A autonomia dos professores de ciências em serviço e a abordagem de questões sociocientíficas. In: Orquiza-de-Carvalho LM, Carvalho WLP, editors. Formação de Professores e Questões Sociocientíficas no Ensino de Ciências. São Paulo: Escrituras; 2012; pp. 297-323.

[15] Abd-Elkhalick F. Socioscientific issues in pre-college Science classrooms: The primacy of learners' epistemological orientations and views of nature of Science. In: Zeidler D, editor. The role of moral reasoning on socioscientific issues and discourse in science education. The Netherlands: Kluver Academic Publishers; 2003; pp. 41-61.

[16] Velho L, Velho P. A controvérsia sobre o uso de alimentação alternativa no combate à subnutrição no Brasil. História, Ciências, Saúde, Manguinhos. 2002;9(1):125-157.

[17] Duso L. A discussão de controvérsias sociocientíficas: uma perspectiva integradora no ensino de ciências [thesis]. Florianópolis: Universidade Federal de Santa Catarina; 2015.

[18] Levinson R. As ciências ou as humanidades: quem deve ensinar as controvérsias em ciência? Pró-posições. 2001;12:62-72.

[19] Reis P, Galvão C. Controvérsias sociocientíficas e prática pedagógica de jovens professores. Investigações em Ensino de Ciências, Instituto de Física. 2005;10(2):131-160.

[20] Ramos MB, Silva HC. Controvérsias científicas em sala de aula: uma revisão bibliográfica contextualizada na área de ensino de ciências e nos estudos sociológicos da ciência & tecnologia. VI Encontro Nacional de Pesquisa em Educação em Ciências (VI ENPEC); December 2007.

[21] Vieira KRCF, Bazzo WA. Discussões acerca do aquecimento global: uma proposta CTS para abordar esse tema controverso em sala de aula. Ciência & Ensino. 2007;1(número especial) pp. 1-12.

[22] Zuin VG, Freitas D. A utilização de temas controversos na formação de licenciados numa abordagem CTSA. Ciência & Ensino. 2007;1(2): pp. 1-9.

[23] Forgiarini MS, Auler D. A abordagem de temas polêmicos na educação de jovens e adultos: o caso do "florestamento" no Rio Grande do Sul. Revista Electrónica de Enseñanza de las Ciencias. 2009;8(2):399-422.

[24] Shulman LS. Knowledge and teaching: foundations of the new reform. Harvard Educational Review. 1987;57:1-22.

[25] Carr W, Kemmis S. Teoría crítica de la enseñanza: la investigación-acción en la formación del profesorado. Barcelona: Martínez Roca; 1988.

[26] Tardif M. Saberes docents e formação profissional. Petrópolis: Vozes; 2011. p. 326.

[27] Fourez G. Crise no ensino de Ciências. Investigações em Ensino de Ciências. Porto Alegre. 2003;8(2): pp. 109-123.

[28] Freinet C. As Técnicas Freinet da Escola Moderna. Lisboa: Editorial Estampa Ltda; 1975.

[29] Jolibert J. Formando crianças leitoras. Porto Alegre: Artes médicas; 1994.

[30] Hernández F. Transgressão e mudança na educação: os projetos de trabalho. Porto Alegre: Artes Médicas; 1998. p. 150.

[31] Santomé JT. A instituição escolar e a compreensão da realidade: o currículo integrado. In: Silva LH, editor. Novos mapas culturais novas perspectivas educacionais. Porto Alegre: Sulina; 1996; pp. 34-57.

[32] Schor T. Reflexões sobre a imbricação entre ciência, tecnologia e sociedade. Revista Scientiae Studia. 2007;5(3):337-367.

[33] Beane JA. Integração Curricular: a Concepção do núcleo da Educação Democrática. Lisboa: Didáctica Editora; 2002.

[34] Richardson RJ. Pesquisa Social: métodos e técnicas. São Paulo: Atlas; 2007.

[35] Moraes R, Galiazzi MC. Análise textual discursiva. Ijuí: Ed. Unijui; 2007. p. 224.

Section 2

Simulation in Science Teaching

Chapter 6

Electric Power System Simulator Tool in MATLAB

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Samih Abdulnabi

Additional information is available at the end of the chapter

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Abstract

An electric power system is a network of electrical components used to supply, transmit, and use electric power. An example of an electric power system is the network that supplies a region's homes and industry with power. Due to the complexity and nonlinearity of the power system, hand calculations may be very complicated in some cases, especially when the number of buses or inputs is very large. Here comes the role of software for convergence, time saving, and accuracy. The "Electric Power System Simulator" focuses on three main concepts in power system analysis, the "Power Flow Calculation," "Faults Calculation," and "Economic Dispatch Calculation."

Keywords: GUI, Newton-Raphson, unsymmetrical faults, economic dispatch, MATALB

1. Introduction

There are two classes of power system simulation tools analysis: commercial and educational programs. Several commercial programs are available in the market (Power World Simulator, Power System Simulator …). These tools present efficient computational programs for analysis. However, they are inadequate for research and education intentions. This drawback is present because they do not authorize the modification of algorithms or adding new models. For research and education goals, flexibility, and simplicity are more important than computation. Due to several educational and research features, MATLAB becomes one of the efficient and adequate programs in many scientific domains and especially in power systems.

This chapter describes a new MATLAB power system analysis toolbox that uses capabilities of MATLAB in numeric computations to investigate fault calculation, power flow, and economic dispatch of a given power systems. This tool is developed to help students in their education and research studies. In addition, it was included in the curriculum for the graduate electrical engineering students in the Lebanese International University. Since its adoption, students show better understanding of these concepts. In addition, they were able to enhance their basic knowledge and improve their way of thinking.

2. Power system analysis methods

An electric power system is sometimes very complex to analyze using hand calculations especially, if there are nonlinear equations, and a high number of buses. Human can deal with little number of buses, and if the number of buses is high, the hand calculations are very complex. In the Newton-Raphson method, computer software may solve up to 100,000 or 150,000 buses in very short time, and more accurate when converging to the final solution obeying a specified level of tolerance. For the unbalanced faults, one must calculate the sequence and phase of voltages and currents depending on the type of fault, but computer software will calculate these values within few milliseconds and very accurately. Finally, for the economic dispatch, the value of the incremental cost and the generated powers will change as the value of the demand changes. Thus, the software performs several calculations as the load changes.

The MATLAB tool we are preparing performs several objectives through many power systems methods including: (i) the unsymmetrical faults analysis including line-to-ground fault, line-to-line fault, and double line-to-ground fault, (ii) the Newton-Raphson method, and (iii) the economic dispatch.

2.1. Unsymmetrical faults analysis

Short circuits occur in three-phase power systems as follows, in order of frequency of occurrence: single line-to-ground, double line-to-ground, and balanced three-phase faults. The path of the fault current may have either zero impedance, which is called bolted short circuit, or nonzero impedance.

When an unbalanced fault occurs in an otherwise balanced system, the sequence networks are interconnected only at the fault location (**Figure 1**). As such, the computation of fault currents is greatly simplified by the use of sequence networks.

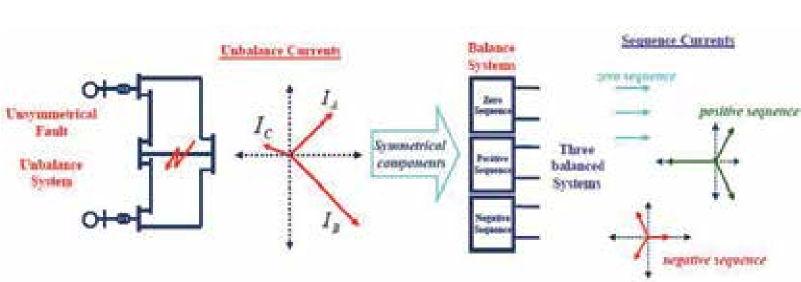

Figure 1. Schematic representation of unsymmetrical fault.

As in the case of balanced three-phase faults, unsymmetrical faults have two components of fault current: an AC or symmetrical components including sub-transient, transient, and steady-state currents, and a dc component [1, 2].

2.1.1. Unbalanced faults analysis

- Single line-ground (SLG) and line-line (LL) are the principle types of faults in a power system. In addition, other types of faults, such as double line-ground (DLG), open conductor, and balanced three phases, could be studied.
- The fault of an unbalanced system is estimated using the concept of symmetrical components [3, 4].

2.1.2. Single line-to-ground (SLG) faults

Unbalanced faults will disturb the balancing of the network at the fault location. Therefore, the sequence network should be combined together with respect to the type of fault. A detailed derivation of these relationships will be discussed through this paragraph [3].

The terminal voltage at phase "a" can be transformed into its sequence components as:

$$V_a = V_a^0 + V_a^+ + V_a^- \tag{1}$$

$$I_a^0 = \frac{V_a}{3Z_f} = \frac{V_a^0 + V_a^+ + V_a^-}{3Z_f} \tag{2}$$

The only way that these two constraints can be satisfied is by coupling the sequence networks in series as shown in **Figure 2**.

2.1.3. Line-to-line (LL) faults

The second most common fault is line-to-line, which occurs when two of the conductors come in contact with each other [3].

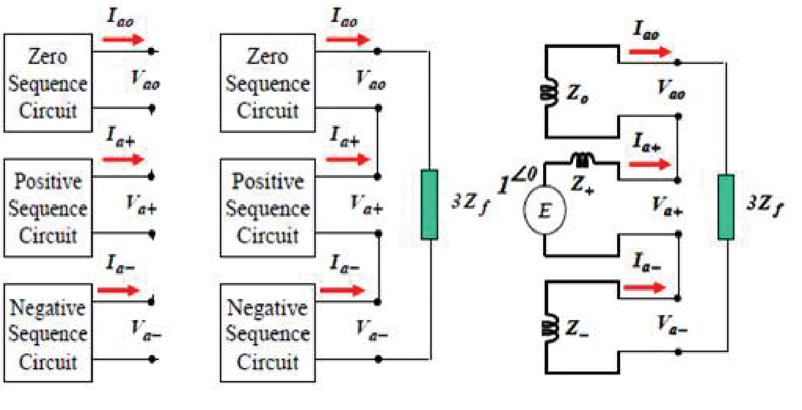

Figure 2. Coupling sequence network for line-to-ground fault.

$$V_a^+ = V_a^- + I_a^+ Z_f \tag{3}$$

To satisfy: $I_a^- = -I_a^+, V_a^+ = V_a^- + I_a^+ Z_f, I_a^0 = 0$, the positive and negative sequence networks must be connected in parallel (**Figure 3**).

2.1.4. Double line-to-ground (DLG) faults

With a double line-to-ground (DLG) fault, two line conductors come in contact both with each other and ground [3] as shown in **Figure 4**.

$$V_a^0 - V_a^+ = 3I_a^0 Z_f \tag{4}$$

To satisfy: $I_a = I_a^0 + I_a^+ + I_a^- = 0$, and $V_a^+ = V_a^-$, the three symmetrical circuits during a double line-to-ground fault are connected as follows:

2.2. Power flow problem

The estimation of the power flow problem can be expressed using an adequate series of nonlinear equations. These equations represent both Kirchhoff's Voltage Law and network operation limits. The assessment of the power flow problem is based on four variables for each "i" bus (network node) [4]:

- V_i: voltage magnitude
- δ_i: voltage angle
- P_i: net active power
- Q_i: net reactive power

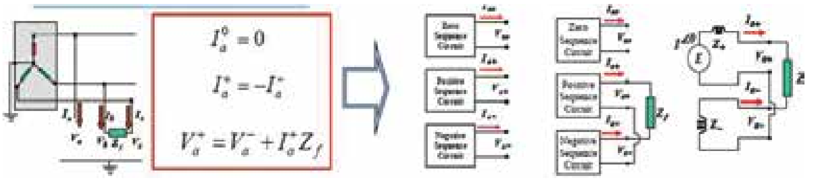

Figure 3. Coupling sequence network for line-to-line fault.

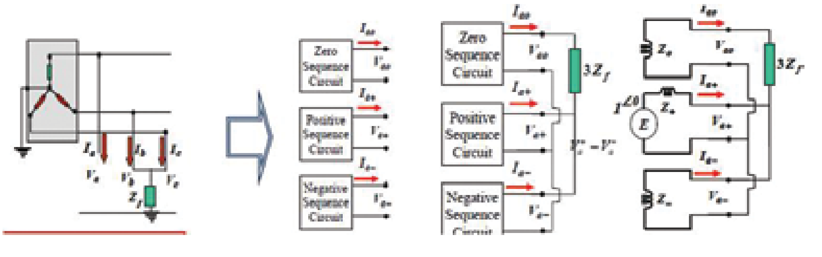

Figure 4. Coupling sequence network for a double line-to-ground fault.

Depending on which of the above four variables are known (given) and which ones are unknown (to be calculated), two basic types of buses can be defined:

- PQ bus: P_i and Q_i are specified; V_i and δ_i are calculated.
- PV bus: P_i and V_i are specified; Q_i and δ_i are calculated.

PQ buses are normally used to represent load buses without voltage control, and PV buses are used to represent generation buses with voltage control in power flow calculations. A third bus is also needed:

- Vδ bus: V_i and δ_i are specified; P_i and Q_i are calculated.

The $V\delta$ bus, also called reference bus or slack bus, has double functions in the basic formulation of the power flow problem:

- It serves as the voltage angle reference.
- Since the active power losses are unknown in advance, the active power generation of $V\delta$ bus is used to balance generation, load, and losses [5, 6].

The polar form of the power flow equations is given by:

$$P_i = \sum_{n=1}^{N} |Y_{in} V_i V_n| \cos(\theta_{in} + \delta_n - \delta_i) \tag{5}$$

$$Q_i = -\sum_{n=1}^{N} |Y_{in} V_i V_n| \sin(\theta_{in} + \delta_n - \delta_i) \tag{6}$$

For each line, numerical values for the series impedance Z and the total line-charging admittance Y are necessary so that the computer can determine all the elements of the $N \times N$ bus admittance matrix of which the typical element Y_{ij} is:

$$Y_{ij} = |Y_{ij}|\theta_{ij} = |Y_{ij}|\cos\theta_{ij} + j|Y_{ij}|\sin\theta_{ij} = G_{ij} + jB_{ij} \tag{7}$$

The voltage at any bus of the system is given by:

$$|V_i| = |V_i|\delta_i = |V_i|(\cos\delta_i + j\sin\delta_i) \tag{8}$$

The net current injected to bus i is given by:

$$I_i = Y_{i1}V_1 + Y_{i2}V_2 + \ldots + Y_{iN}V_N = \sum_{n=1}^{N} Y_{in}V_n \tag{9}$$

The net scheduled power being injected into the network at bus i is:

$$P_{i,sched} = P_{gi} - P_{di} \tag{10}$$

where P_{gi} is the scheduled power being generated at bus i, and P_{di} is the scheduled power demand.

The mismatch value of the power is given by:

$$\Delta P_i = P_{i,\,sched} - P_{i,\,calc.} \tag{11}$$

Similarly, for the reactive power at bus i:

$$\Delta Q_i = Q_{i,\,sched} - Q_{i,\,calc.} \tag{12}$$

Table 1 lists the general number of equations and the state variables in function of the number of buses.

2.2.1. Newton-Raphson method applied to power flow study

In all realistic cases, the power flow problem cannot be solved analytically, and hence iterative solutions implemented in computers must be used. Here, we are going to discuss the Newton-Raphson method.

To apply the Newton-Raphson method to the solution of the power flow equations, we express bus voltages and line admittances in polar form as follows:

$$P_i = |V_i|^2 G_{ii} + \sum_{\substack{n=1 \\ n \neq i}}^{N} |V_i V_n Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i) \tag{13}$$

$$Q_i = -|V_i|^2 B_{ii} + \sum_{\substack{n=1 \\ n \neq i}}^{N} |V_i V_n Y_{in}| \sin(\theta_{in} + \delta_n - \delta_i) \tag{14}$$

Collecting all the mismatch equations into vector-matrix form yields:

$$\underbrace{\begin{bmatrix} \begin{pmatrix} \frac{\partial P_2}{\partial \delta_2} & \cdots & \frac{\partial P_2}{\partial \delta_n} \\ \vdots & J_{11} & \vdots \\ \frac{\partial P_n}{\partial \delta_2} & \cdots & \frac{\partial P_n}{\partial \delta_n} \end{pmatrix} & \begin{pmatrix} |V_2|\frac{\partial P_2}{\partial |V_2|} & \cdots & |V_n|\frac{\partial P_2}{\partial |V_n|} \\ \vdots & J_{12} & \vdots \\ |V_2|\frac{\partial P_n}{\partial |V_2|} & \cdots & |V_n|\frac{\partial P_n}{\partial |V_n|} \end{pmatrix} \\ \begin{pmatrix} \frac{\partial Q_2}{\partial \delta_2} & \cdots & \frac{\partial Q_2}{\partial \delta_n} \\ \vdots & J_{21} & \vdots \\ \frac{\partial Q_n}{\partial \delta_2} & \cdots & \frac{\partial Q_n}{\partial \delta_n} \end{pmatrix} & \begin{pmatrix} |V_2|\frac{\partial Q_2}{\partial |V_2|} & \cdots & |V_n|\frac{\partial Q_2}{\partial |V_n|} \\ \vdots & J_{22} & \vdots \\ |V_2|\frac{\partial Q_n}{\partial |V_2|} & \cdots & |V_n|\frac{\partial Q_n}{\partial |V_n|} \end{pmatrix} \end{bmatrix}}_{\text{Jacobian}} \underbrace{\begin{bmatrix} \Delta\delta_2 \\ \vdots \\ \vdots \\ \Delta\delta_n \\ \frac{\Delta|V_2|}{|V_2|} \\ \vdots \\ \frac{\Delta|V_n|}{|V_n|} \end{bmatrix}}_{\text{Corrections}} = \underbrace{\begin{bmatrix} \Delta P_2 \\ \vdots \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \vdots \\ \vdots \\ \Delta Q_n \end{bmatrix}}_{\text{Mismatches}} \tag{15}$$

Bus type	Number of buses	Quantities specified	Number of available equations	Number of δ_i, ∣Vi∣ state variables
Slack ($i = 1$)	1	δ_i, ∣Vi∣	0	**0**
PV ($i = 2,\ldots, \mathrm{Ng} + 1$)	Ng	P_i, ∣Vi∣	Ng	**Ng**
PQ ($i = \mathrm{Ng} + 2,\ldots,\mathrm{N}$)	N-Ng-1	P_i, Qi	2(N-Ng-1)	**2(N-Ng-1)**
Totals	N	2N	2N-Ng-2	**2N-Ng-2**

Table 1. The number of equations and state variables of power flow problem.

The solution of the above equation is found by an iterative method as follows [4–6]:

- Estimate values $\delta_i^{(0)}$ and $|V_i|^{(0)}$ for the state variables.
- Use the estimates to calculate: $P_{i,calc.}^{(0)}$ and $Q_{i,calc.}^{(0)}$, from (5) and (6).
- Mismatches $\Delta P_i^{(0)}$ and $\Delta Q_i^{(0)}$ from (11) and (12).
- Partial derivatives elements of the Jacobian matrix.
- Solve the above equation of the Jacobian matrix, the corrections, and the mismatches to find the initial corrections $\delta_i^{(0)}$ and $\Delta|V_i|^{(0)}/|V_i|^{(0)}$.
- Add the solved corrections to the initial estimates to obtain:

$$\delta_i^{(1)} = \delta_i^{(0)} + \Delta\delta_i^{(0)} \tag{16}$$

$$|V_i|^{(1)} = |V_i|^{(0)} + \Delta|V_i|^{(0)} = |V_i|^{(0)}\left(1 + \frac{\Delta|V_i|^{(0)}}{|V_i|^{(0)}}\right) \tag{17}$$

Use the new values $\delta_i^{(1)}$ and $|V_i|^{(1)}$ as starting values for iteration and then continue.

In more general terms, the updated formulas for starting values of the state variables are:

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)} \tag{18}$$

$$|V_i|^{(k+1)} = |V_i|^{(k)} + \Delta|V_i|^{(k)} = |V_i|^{(k)}\left(1 + \frac{\Delta|V_i|^{(k)}}{|V_i|^{(k)}}\right) \tag{19}$$

2.3. Economic dispatch

This section is dedicated to study the economic dispatch concept. For this reason, we consider the system configuration shown is **Figure 5**. This configuration based on N thermal units serving as a source of generation that would deliver the suitable electric power to the load.

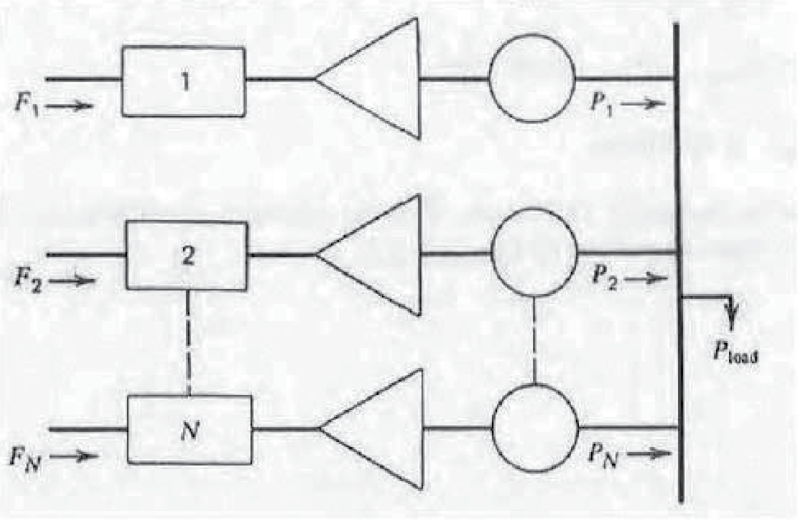

Figure 5. Thermal units committed to serve electrical load.

Each unit has the cost rate F as an input and its electrical power generated as an output. Therefore, the total system cost is represented by F_T, which is the sum of each unit cost rate. The fundamental condition of this system considers that the total output powers should be equal to total power demand.

The main objective from the economic dispatch concept is to minimize $F_T$with respect to the considered constraints. Note that any transmission losses are neglected and any operating limits are not explicitly stated when formulating this problem [7, 8]. That is,

$$F_T = F_1 + F_2 + F_3 + \dots + F_N \tag{20}$$

$$F_T = \sum_{i=1}^{N_{gen}} F_i(P_i) \tag{21}$$

$$\varnothing = 0 = P_{load} - \sum_{i=1}^{N_{gen}} P_i \tag{22}$$

This type of optimization system is solved using the Lagrange concept. The extreme value condition of the objective function is determined using the multiplication of the constraint by a constant and adding this factor to the objective function as shown below:

$$L = F_T + \lambda\varnothing \tag{23}$$

The paramount conditions needed to determine the highest value of the objective function are based on the derivative of the Lagrange function with respect to the independent variables of each unit. These derivatives should be equal to 0. Consequently, there will be $N + 1$ variables (value of P_i for each N units and λ). In addition, the constraint equation is obtained by the derivative of the Lagrange function by P_i with respect to λ [9–11]:

$$\frac{\partial L}{\partial P_i} = \frac{dF_i(P_i)}{dP_i} - \lambda = 0 \tag{24}$$

or

$$0 = \frac{dF_i}{dP_i} - \lambda \tag{25}$$

With respect to the above-mentioned condition, the minimum operating cost is established when all incremental unit cost are equal to λ. The final step for this procedure is pointed out by the addition of the power demand constraint and the limitation value (minimum and maximum) of each power output unit (inequality constraint) [12].

These constraints are summarized below:

$$\frac{dF_i}{dP_i} = \lambda \quad \ldots N_{gen}\ equations \tag{26}$$

$$P_{i,\min} \le P_i \le P_{i,\max} \quad \ldots 2N_{gen}\ equations \tag{27}$$

$$\sum_{i=1}^{N} P_i = P_{load} \quad 1\ constra\text{int} \tag{28}$$

When we recognize the inequality constraints, then the necessary conditions may be expanded slightly as shown in the set of equations:

$$\frac{dF_i}{dP_i} = \lambda \quad \text{for } P_{i,\min} \le P_i \le P_{i,\max} \tag{29}$$

$$\frac{dF_i}{dP_i} \le \lambda \quad \text{for } P_i = P_{i,\max} \tag{30}$$

$$\frac{dF_i}{dP_i} \ge \lambda \quad \text{for } P_i = P_{i,\min} \tag{31}$$

3. Flow chart

3.1. Unsymmetrical faults case

The implementation of the unsymmetrical faults analysis in MATLAB is based on the following flow chart (**Figure 6**):

- Define the zero, positive, and negative impedance matrices.
- Define the pre-fault voltage and the faulted impedance.

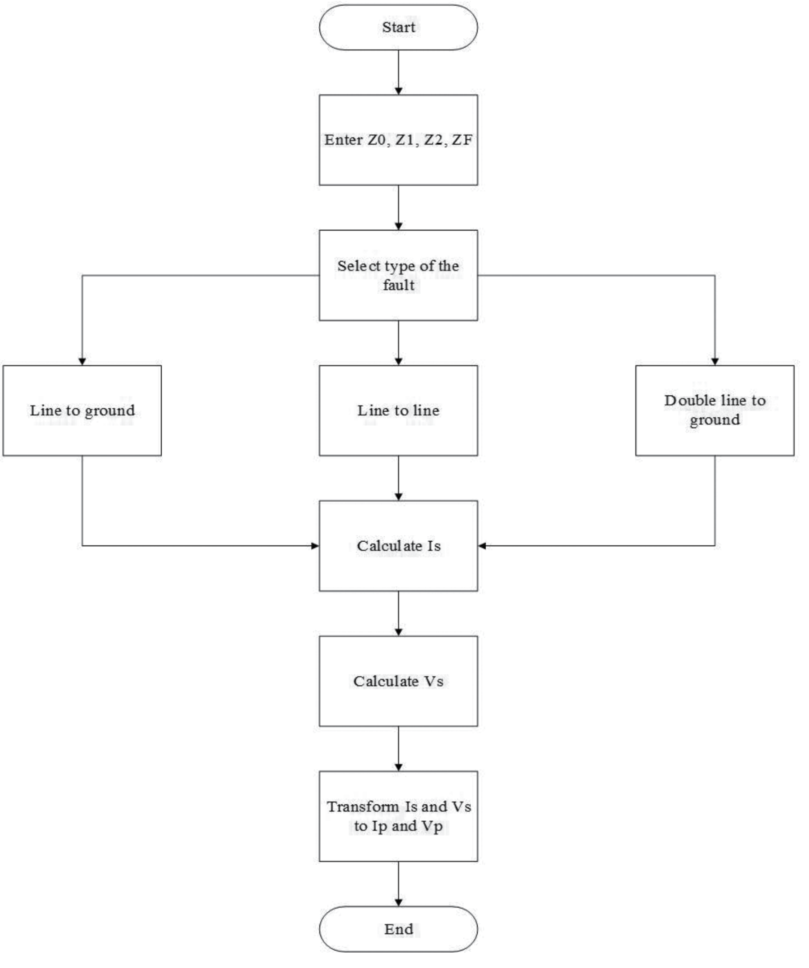

Figure 6. Flow chart for the unsymmetrical faults.

- Select the type of fault.
- Calculate the admittance and impedance matrices of the power system.
- Calculate the sequence current and voltage for the selected fault.
- Calculate the phase voltages and currents for all buses or the faulted buses.
- Save all results in a text file.

3.2. Power flow case

Power flow solution is estimated using the Newton-Raphson method. The fulfillment of this method is achieved using an adequate flowchart (**Figure 7**):

- Define the number of buses.

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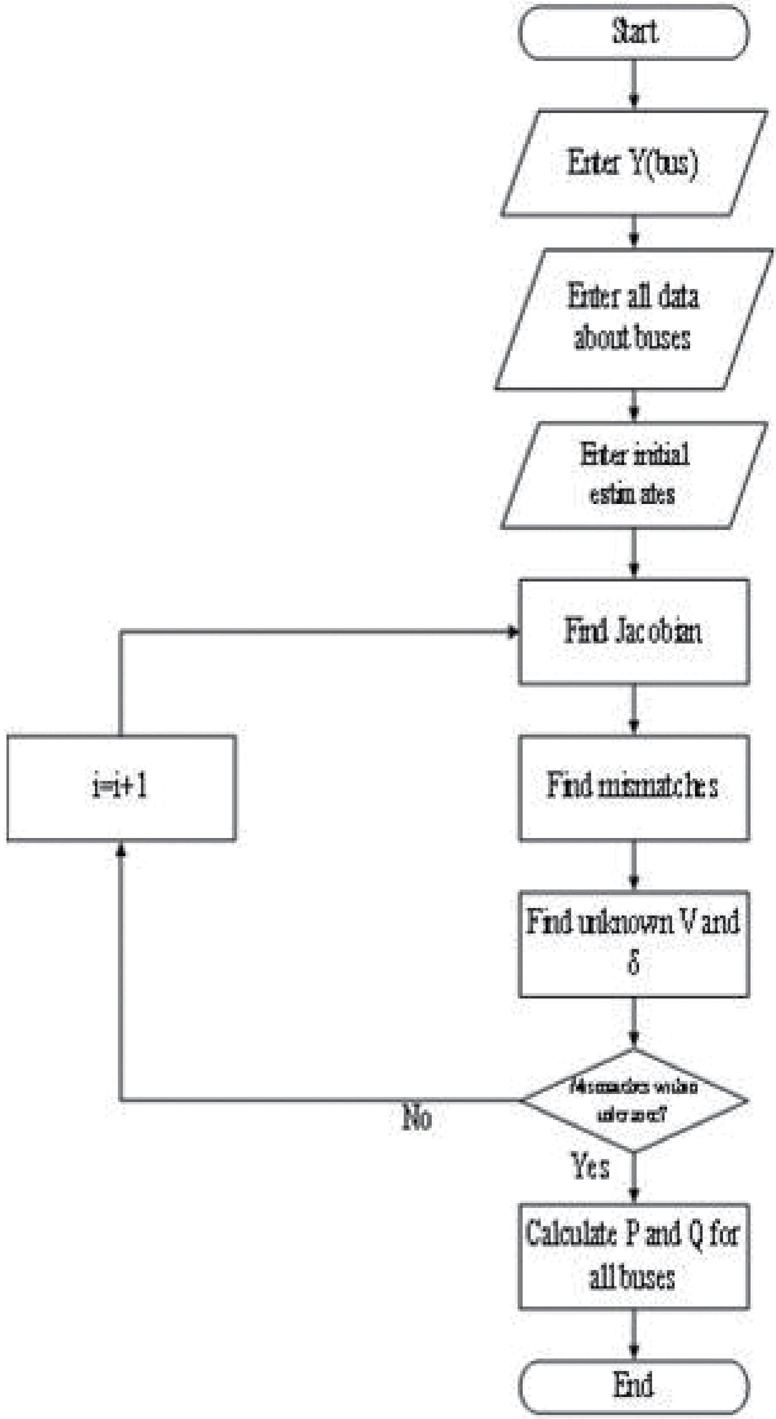

Figure 7. Flow chart for the power flow calculation.

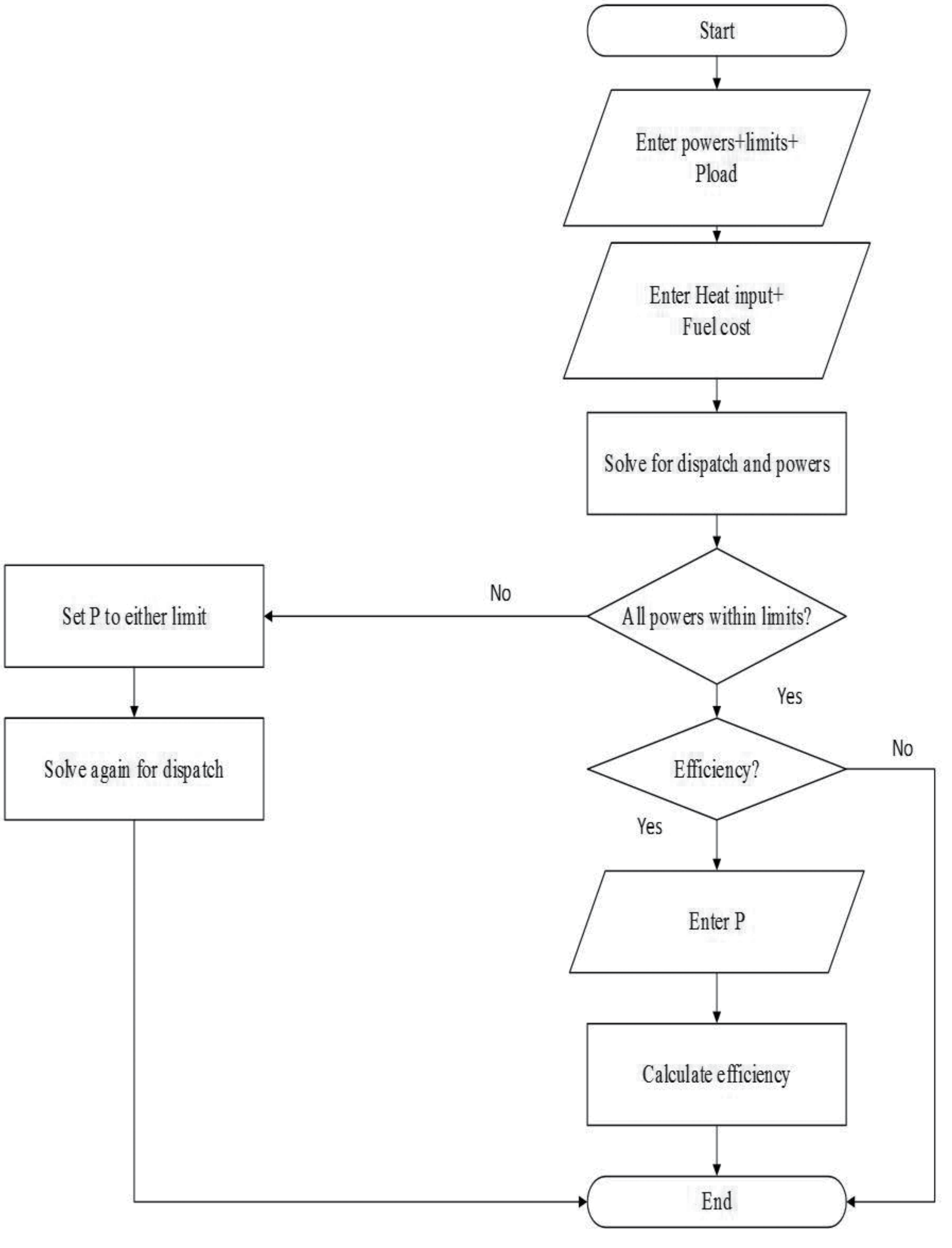

Figure 8. Flow chart for the economic dispatch.

- Determine the resistance, admittance, and the power specification of each bus.
- Assign the initial values of the variables.
- Find the mismatches and Jacobian matrix.
- Find the unknown variables.
- Verify the accuracy of the calculation.
- Calculate the real and imaginary power in each bus and line.
- Calculate the real and imaginary power losses in each bus and line.
- Save the power flow solution report in a text file.

3.3. Economic dispatch case

The execution of economic dispatch procedure depends on several parameters. **Figure 8** shows the flow chart of this phenomenon.

- Define the number of units $(P_1, P_2, P_3 \ldots P_n)$.
- Precise the lower and upper bounds of each unit.
- Determine the total demand load and the fuel cost ($/MBtu).
- Introduce the cost function ($/h) or heat rate function (MBtu/h).
- Calculate the incremental cost rate λ ($/MWhr).
- Estimate the cost function ($/h) or heat rate function (MBtu/h).
- Compute the economic operating point using Lagrange and the efficiency.

4. MATLAB implementation

4.1. Main display page

The main display page of the MATLAB tool gives the choice for the user to choose between one of the three methods as shown in **Figure 9** [13].

4.2. Unsymmetrical fault analysis implementation

As the user chooses the first method, which is the "Fault Calculation," the interface shown in **Figure 10** appears [13].

The principle of unsymmetrical faults method throughout the "Power System Simulator" software can be made through two modes:

Figure 9. Main display page of the electric power simulator tool.

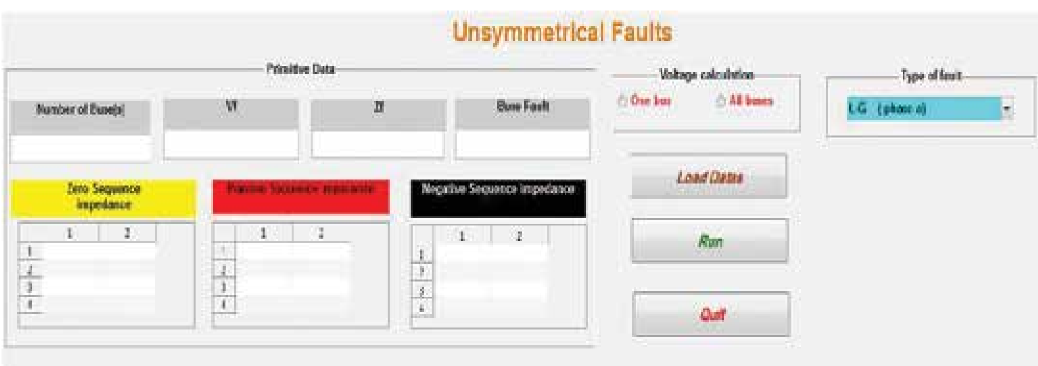

Figure 10. Unsymmetrical faults interface.

- Mode 1: The user enters all the data manually.
- Mode 2: The user loads the data from a specified file.

Results will show the following: The Ybus and Zbus, the figure of the faults, and the output data (current and voltage) in sequence and phase domain as shown in **Figure 11**.

Figure 11. Unsymmetrical faults output interface.

Finally, each result (Ybus, Zbus, Vbus, and Ibus) for both sequence and phase configuration is saved in a separated text file.

4.3. Power flow implementation

As the user chooses the first method, which is the "Power Flow Calculation," **Figure 12** appears [13].

The principle of the Newton-Raphson method throughout the "Power System Simulator" software can be made through two modes:

- Mode 1: The user enters all the data manually.
- Mode 2: The user loads the data from a specified file.

Two table results are now filled, the first one is the load flow analysis, and the second is the line flow and losses as shown in **Figure 13**.

4.4. Economic dispatch implementation

As the user chooses the first method, which is the "Power Flow Calculation," **Figure 14** will appear [13].

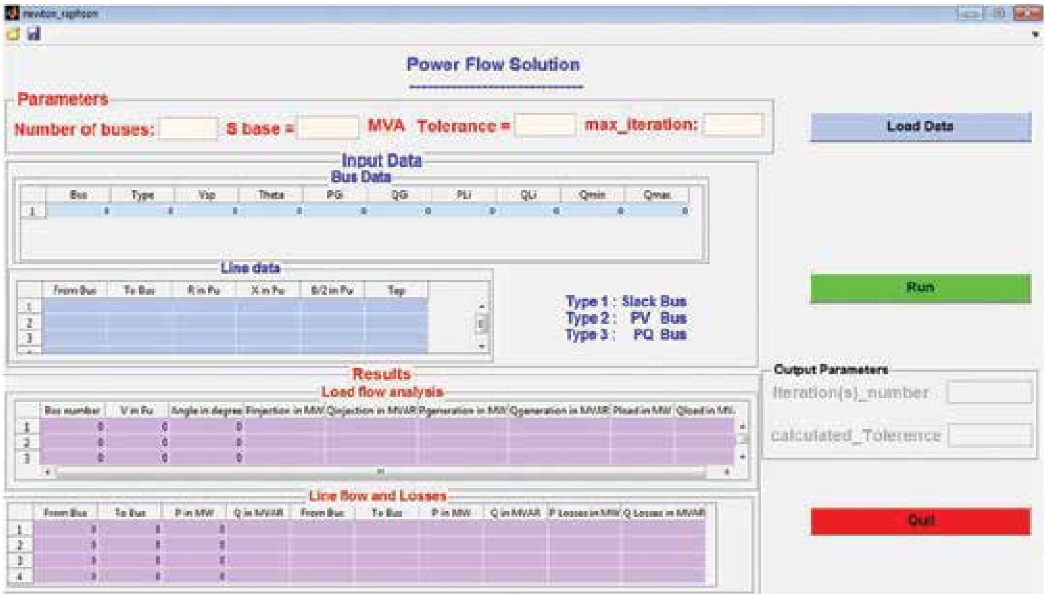

Figure 12. Power flow solution interface.

Figure 13. Power flow solution output interface.

The principle of the economic and optimal dispatch method throughout the "Power System Simulator" software can be made through two modes:

- Mode 1: The user enters all the data manually.
- Mode 2: The user loads the data from a specified data.

In case of over or under limit estimation, the tool will provide a notification and the number or this unit to the user as shown in **Figure 15**.

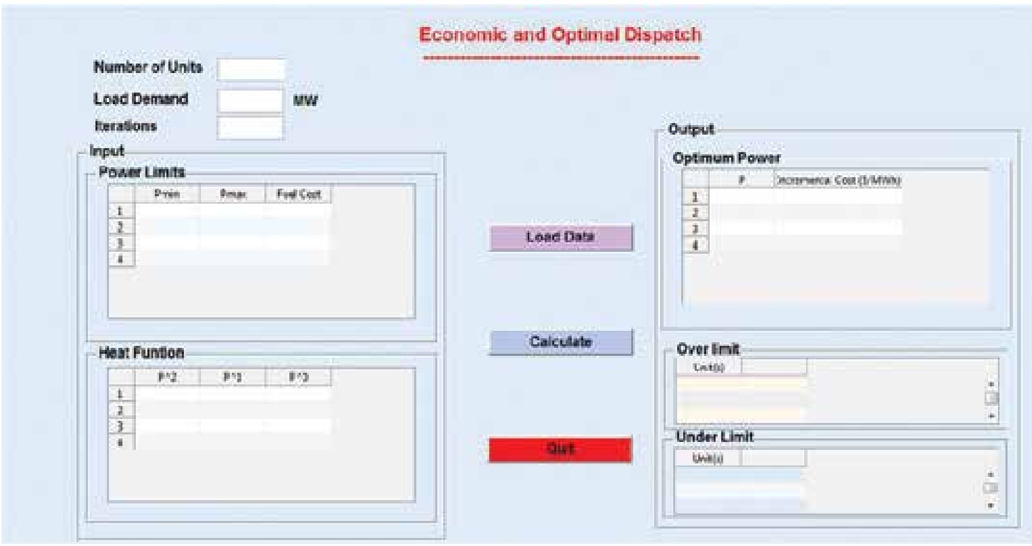

Figure 14. Economic dispatch interface.

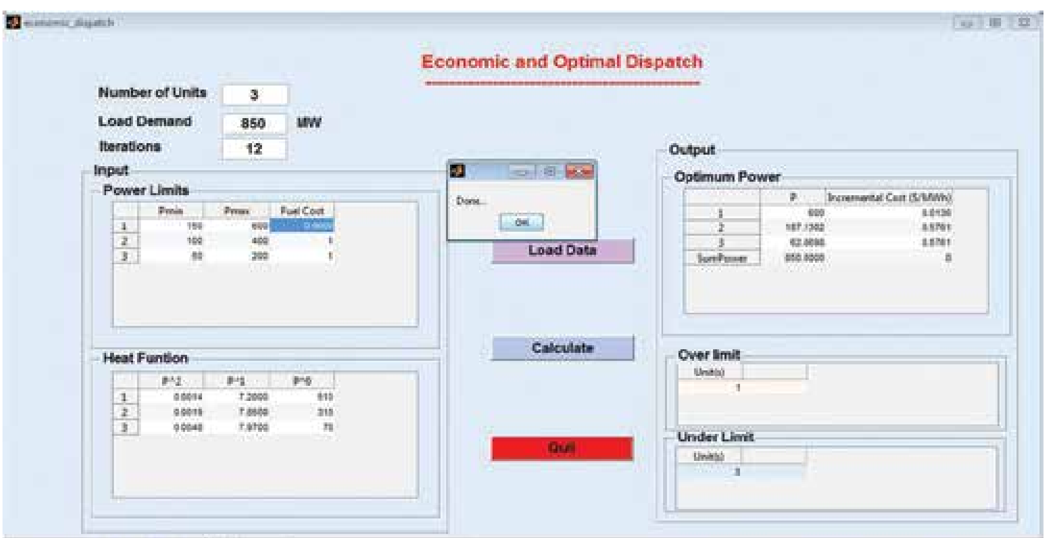

Figure 15. Economic dispatch output interface.

5. Conclusions

This chapter considers an appropriate guide for electrical engineers students who specialized in power systems analysis and design. The above-mentioned paragraphs give to them an adequate MATLAB tool in order to facilitate the comprehension of some concept.

These concepts can solve a lot of problems such as power flow solution, unsymmetrical faults analysis, and economic dispatch with or without constraints.

They could also be adopting this tool for their practical studies without any complexity because it is related with their own theoretical knowledge.

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References

[1] Stoft S. Power system economics. IEEE Press. 2002;**1**(1):11

[2] Rustebakke HM. Electric Utility Systems Practice. 4th ed. New York: Wiley; 1983

[3] Golver D, editor. Power System Analysis and Design. 5th ed. New York: Global Engineering; 2012. p. 853

[4] Saadat H, editor. Power System Analysis. 3rd ed. New York: PSA; 2010. p. 775

[5] Vijay ARB, editor. Power Systems Analysis. 2nd ed. Prentice Hall; 2000. p. 619

[6] Andersson G, editor. Power System Analysis. 1st ed. Zurich: ETH; 2012. p. 185

[7] Wood AJ, Wollenberg BF, editors. Power Generation Operation and Control. New York: Wiley; 2014

[8] Grainger J, Stevenson W, editors. Power System Analysis. McGraw-Hill Inc.; 1994

[9] Dommel HW, Tinney, WF. Optimal power flow solutions. IEEE Transactions on Power Apparatus and Systems. 1968;**PAS-87**:1866–1876

[10] Happ, H. Optimal power dispatch—A comprehensive survey. IEEE Transactions on Power Apparatus and Systems. 1977;**PAS-96**:841–854

[11] Horton JS, Grigsby LL. Voltage optimization using combined linear programming and gradient techniques. IEEE Transactions on Power Apparatus and Systems. 1984;**PAS-103** (7):1637–1643

[12] Lee KY, Park YM, Ortiz JL. A united approach to optimal real and reactive power dispatch. IEEE Power Engineering Review. 1985; **PER-5**(5):1147–1153

[13] Arnaout M. An educational electric power simulator. In: International Conference on Advances in Computational Tools for Engineering Applications; 14 July; Louayzi. Beirut: IEEE; 2016. p. 231–235

Software for Simulation of Static Switch Controllers

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Niculescu Titu

Additional information is available at the end of the chapter

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Abstract

In the power supply systems, static converters are increasingly used to feed every kind of consumers. Static converters are used widely in electric drive systems for the change in voltage and/or frequency power of electric machines. The authors realized a Windows software application to simulate the static converter function which is used for better understanding of the students. This software is realized like an independent application helping with Visual Basic software package.

Keywords: static switch converters, software development, Visual Basic, operating regime simulation

1. Introduction

The development of industrial automation leads by default also to the improvement of electrical drive systems as more than these systems represent the most spread conversion type of the electrical energy in the mechanical energy.

Hereby, by an adequate command given by a controller into a close circuit, the static converters adjust the output electrical energy parameters, to the necessity demand by an electrical motor.

The static switch controllers are converters where the exit size has the same form with the entry size. By changing the control angle of the converter thyristor is obtained a variation of the effective/average value of the output voltage [2, 3].

2. AC switch controllers

2.1. Single-phase AC switch controllers

In the case of these static converters, the control angle α of the thyristor is defined as the angle determined from the time of zero crossing of the voltage up to input in conduction of the thyristor [2, 5].

The AC switch controllers are AC to AC static converters. The converter output voltage is chopped so that the RMS value of AC output voltage is modified with change of the switching period of the power semiconductors.

Figure 1 shows a single-phase AC switch controller scheme and the voltage waveforms. The switching angle α can be modified between 0 and π. If the switching angle is $\alpha = 0$, the output voltage is $u_s = u_{smax}$ [3].

The instantaneous value of output current is given by Eqs. (1–3) [2, 5]:

- For resistive load:

$$i = \begin{cases} \frac{U_m}{R} \sin \omega \cdot t & \text{for} \quad \omega \cdot t \in [\alpha, \pi] \cup [\pi + \alpha, 2\pi] \\ 0 & \text{for} \quad \omega \cdot t \in [0, \alpha] \cup [\pi, \pi + \alpha] \end{cases} \tag{1}$$

- For inductive load:

$$i = \begin{cases} U_m \left[\sin \left(\omega \cdot t - \frac{\pi}{2} \right) - \sin \left(\alpha - \frac{\pi}{2} \right) \right] \\ for \quad \omega \cdot t \in [\alpha, 2\pi - \alpha] \cup [\pi + \alpha, 3\pi - \alpha] \\ 0 \quad for \quad \omega \cdot t \in [0, \alpha] \cup [2\pi - \alpha, 2\pi] \end{cases} \tag{2}$$

- For resistive-inductive load:

$$i = \frac{U_m}{\sqrt{R^2 - (\omega \cdot L)^2}} \left[\sin (\omega \cdot t - \varphi) - e^{-\frac{R}{\omega \cdot L}(\omega \cdot t - \alpha)} \sin (\alpha - \varphi) \right] \tag{3}$$

The output current average value can be determined with Eqs. (4) and (5):

- For resistive load:

$$I_{med} = \frac{I_m}{2\pi} (1 + \cos \alpha) \quad \alpha \in [0, \pi] \tag{4}$$

- For inductive load:

$$I_{med} = \frac{2I_m}{2\pi} [\sin \alpha + (\pi - \alpha) \cos \alpha] \quad \alpha \in \left[\frac{\pi}{2}, \pi \right] \tag{5}$$

These values are useful for dimensioning of power semiconductor devices of the switch controllers.

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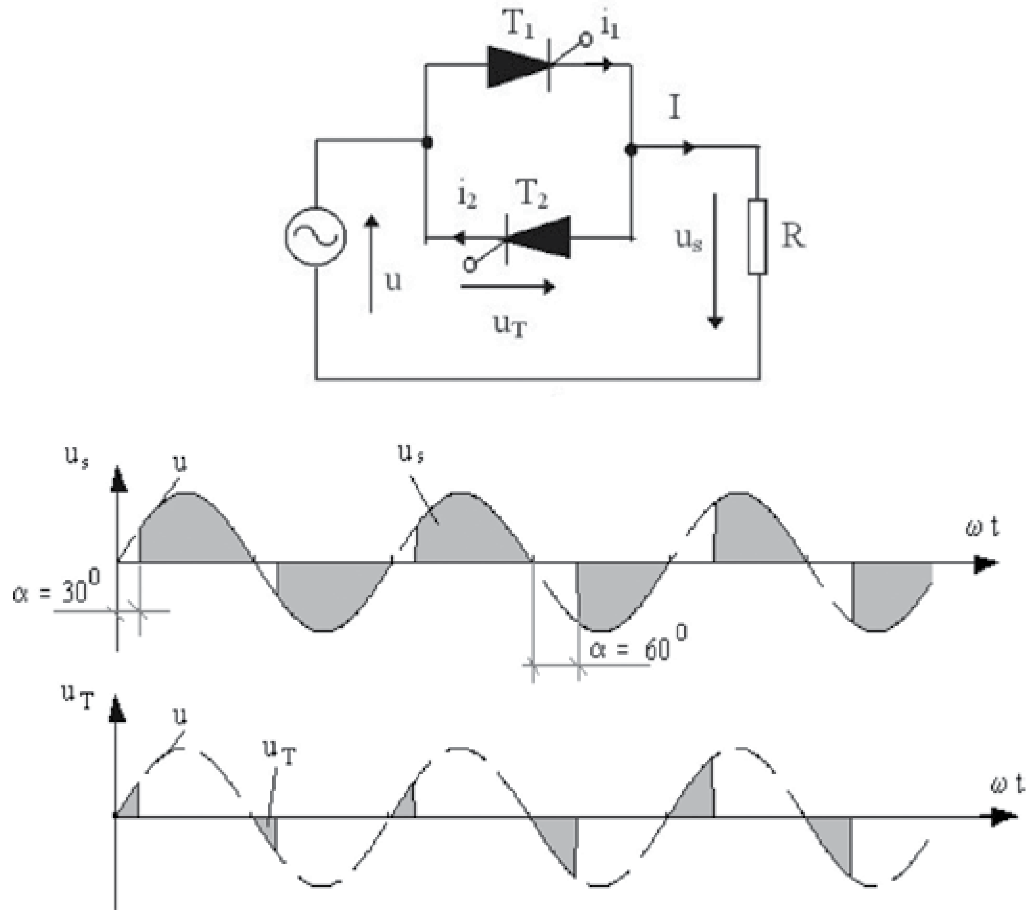

Figure 1. Single-phase AC switch controller electric scheme and the voltage waveforms.

The RMS output current is given by Eqs. (6) and (7) [2]:

- For resistive load:

$$I_{ef} = I_m \sqrt{\frac{1}{\pi}\left[\frac{1}{2}(\pi - \alpha) + \frac{1}{4}\sin 2\alpha\right]} \tag{6}$$

- For inductive load:

$$I_{ef} = I_m \sqrt{\frac{8}{\pi}\left[(\pi - \alpha)\left(\cos^2\alpha + \frac{1}{2}\right) + \frac{3}{4}\sin^2\alpha\right]} \tag{7}$$

Figure 2 presents the output current waveforms of the AC switch controller in the case of using different kinds of loads, and for different values of the switching angle α [5, 8].

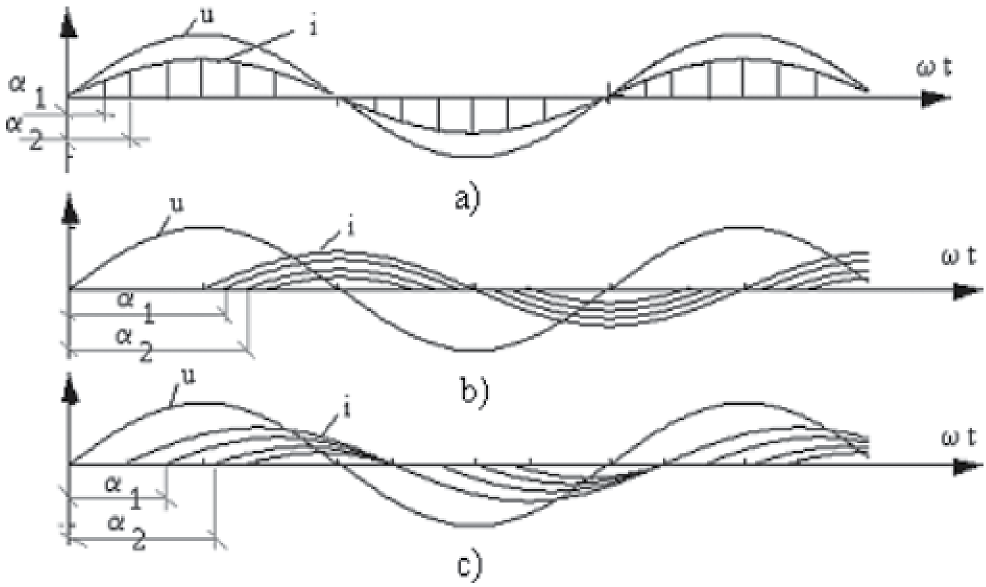

Figure 2. Current waveforms for a resistive load (a), inductive load (b), and a resistive-inductive one (c).

The AC switch controllers can be designed using only one thyristor. **Figure 3** presents the basic schemes and the output waveforms of these AC switch controller types.

2.2. Three-phase AC switch controllers

The three-phase AC switch controllers are designed using three single-phase AC switch controllers (k_R, k_S, k_T), one for each phase (**Figure 4**). The switching angle for each of the single-phase AC switch controllers is the same, but they must be phase angle with 2π/3 [3].

By changing the control angle, α, of the thyristors from each phase, changes the power absorbed by load between the maximum value and zero. Order the thyristors is performed using of the control device grid (DC), which must ensure a phase shift of the control pulses of 2π/3 between the phases [2, 5].

Variation the ignition angle of the voltages and of the currents depends on the load nature.

The voltage waveforms are determined from the vector diagram shown in **Figure 5**.

So, the voltage U_{KR} on a single-phase of R phase is zero on the period while one of two thyristors leads. The length of time while the thyristors are blocked, the load neutral point moves from 0 to 0′ and the voltage thyristor will be 3/2 U_R corresponding phasor $U_{0'\mathbf{R}}$. The voltage values are as follows:

- single-phase AC switch controller voltage is given by Eq. (8):

$$u_{kR} = \begin{cases} \frac{3}{2} u_R & \text{if} \quad k_R - \text{switch} - \text{off} \\ 0 & \text{if} \quad k_R - \text{switch} - \text{on} \end{cases} \tag{8}$$

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output line-to-line voltage is fit Eq. (9):

$$u'_{RS} = \begin{cases} u_{RS} & \text{if} \quad k_R, k_S - \text{switch} - \text{on} \\ -\frac{1}{2}u_{ST} & \text{if} \quad k_R - \text{switch} - \text{off} \\ -\frac{1}{2}u_{TR} & \text{if} \quad k_S - \text{switch} - \text{off} \end{cases} \tag{9}$$

output phase voltage (depending of the single phase switch converters which are in conduction) is given by Eq. (10):

$$u'_{R} = \begin{cases} 0 & \text{if} \quad k_R - \text{switch} - \text{off} \\ u_R & \text{if} \quad k_R, k_S, k_T - \text{switch} - on \\ \frac{1}{2}u_{RS} & \text{if} \quad k_T - \text{switch} - \text{off} \\ -\frac{1}{2}u_{TR} & \text{if} \quad k_S - \text{switch} - \text{off} \end{cases} \tag{10}$$

Figure 6 presents the voltage waveforms for a resistive load of an AC switch controller.

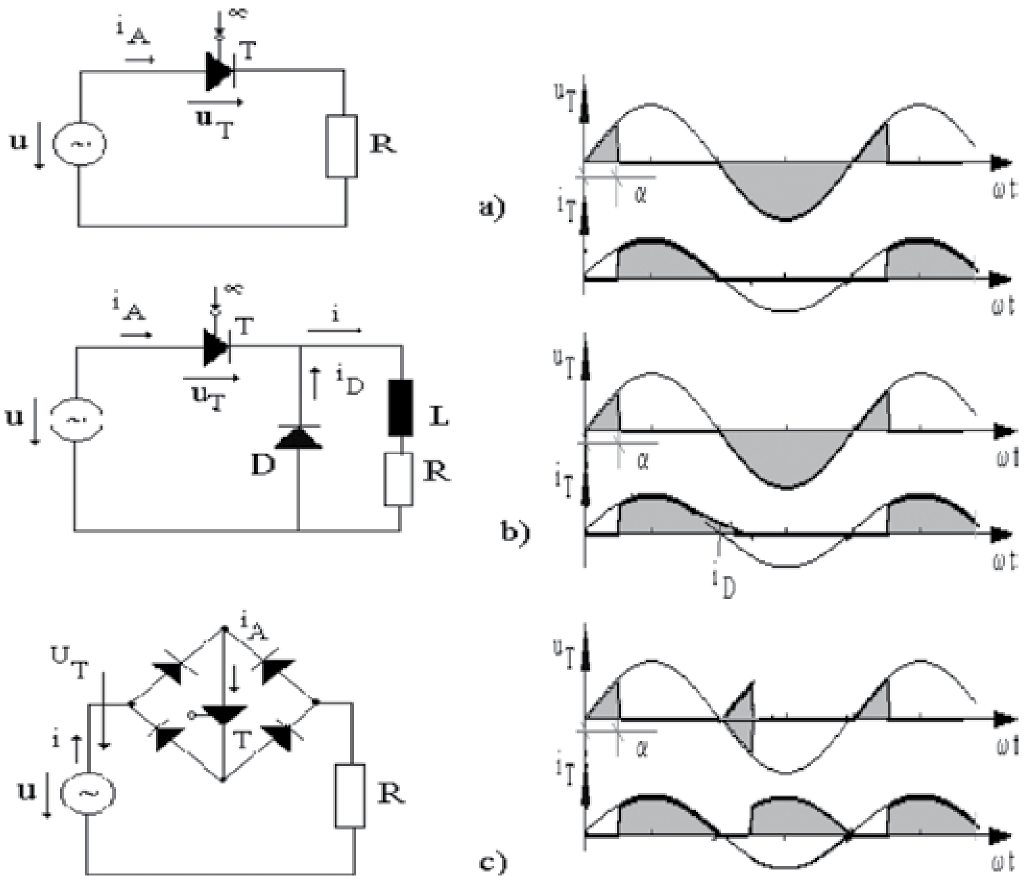

Figure 3. Basic schemes and output waveforms of different AC switch controllers: a) with one thyristor, b) with one thyristor and a diode, c) with one thyristor in a diode bridge.

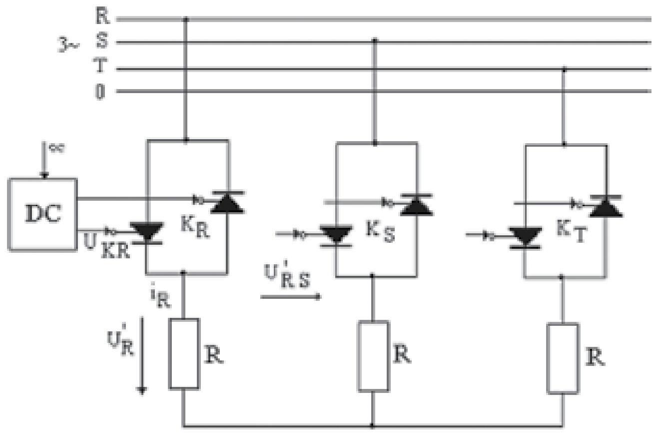

Figure 4. Three-phase AC switch controllers electric scheme.

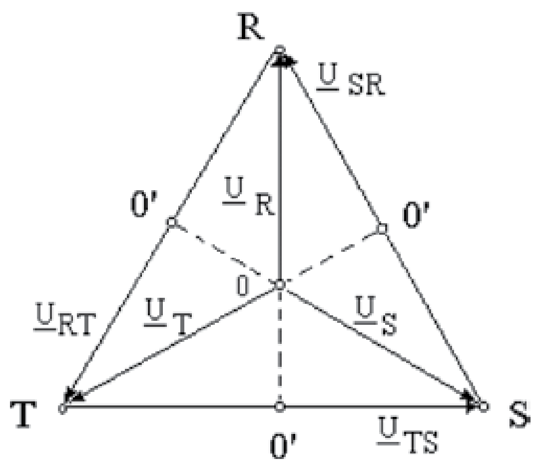

Figure 5. Vector diagram.

Because the load is resistive, the current waveform through the load is the same as the voltage phase raised on another scale.

In the case of an inductive load, the voltage waveforms are obtained similarly like in case of resistive load, but the thyristor ignition angle (α) is between ϕ and π, where φ is the delay angle between voltage and current due to the load. The current and voltage waveforms for an inductive are present in **Figure 7** [2, 3, 5].

If the three-phase AC switch controller supplies AC motors, the supply system must have the possibility to change the phase sequence to obtain a reversible drive system.

Figure 8 presents two schemes of AC switch controllers for reversible AC drive systems.

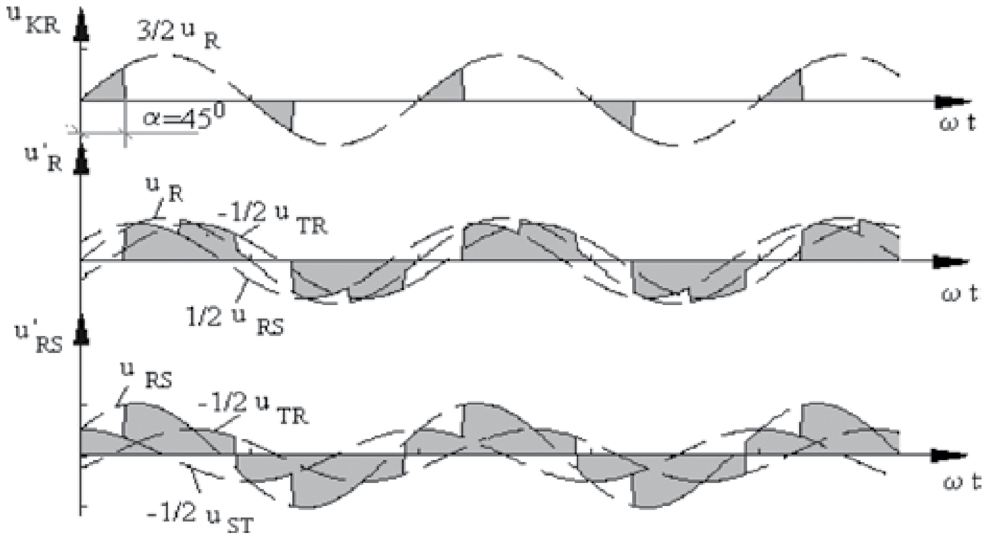

Figure 6. Voltage waveforms for a resistive load.

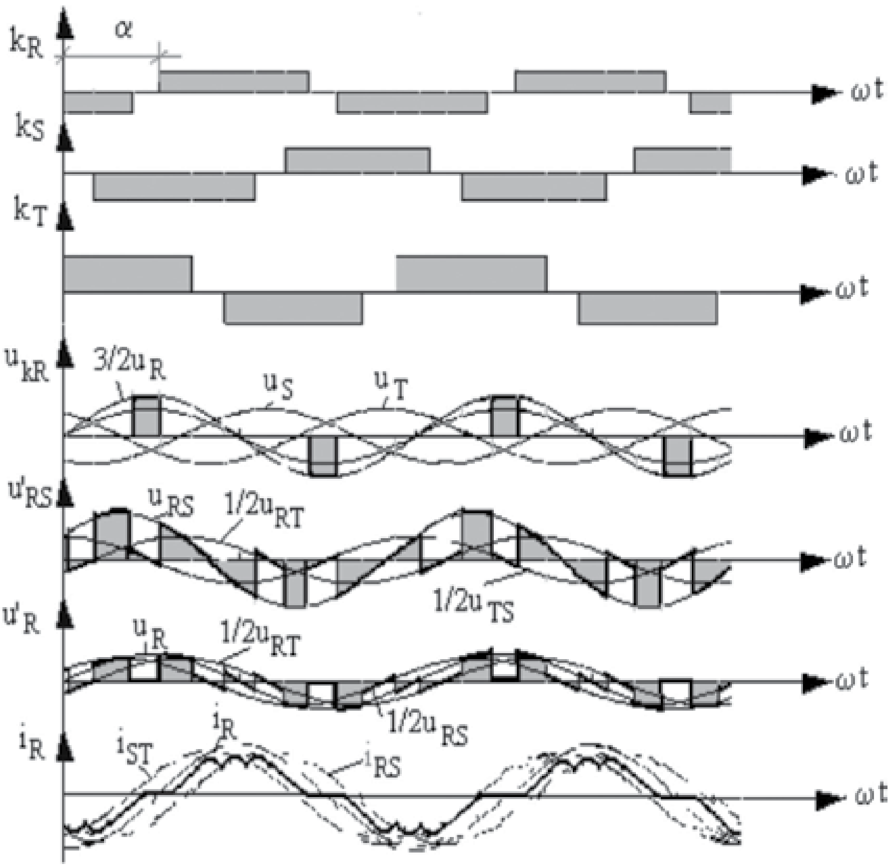

Figure 7. Current and voltage waveforms for an inductive load.

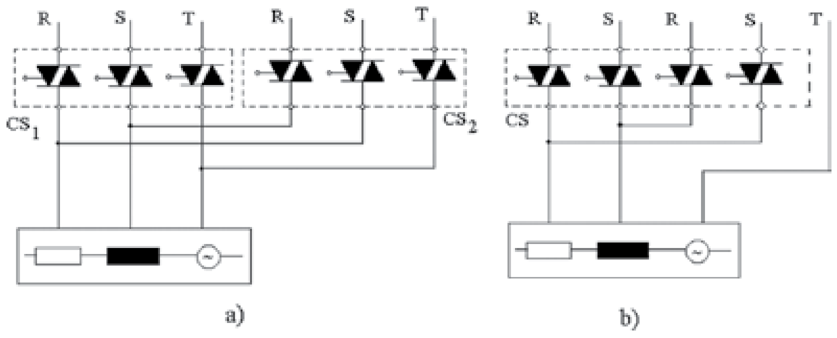

Figure 8. Reversible AC switch controllers: a) Symmetrical scheme, b) Non-symmetrical scheme.

3. Simulation of AC static switch controllers

The simulation of static switch function is realized like a Windows independent application helping with Visual Basic's software package [1, 4, 5]:

- It launches the simulation software.
- It opens the main simulation window of the switch controllers.
- In the main window, the user can choose the simulation type to be run with some radio buttons. The window also contains two buttons, one to continue the simulation (Continua) and the other to exit the application (Iesire) (**Figure 9**).
- It can choose the single-phase AC switch controller simulation, three-phase AC, or the chopper simulation using radio buttons.

Press the button for the continuation of simulation (Continua).

It opens the simulation window of the single-phase AC switch controller (**Figure 10**).

The simulation window containing three main parts [4]:

- A part that contains simulation scheme.
- Another part is dedicated to information area.
- The third part is the area where is dynamically getting up the waveforms characteristic to the switch controller analyzed.
- According to the manner of the scheme, choose the type of the single-phase AC switch controller, which can be with two thyristors, with one thyristor, or with one thyristor in diagonal of a diode bridge (**Figure 11**) [5].

In the laboratory classes, students choose the type of the switch controller, making different simulations to understand the principle of operation in each case. During the simulation, besides information in the text, the teacher explains what happens in each case.

Figure 9. The main simulation window of the switch controllers.

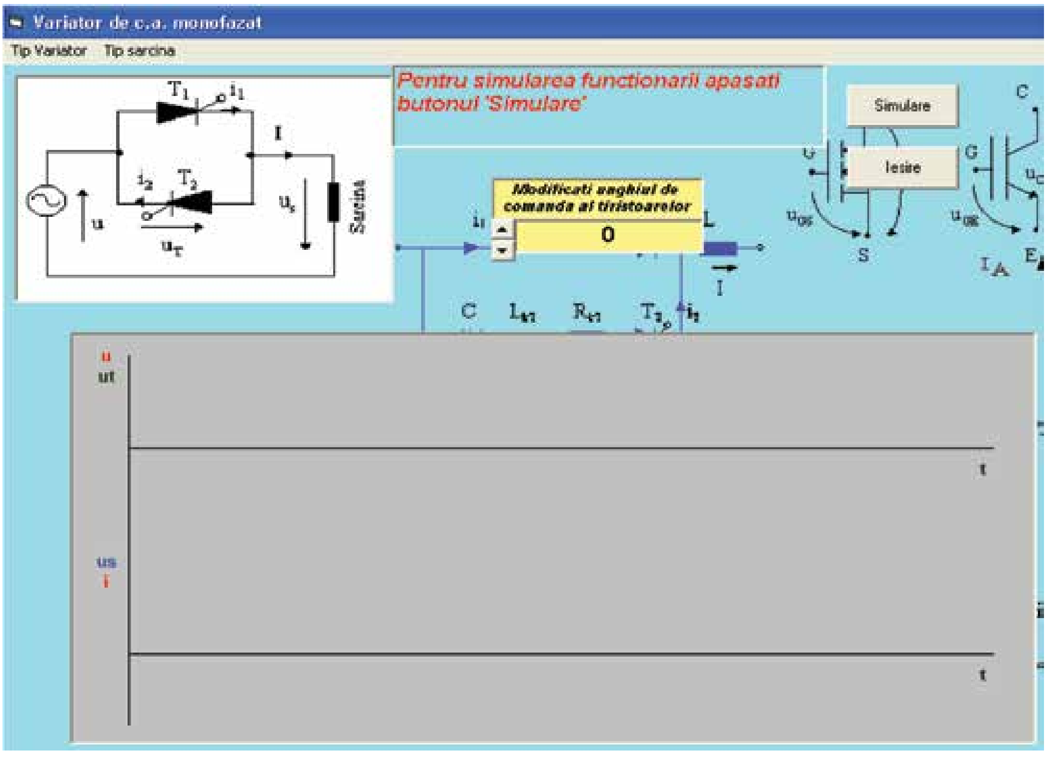

Figure 10. The simulation window of the single-phase AC switch controller.

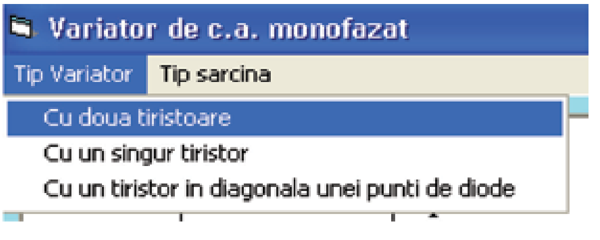

Figure 11. Choosing the single-phase AC switch controller type.

- It chooses the single-phase AC switch controller type (e.g., single-phase AC switch controller with two thyristors) (**Figure 12**).
- It chooses the load type which can be resistive, inductive, or resistive-inductive (**Figure 13**) [7].

The range of variation of the single-phase converter phase angle and the current variation depends on the type of load. To observe the differences in the different tasks, in laboratory classes are being analyzed converter function with resistive, inductive, or resistive-inductive loads, and is being drawn conclusions about the current variation. During the simulation, the students change the command angle to observe the modification of the RMS voltage and current.

- The command angle may be modified using up/down arrows, being shown their values. Along the simulation, it modified the command angle of the switch controller, in order to evidence the way of voltage modification, or the current through load (**Figure 14**).

Notes

It may choose any load type in combination with any switch controller types.

The command angle of the thyristors may vary between 90° and 180°, in the case choosing an inductive load (**Figure 15**).

In the case of choosing a resistive-inductive load, the command angle of the thyristors depends on the value that we want to establish by introducing a delay angle, changing the command angle of the thyristors being made from that value in up (**Figure 16**) [5].

In all three cases, if the command angle changes below or above the permissible values, the program alerts the user by an error message (**Figure 17**).

- It launches in running the single-phase AC switch controllers with two thyristors, with the control button (Simulare), which is then converted to the simulation stop button (Stop), which is located on the top right (**Figure 18**).
- During the simulation, the scheme dynamically changes its color, the sides what are in conduction at a time (**Figure 19**).
- It will follow the area in which text information about the function mode of the single-phase AC switch controllers are presented (semiconductor elements that are in conduction, semiconductor elements direct polarized, etc.) (**Figure 20**).
- Is watching the area in which is rises dynamically the characteristic waveforms of the single-phase AC switch controllers **Figure 21**.
- It is observed that by changing the command angle α between zero and π, the current by resistive load varies between maximum value U/R and zero. In the case of inductive load, because the current by load is a lag behind with $\pi/2$, the command angle can be varied by interval $[\pi/2, \pi]$, and in the case of resistive-inductive, the command angle varies between ϕ and π.

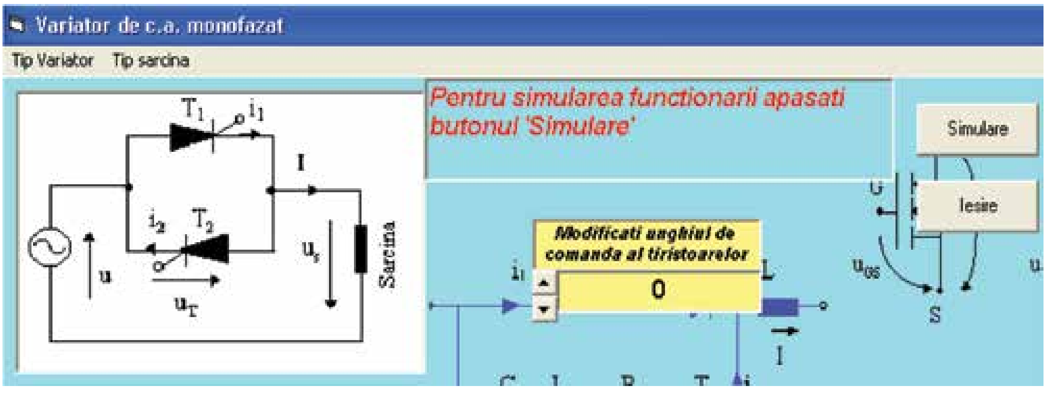

Figure 12. The single-phase AC switch controller window.

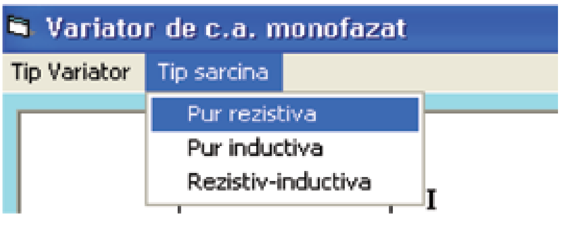

Figure 13. Choosing the load type.

Figure 14. Changing command angle in case of single phase switch controller.

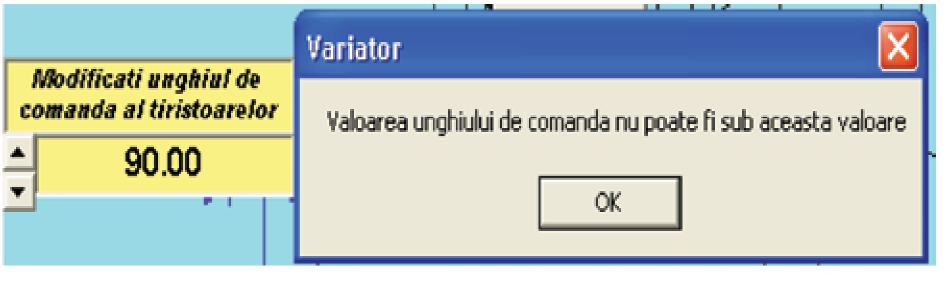

Figure 15. The error message in the case an inductive load.

Figure 16. The changing of command angle in the case resistive-inductive load.

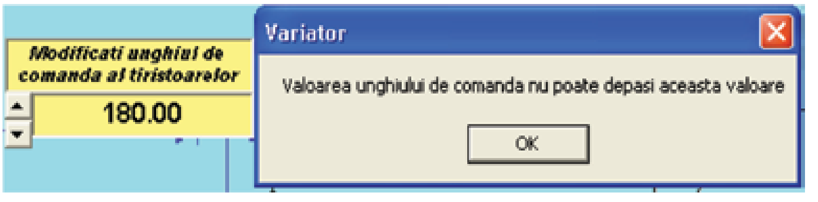

Figure 17. The error message.

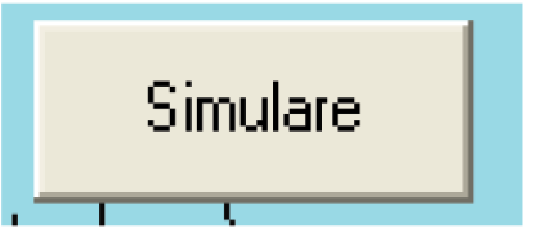

Figure 18. The control button (Simulare) in case of single phase switch controller.

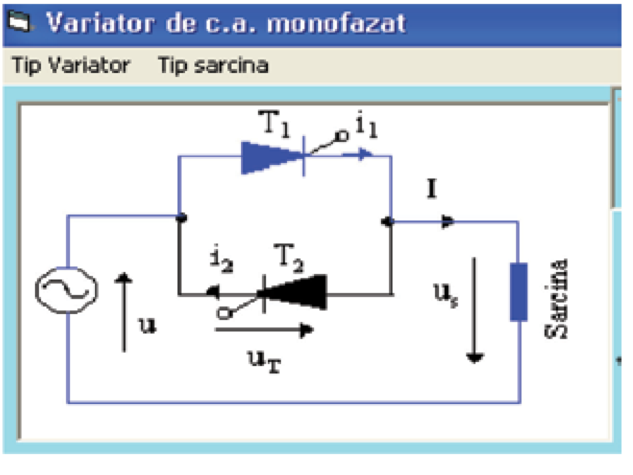

Figure 19. Simulation scheme in case of single phase switch controller.

Figure 20. The information area of text type in case of single phase switch controller.

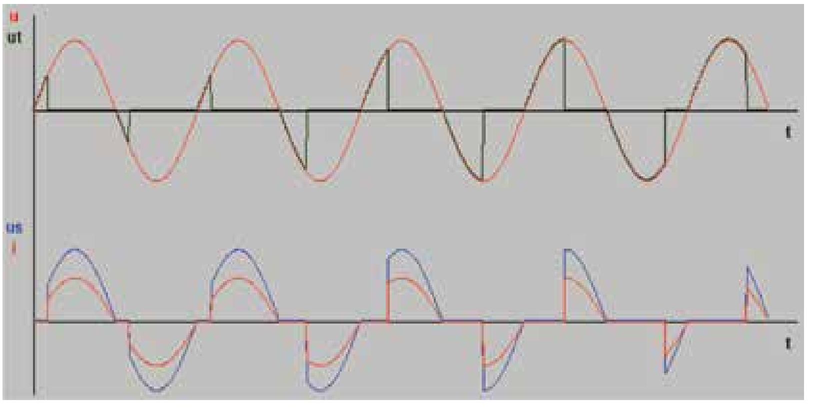

Figure 21. The waveforms area for the single-phase AC switch controllers with resistive load.

For the three-phase AC switch controller, simulation is opening the window as shown in **Figure 22**.

And to the three-phase AC switch controller, the simulation windows are three main part formats from the first part which contains simulation scheme, the second part is dedicated to information area, and the third part is the area where is dynamically getting up the waveforms characteristic to the switch controller analyzed [5].

- Choose the type of the three-phase AC switch controller, which can be with two thyristors on phase, with one thyristor and one diode on the phase (**Figure 23**).
- The command angle may be modified using up/down arrows, being shown their values. Along the simulation, it modified the command angle of the three-phase AC switch controller with two thyristors on the phase, in order to evidence the way of voltage modification, or the current through load (**Figure 24**).
- It launches in running the single-phase AC switch controllers with two thyristors, with the control button (Simulare), which is then converted to the simulation stop button (Stop), which is located on the top right (**Figure 25**).
- During the simulation, the scheme dynamically changes its color, the sides what are in conduction at a time (**Figure 26**) [6].

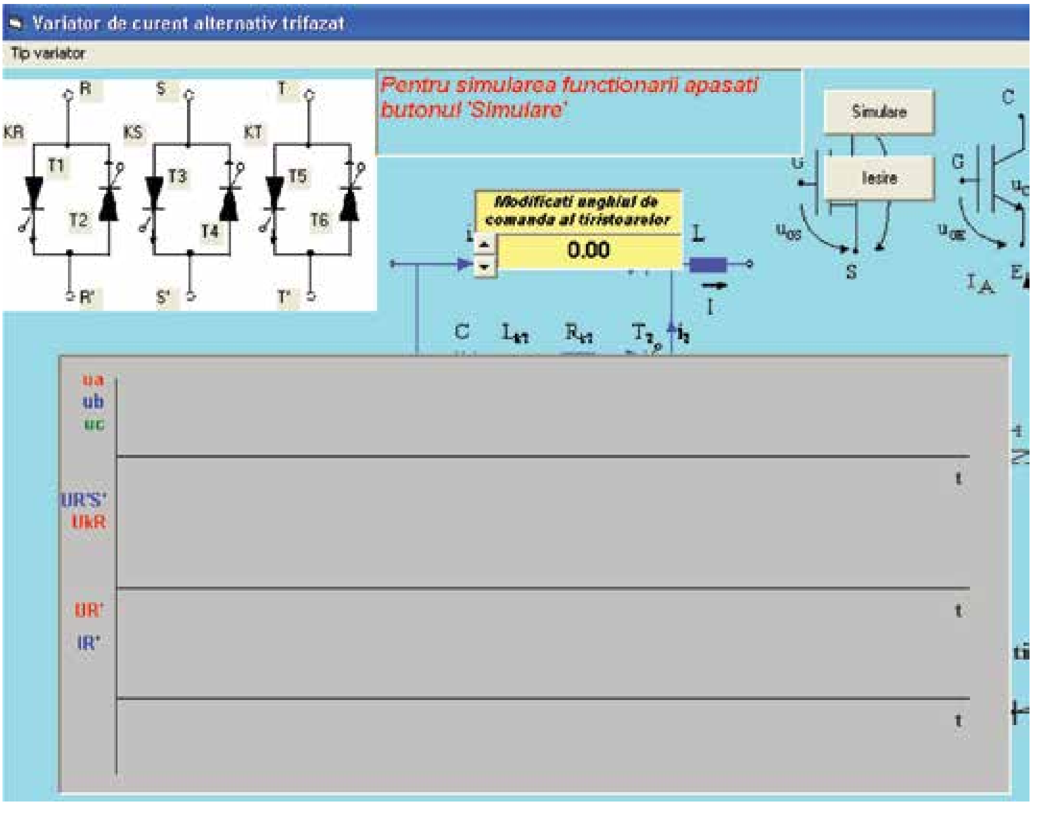

Figure 22. The simulation windows of the three-phase AC switch controller.

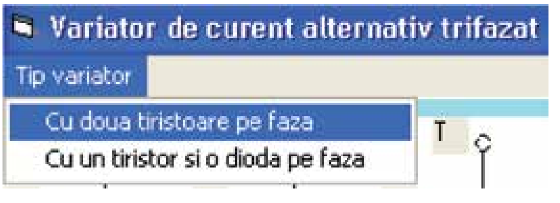

Figure 23. Choosing the three-phase AC switch controller type.

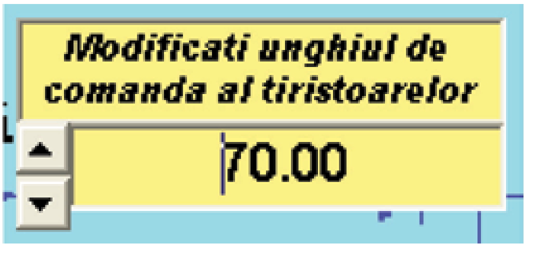

Figure 24. Changing command angle in case of thre-phase switch controller.

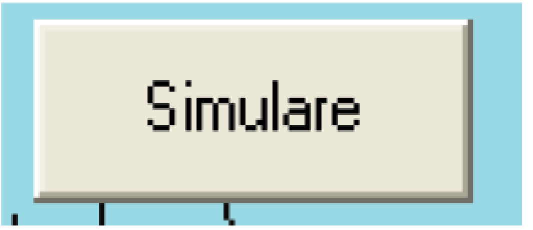

Figure 25. The control button (Simulare) in case of thre-phase switch controller.

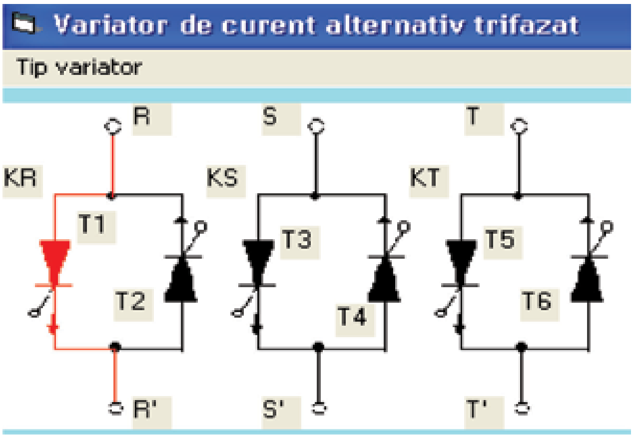

Figure 26. Simulation scheme in case of thre-phase switch controller.

- It will follow the area in which text information about the function mode of the three-phase AC switch controllers are presented (semiconductor elements that are in conduction, semiconductor elements direct polarized, etc.) (**Figure 27**).
- Is watching the area in which is rises dynamically the characteristic waveforms of the three-phase AC switch controllers (**Figure 28**).

The simulation of three-phase switch controller is made for different types of load and by changing the angle of the semiconductor elements. Based on information from the simulation, the students made a report on the functioning in different cases, which is then analyzed together with the teacher, being clarified with aspects of the operating principle.

Figure 27. The information area of text type in case of thre-phase switch controller.

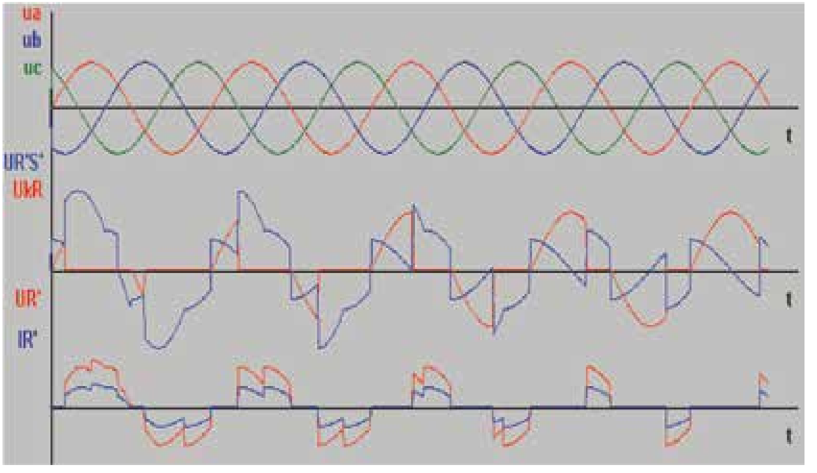

Figure 28. The waveforms area for the three-phase AC switch controllers with resistive load.

- In the resistive load case, the angle ignition variation to the thyristors is comprised between zero and π, the thyristors of K_R being in conduction on period $\alpha \div \pi$, for the positive semi-alternate and $\pi + \alpha \div 2\pi$ for the negative alternate.
- At the end of simulation is pressed the button (Iesire) for application exit, after that is being able to choose, from the main simulation window, another simulation to run (**Figure 29**).

Figure 29. The button for application exit (Iesire).

4. Conclusions

In electrical devices, the AC switch controller is used for asynchronous motor speed change by changing the supply voltage and to the asynchronous motor startup by varying the voltage between zero and nominal value.

These types of static converters are used to control the voltage applied to the stator windings of a cage induction motor or to modify the effective rotor resistance of a wound induction motor. In first case, the converter is connected in series with the stator windings, and in second case in parallel with a resistance.

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Using an AC switch controller is the simplest way to control the speed of AC drive systems. However, this method has some disadvantages such as low input power factor, decreasing efficiency with lower speeds, increasing losses of a drive system if the converter used modifies the effective rotor resistance.

The simulation scheme dynamically changes its color, the sides what are in conduction at a time. In the simulation window, there is a text area where information about the function mode of the converter, the semiconductor elements direct polarized or which are in conduction at that moment are displayed. The window contains also an area with buttons for changing the command angle.

Some of the simulation windows contain a pull-down menu button used to change some parameters or to choose different types of loads. All windows contain two command buttons, one for starting up the simulation (Simulare), which is transformed in button for stop the simulation (Stop) and a button to exit of the window (Iesire).

This documentation describes a Windows application, useful for understanding the functioning of the static variators, converters, and typing to cover all the needed aspects. This application has a teaching purpose, being useful for the students studying static converters.

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References

[1] * * * Visual Basic. User's manual

[2] Marcu MD, Borca D. Static Converters in Electrical Devices. Bucharest: Ed. Topoexim; 1999

[3] Marcu MD, Orban M, Yanakiev K, Kartzelin E. Static Converters and Their Applications. Sofia: St. Ivan Rislki Publishing House; 2001

[4] Marcu MD, Utu I, Popescu FG. Simulation program for static speed variating devices function. Revista Minelor, 2007;**5:**31–33

[5] Marcu MD. Popescu FG. Static Converters – Laboratory. Petrosani: Ed. Universitas; 2010

[6] Marcu MD, Samoila LB, Popescu FG. Simulation software for power electronics. In: Computer Science and Software Techniques in 2011. Vol. I. Czech Republic: Ed. Silhavy Sro; 2011. pp. 121–127

[7] Pătrăscoiu N. Some consideration on understanding the dynamic systems through the use of modeling and simulation technique. In: Proceedings of the 12th International Conference on Applied Computer and Applied Computational Science (ACACOS'13), Kuala Lumpur; 2013. pp. 93–98

[8] Niculescu T, Marcu MD, Popescu FG. Study of transitory phenomena at connecting the capacitive loads to an AC power source. Journal of Advanced Computer Science & Technology. 2015;**4**(1):212–219

Chapter 8

Computer Science Education and Interdisciplinarity

Cristina-Maria Dabu

Additional information is available at the end of the chapter

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Abstract

The world today is characterized through three major elements in the scientific field: the development of classical sciences, the increasingly evolution in the field of computer science and, as result, the emergence of a large number of new border sciences or interdisciplinary and transdisciplinary sciences. In the formation of future specialists, computer science education cannot ignore the reality of a society in which research and technological progress are based primarily on interdisciplinarity and transdisciplinarity. Throughout this chapter, we will analyze the way in which all these elements are evolving in a very closely interdependency one of each other: the evolution of computer science accelerates the development of classical sciences, and the development of classical sciences and computer science generates the emergence and progress of new border sciences and how the educational curricula in computer sciences have to be adapted to this trend. We will present and analyze the ways in which computer science education can be performed in an interdisciplinary and/or transdisciplinary manner at all educational levels. In the same time, we will emphasize the reasons why it is necessary to teach computer science in an interdisciplinary and/or transdisciplinary way and the benefits that teaching strategy brings in the training of future specialists.

Keywords: computer science, education, interdisciplinarity, transdisciplinarity, barriers, emergent science, curricula, creativity, research, skills, development

1. Introduction

The world today is characterized through three major elements in the scientific field: the development of classical sciences, the increasingly evolution in the field of computer science and, as result, the emergence of a large number of new border sciences or interdisciplinary and transdisciplinary sciences.

Interdisciplinary and transdisciplinary research has emerged as a result of the complexity of the world that surrounds us and as a result of the fact that in all fields of scientific research, the complexity of the studied phenomena transcends the borders of a single science.

Another cause that determined the apparition of transdisciplinarity and interdisciplinarity is that the most important discoveries in scientific fields such as life sciences, aerospace sciences, biophysics and other sciences are emerging at the interface between two or more scientific fields.

Even though it is obvious that transdisciplinary and interdisciplinary research leads to spectacular results and that without interdisciplinary and transdisicplinary research current science does not have how to evolve; however, they have been identified a number of barriers that slows interdisciplinary and transdisciplinary approach in scientific research.

A study regarding interdisciplinarity in sciences, conducted by the Academy of Finland [1], highlights a number of barriers of different nature that occur in communication processes and interactions within teams working in interdisciplinary research projects, generating tensions, conflicts or delays in the completion of those projects.

These barriers can be classified into:

- Structural
- Knowledge
- Cultural
- Epistemological
- Methodological
- Psychological
- Reception

We will briefly introduce what each of these barriers represents. A thorough analysis of them is available in Ref. [1].

Structural barriers are related to the organizational structure of the institution or institutions where interdisciplinary research activity occurs: the hierarchy and decision systems, organizational rules, financing sources, influencing how it is carried out the research activity.

Knowledge barriers are generated by the gap of knowledge that specialists in a particular scientific field they have compared to other scientific fields involved in an interdisciplinary research project.

Cultural barriers occur because of problems related to the language used in communication within teams working in multidisciplinary research projects. Each scientific field is characterized by its own specialized terminology, the used terms may sometimes be the same, but in a greater or lesser measure, different in their meanings. As a result, confusion and misunderstandings can arise in the communication on the project, because different terms are used to refer to the same concepts, or similar terms have different meanings from one scientific field to another.

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Epistemological barriers are generated by the vision that various scientific fields have regarding the world and by the way in which the various phenomena are perceived in terms of importance by each scientific field separately. It was also found that epistemological barriers depend on the way in which the various scientific fields have evolved over the time.

Methodological barriers are result of the fact that each scientific field is characterized by its own research methodologies in designing, conducting and reporting research.

Psychological barriers arise due to the fact that each scientific researcher involved in an interdisciplinary project is intellectually and emotionally attached to the scientific field to which he/her belongs and in which he/her has invested intellect, time and labor. In addition, the migration of scientific researchers from a research field in a multidisciplinary team, in which they have to interact with other researchers from other scientific fields, characterized by their own culture, especially in the early stage can generate negative emotions.

Reception barriers are specific to those interdisciplinary research project phases in which, in various forms (reports, publications, presentations, applications for funding), the results of interdisciplinary research activity are disclosed to the layman public (appraisers, financiers, civil society), and there are attempts to assess the interdisciplinarity in the project.

We found that similar barriers can also be identified in the case of transdisciplinary scientific research.

The study [1] identifies two main reasons of these barriers:

- The fact that theories and methods belonging to different disciplines are very difficult to integrate in a new common perspective.
- Scientific disciplines are conventions socially constructed that have their own institutional and ideological structures [1].

The Report of the MASIS Expert Group "Challenging Futures of Science in Society—Emerging trends and cutting-edge issues" [2] brings into discussion new concepts regarding science:

- Recontextualization of science
- Strategic research and strategic science
- Governance of scientific institutions
- Reflexive science
- Innovation-oriented research
- Industrialized science
- Structural and cultural transformations regarding science.

Through the concepts introduced and explained in the document, the report highlights new approaches regarding the evolution and philosophy of science. These approaches are generated both by the development sciences (classic sciences and new emerged sciences) and by the complexity of the world we live.

Considering the direction of evolution in scientific research, in order to prepare future professionals who can successfully face the challenges of sciences, education systems must adapt at all levels of education to the interdisciplinary and transdisciplinary trends in scientific research.

Moreover, one of the main objectives of the educational system should be eliminating the barriers identified in interdisciplinary and transdisciplinary research, in order to accelerate the progress of sciences and technology and through them, as result, to accelerate the progress of entire society.

The removal or mitigation of cultural, methodological or knowledge barriers that occur in interdisciplinary and transdisciplinary research can be achieved only through interdisciplinary and transdisciplinary orientation in teaching-learning activities, such that current students, future professionals, will develop from early stage during the years of study those skills that will make them competitive in an interdisciplinary or transdisciplinary scientific research activity.

The report emphasizes the absolute necessity for students to be familiarized with various fields of computer science during their schooling. In order to be an effective approach in favor of students, with long-term beneficial effect on the training of future specialists, familiarizing students with various areas of computer science should be done according on their own leaning skills and interests.

Thus, the discipline computer science should be studied in an interdisciplinary way, correlated with other scientific field (or fields), which constitute the subject of interest for every student.

In the same sense, in another important document, the report of the joint Informatics Europe & ACM Europe Working Group on Informatics Education, we have identified the following objectives concerning computer science education in Europe [3]:

1. Generalization of education in computer literacy and computer science (informatics) at all educational levels.
2. Creating a Europe based on an Informational Society and an informational economy.
3. Introducing digital literacy and computer science in the curriculum for all European countries.
4. Enhancement of The students training in computer science (informatics) so as to make Europe a major player in Information Technology.

The two bodies have developed the following recommendations for educational systems across Europe regarding computer science education [3]:

1. "All students should benefit from education in digital literacy, starting from an early age and mastering the basic concepts by age 12. Digital literacy education should emphasize not only skills, but also the principles and practices of using them effectively and ethically."

2. “All students should benefit from education in informatics as an independent scientific subject, studied both for its intrinsic intellectual and educational value and for its applications to other disciplines”.

3. “A large-scale teacher training program should urgently be started. To bootstrap the process in the short term, creative solutions should be developed involving school teachers paired with experts from academia and industry”.

4. “The definition of informatics curricula should rely on the considerable body of existing work on the topic and specific recommendations of the present report” [3].

As it will be seen in the next chapters, the Romanian educational system integrated in the curricula at all educational levels, computer science education and computer literacy education, correlated with other disciplines included in the school curricula.

2. Computer science in actual science

In the contemporary society, the role of computer science has become and is becoming more and more important in all scientific fields: medicine, pharmacy, economics, education, sociology, physics, chemistry, biochemistry, anthropology, aerospace and others.

The evolution of computer science provides to other scientific research fields powerful instruments for research: high capacity computational systems, able to manage huge databases, powerful and sophisticated calculus algorithms for data analysis and data mining and dedicated software for computer-assisted modeling and simulation. At the same time are being built increasingly sophisticated measuring devices based on highly specialized sensors and biosensors, that incorporate dedicated software packages for automatic processing of collected data. Fall into this category devices used in the study of outer space, devices for measuring biological parameters in medicine, biotechnology, marine research and other similar devices used in physics, chemistry and others.

All these specialized devices, dedicated for gathering and automatic processing of large amounts of data on the one hand, have led to spectacular developments in various scientific fields like medicine, pharmacy, physics, biophysics, chemistry, biochemistry and others, and on the other hand, they have led to the emergence of new sciences, such as exo-oceanography, exo-biology, computing sociology, computing anthropology, computing ecology, computing toxicology and others.

The huge amount of data collected in all scientific fields using specialized devices allow the possibility to use these data in order to elaborate specific prognosis (population health prognosis, population movement prognosis, meteorological and exo-meteorological prognosis, environment evolution prognosis and others). As a result, in almost all fields of research are extensively used experimental models and simulations. This relatively new approach, belonging to the past 25–30 years, has made simulation and modeling to be considered an <<emerging “third leg” of Scientific Investigation>> [4].

Computer science is an extremely abstract, intellectually challenging field, because programming technologies operate with very abstract and codified representations for the surrounding reality. For this reason, especially in the initial stages, interdisciplinary and transdisciplinary research projects involving computer science are faced with certain difficulties, especially concerning the transposition into an abstract representation specific to computer science, the experimental reality belonging to a different scientific field.

These difficulties occurring in research activities constitute another reason for teaching computer science discipline, at all levels of education, in an interdisciplinary manner. Through teaching computer science in an interdisciplinary and transdisciplinary manner, on one hand the future specialist in computer science will have early formed the necessary skills to conduct a dialogue with specialists belonging to other scientific fields, and on the other hand, for specialists from different scientific fields (physics, chemistry, biochemistry, medicine), computer science will no longer be a stranger and abstract area.

Another important issue is that in the era of Big Data, characterized by huge databases in all fields of science (medicine, genetics, sociology, anthropology) collected through most various channels, one of the most challenging scientific work is to identify patterns and consistent elements of knowledge in large databases.

Big Data technology development determined that currently some of of the most increasingly used computing applications and algorithms, used today by researchers in most fields of science, are those dedicated for Data Mining.

In the scientific literature, it is defined the activity of Knowledge Discovery in Databases (KDD) as "the process of identifying valid, novel, potentially useful and ultimately understandable patterns in data" [5]. The most powerful tool used for Knowledge Discovery in Databases, Data Mining represents "a collection of methods of data analysis coming from different fields of computer science, artificial intelligence and statistics" [5].

Taking into account that, as we noted above, computer science is deeply involved in all current sciences, it is considered that "interdisciplinary computer science is becoming the norm" [6].

They are science or scientific results, which could not exist in the absence of computer science. An example of this is the genomic sequencing, a remarkably successful genetics result, which would not be achieved in the absence of tools provided by computer science [6].

In other sciences, like the aerospace sciences or exo-meteorology, they could not exist as scientific fields itself in the absence of computer science, because both in the collection of scientific data and in the processing thereof are being used computer systems and devices coordinated by computer systems (space probes, spatial robots, artificial satellites).

3. Science evolution and emergence

How we have mentioned above, the development of computer science has an huge impact upon the evolution of other science fields (chemistry, biochemistry, physics) and the emergence of new sciences such as Computational Social Science, Synthetic Biology, Quantum

Biology, Exo-meteorology, Exo-oceanography, Cliodynamics, Computational Anthropology, Computational Toxicology, Computational Ecology and others.

This is due primarily to the fact that knowledge itself has an interdisciplinary character, and the human brain is trained to process permanently information coming from different scientific areas, and to make extremely rapid correlations between the newly acquired elements of knowledge and the oldest already stored elements of knowledge, belonging to other scientific fields.

Secondly, the extremely rapid evolution of computer science field, as noted in the previous chapters, has provided to the various scientific fields devices and applications able to collect, store and process huge amounts of information. As a result, the amount of scientific knowledge in all areas has grown exponentially and has become much more complex.

Explaining the phenomena based on vast amounts of information collected by devices made available by means of computer science, required the gradual emergence of new interdisciplinary or transdisciplinary scientific fields, some of them impossible to exist in the absence of computer science, and each of them having its own research methodologies, scientific terminology and their own areas of interdisciplinary knowledge.

We will present in the following some such new scientific fields, emerged at the intersection between computer science and other fields of scientific research.

3.1. Computational Anthropology

Computational Anthropology is emerging from a multitude of sciences: Computer Science, Anthropology, Sociology and Geographic Information Science.

The main objective of this new emerged science is the study how patterns of human behavior change over time and space [7].

The scientists in Computational Anthropology are analyzing data collected from social networks and geolocation systems in order to provide new insights regarding the nature of human society [7].

In the last decade, the increasing availability of big data generated by mobile phones and location-based applications has triggered a revolution in the understanding of human mobility patterns. Using specific algorithms for data mining, simulation and prognosis, one can be identified patterns regarding travel around the world, and very important for the health systems from all countries, one can be made forecasts on the spread of diseases and epidemics [7].

In the scientists in Computational Anthropology opinion, "there is considerable interest in looking more closely at human mobility patterns to see just how well it can be predicted and how these predictions might be used in everything from disease control and city planning to traffic forecasting and location-based advertising" [7].

3.2. Computational Ecology

Computational Ecology is another new emerged sciences, based on computer science and ecology.

Computational Ecology is using numerical models and computer simulations in researches regarding dynamics of populations and systems. There are studied tendencies and specificities for a better understanding and prognosis in areas such as fisheries, forestry, agriculture, climate change and evolutionary ecology [8].

Ecosystems are living systems that are formed and evolves in years, decades, hundreds or thousands of years. Consequently, experiments in the classical conception of scientific experiment in order to understand the dynamics and evolution of ecosystems are difficult or even impossible to carry out.

Computing Ecology through powerful research tools provided by mathematical models and computer aided simulations, software systems able to analyze large amounts of data gathered in situ, enables understanding of phenomena and processes occurring and enables elaborating predictions regarding the evolution of ecosystems.

This newly emerged science is of great importance in the heavily industrialized contemporary society, where the ecological disasters caused by various agents have become very common.

3.3. Computational Toxicology

Computational Toxicology is another new emerged science, correlated with computational ecology and environmental protection.

It was officially mentioned for the first time in September 2009 when the National Research Council Committee on Use of Emerging Science for Environmental Health Decisions held a public meetings titled “Computational Toxicology: From Data to Analyses to Applications” [9].

Computational Toxicology offers the opportunity to study and forecast, based on mathematical models and computer-aided simulation, the harmful effects that various toxic pollutants or sources may have on the environment, humans and animals.

The new emerged science brings substantial scientific contribution in a field in which experimental research are extremely harmful for the environment and humans. For this reason, experiments have to be replaced with computer-assisted simulations based on mathematical models, without danger for humans, animals and environment.

3.4. Exo-Meteorology

Exo-meteorology is a new emerged scientific and research field which is studying the meteorological phenomena that take place on other planets existing our solar system [10].

Field of research could not exist in the absence of computer science. Computerized systems are needed both in the collection and storage of data, as well as for their processing and interpretation and for the elaboration of forecasts.

Forecasts elaborated by this newly emerging science are important in planning space missions [11].

4. Computer science education in curricula

As we have seen in the previous chapters, in the context of actual science and society evolution, the goal of computer science education is to prepare actual students, future specialists, to work and think at the intersection between computer science and other scientific fields.

Considering that the in almost all scientific fields are used computer-assisted modeling and simulations, it is essential for future researchers to be familiar with algorithmic thinking and computer science. In addition, the barriers that arise during interdisciplinary and transdisicplinary research activities, mentioned in previous chapters, represent another important reason for approaching an interdisciplinary manner in teaching computer science, using examples and applications from other disciplines or from the world around us.

In the Romanian educational system, at all levels of education, curricula contain computer science education with multiple goals:

- To familiarize the student as computer user as future specialist in a particular scientific branch.
- Development of specific algorithmic thinking skills, useful for a future specialist in any scientific field.
- Development of programming skills for creating dedicated software systems in other scientific fields (biology, chemistry, physics).

In order to attain these objectives in teaching computer science, in the Romanian education, one has been made remarkable progress in the last 17 years, both in terms of technical endowment and in terms of improving the school curricula:

- Schools, high schools and universities were equipped with computer networks, connected to the internet.
- One was developed educational software packages for almost all subjects in the curricula.
- One has been made available for students' online platforms for training in computer science for Olympiads in informatics and other informatics competitions.
- One has been developed support materials and training programs for teachers.
- Many programs or projects aimed to promote new technologies in education and supporting computer-assisted learning (eLearning).

The Romanian education curricula take into consideration more categories of competencies:

- European key competencies
- Competencies established by the Romanian Education Law

At the fifth grade level, the European key competencies that need to be developed throughout the course information and communication technology are:

- Digital competences
- Mathematical competence and basic competences in science and technology [12].

Consistent with these European key competencies, the competencies established by the Education Law in Romania are as follows:

- Digital skills to use information technology as a tool for learning and knowledge
- Basic skills in mathematics, science and technology
- Social and civic competences
- Competence of learning to learn [12].

To ensure the interdisciplinary study of computer science, the curriculum recommends: “For the good development classes and curriculum implementation, to correlate is recommended teaching activities of other subjects studied the content” [12].

The main topics of the computer science curricula (Computer Literacy) at the fifth grade are:

- Basic computer hardware
- Windows
- Paint
- Microsoft Word
- Powerpoint

At high school level, the curricula provide differentiated study of computer science, according to the high school profile:

- Humanities
- Real (science)
- Computer science
- Arts and crafts

In Romania, the school curricula for computer science education provide both teaching hours and laboratory hours.

For high school, profile humanities, computer science education, consist in Computer Literacy (general) and Desktop Publishing.

On the other hand, for high school profiles real (science) and computer science, there are hours of algorithms, computer literacy, computer programming course in C++ or Pascal and laboratory courses.

During the programming courses (C++ or Pascal), there are taught concepts like:

- Data types and variables
- Operators
- Simple instructions

- Control structures
- Pointers
- Functions
- Lists, stacks and queues
- Algorithms for searching and sorting

During the laboratory courses, students develop their own computer programs applying concepts learned in the classroom.

Involving students during the laboratory classes in interdisciplinary projects like:

- Software system for the study of geography
- Software system for the study of foreign languages with computer
- System Software for the modeling of some physical phenomena
- Software system for studying cell division
- Software system for mathematics study
- Software system for chemistry study

stimulates the development of interdisciplinary skills of the students.

Working organized in teams on projects such as those mentioned above, students are challenged to develop their critical thinking, analytical skills and abilities:

- They must know and implement concepts learned during the hours of Computer Science.
- They need to know at a sufficiently high level concepts belonging to the scientific fields for which they develop the software system.
- They must select which concepts will be introduced in the software system they build.
- They have to organize logically and easily accessible the informations within the software system.

The students have to analyze and determine what information from the selected scientific field that will take in the information system (theoretical concepts, exercises, tests for assessing knowledge).

They should consider how they will present the information in the software system in order to be easily accessible for the final user.

Students have to design and implement interfaces between the user and the computer system, students must show creativity and develop their creativity, and they have to know concepts regarding ergonomics of man-machine interfaces.

They design and implement computer-assisted exercises, quizzes and tests and evaluation algorithms for the verification of the acquired knowledge.

Through these projects, students are challenged to research and development of interdisciplinary and transdisciplinary knowledge of various fields merging computer science and other school disciplines, depending on the project and on students own preferences.

In addition, the teamwork activity forces them to develop their communication skills, collegiality, adaptability and other skills needed for teamwork, skills required also as future professionals who will need to integrate into a team of interdisciplinary and/or transdisciplinary research.

Under this manner, teaching computer science is done in an interdisciplinary and transdisciplinary way, which encourages students not only to study strictly the discipline of computer science but also encourages them to expand their knowledge in other scientific fields in order to develop their software projects during the laboratory hours.

Another extremely challenging exercise for students, which we use in teaching the chapter regarding computer structure (computer hardware), is to identify the various components of a computer in other devices that run based on computer programs and computational systems:

- Devices to monitoring patients in hospitals
- Fuel pump from gas stations
- Washing machine
- Mobile phones
- Other similar systems

Students are encouraged to identify for each case what would be the input unit, the output unit, whether the device is equipped with external memory or not and what would be their role and what would be the role of command and control unit. Such students are encouraged to think about a computer device in the context of another domain (medical, telecommunication, oil and appliances), helping them to develop their interdisciplinary and transdisciplinary thinking ability.

We have used these methods for teaching computer science in many schools throughout time and every time which have given very good results. Students have very good results informatics Olympiads and competitions, and some of them, who have followed careers in computer science, have integrated very well on the job.

At academic level, interdisciplinarity and transdisciplinarity of computer science education are reflected in the large offer of masters or doctoral programs and academic courses that universities offer their students on various interdisciplinary or transdisciplinary areas:

- Computational Biology,
- Computational Biochemistry
- Computational Bioengineering
- Computational Geometry

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- Computational Linguistics
- Computational Physics
- Computational Ecology
- Computational Economics and others.

All these <<computational X>> [13] programs and courses at academic level are in close correlation with the new emerging scientific and research fields, in order to train specialists for the respective fields.

In addition, these interdisciplinary programs or courses, based on computer science, contribute significantly to removing some of the barriers involved in interdisciplinary research, we have mentioned in the previous chapters. Students trained in two or more different scientific fields, as future professionals working on interdisciplinary or transdisciplinary research projects could more easily overcome with the difficulties raised by cultural barriers, methodological barriers or knowledge barriers.

5. Conclusions

Without exhausting the subject, throughout chapter, we have presented that the reasons that have lead to interdisciplinary and transdisciplinary research and the barriers that appear in interdisciplinary and transdisciplinary research activity.

Our society is in constant evolution, scientific and technical and educational program must follow this evolution in order to prepare future specialists to the standards required by the society.

Evolution of computer science has a major impact in the development of science, not only by the contribution to getting some spectacular scientific results already established in areas of science but also by contributing to the emergence of new scientific fields. There have been summarized in this regard several new emerged scientific fields whose research activities have major impact in human society: Computational Ecology, Computational Toxicology, Computational Anthropology.

Education in the field of computer science can be done both as a self-contained discipline, but more important is the study of computer science in an interdisciplinary manner.

Teaching computer science in interdisciplinary and/or transdisciplinary manner, by engaging students in interdisciplinary projects or offering them interdisciplinary and/or transdisciplinary courses and specialization programs, as we have shown in the chapter, will help them to develop a series of skills needed for future interdisciplinary scientific research.

Also engaging students during computer science hours to identify ways, in which computer systems are used in the management of various processes in the world around us, contribute to help the students to develop specific skills regarding analysis and identification of systems.

Systems analysis and identification are concepts belonging to systems theory and are currently applied in most fields of scientific research. They are used for many years in scientific research concepts such as biochemical systems, biological systems, ecological systems and others.

All these concepts are interdisciplinary concepts which correlate computer science and systems theory with other scientific fields and are crucial especially in computer aided modeling and simulation. It is therefore important that during the classes of computer science, students become familiar from early stages with systemic thinking, which is essential in building software applications dedicated to other scientific fields.

Interdisciplinary and transdisciplinary approach stimulates scientific curiosity, an essential feature for a future scientific researcher. Scientific curiosity is typical of human nature, which always, from the ancient times, sought to understand and explain phenomena that occur in the natural world and modern education systems should aim to encourage and develop this scientific curiosity.

School systems from everywhere, through educational curricula content and through educational strategies, should stimulate and develop scientific curiosity of students in light of forming future specialists.

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References

[1] Bruun H, Hukkinen J, Huutoniemi K, Thomson Klein J. Promoting Interdisciplinary Research: The case of the Academy of Finland. http://www.aka.fi/globalassets/awanhat/documents/tiedostot/julkaisut/8_05-promoting-interdisciplinary-research_-the-case-of-the-academy-of-finland.pdf [Accessed 17.01.2017]

[2] European Commission Challenging Futures of Science in Society-Emerging trends and cutting-edge issues, Report of the MASIS Expert Group setup by the European Commission, 2009, https://ec.europa.eu/research/science-society/document_library/pdf_06/the-masis-report_en.pdf [Accessed 21.12.2017]

[3] Informatics education: Europe cannot afford to miss the boat. Report of the joint Informatics Europe & ACM Europe Working Group on Informatics Education, April

2013, http://www.informatics-europe.org/images/documents/informatics-education-acm-ie.pdf [Accessed 22.01.2017]

[4] Bradly Alicea, Scientific simulation and modeling, https://msu.edu/~aliceabr/sci_sim_class.pdf [Accessed 22.01.2017]

[5] Marco Remondino, Gianluca Correndo, Data Mining Applied to Agent Based Simulation, 2005. http://eprints.soton.ac.uk/267933/1/or-14.pdf [Accessed 22.01.2017]

[6] Computing Education Computing Research Association Innovative Approaches to Computing Education, http://cra.org/wp-content/uploads/2015/08/ComputingEducation-Final-Report.pdf [Last visited 22.01.2017]

[7] https://www.technologyreview.com/s/528216/the-emerging-science-of-computational-anthropology/ [Accessed 17.01.2017]

[8] http://rsfs.royalsocietypublishing.org/content/2/2/241 [Accessed 10.01.2017]

[9] http://nas-sites.org/emergingscience/files/2011/05/newsletter4_comptox-rev.pdf [Accessed 21.12.2017]

[10] http://io9.gizmodo.com/5987296/11-emerging-scientific-fields-that-everyone-should-know-about [Accessed 17.02.2017]

[11] http://www.solaciumcorp.com/what-we-do/air-space/exo-meteorology/[Accessed 17.02.2017]

[12] http://www.ls-infomat.ro/user/content/1731programa_tic_cls_a_v_a.pdf [Accessed 10.01.2017]

[13] Joint Task Force on Computing Curricula, Association for Computing Machinery (ACM) and IEEE Computer Society. Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science. ACM, 2013

Chapter 9

Electric Machines: Tool in MATLAB

Rabih Rammal and Mohamad Arnaout

Additional information is available at the end of the chapter

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Abstract

This chapter presents an educational modeling and parametric study of specific types of transformers, generators, and motors used in power system. Equivalent circuit models are presented and basic equations are developed. Through tests and operating conditions, essential parameters for each presented machine are extracted. Graphical user interface (GUI) on MATLAB software is used to study and analyze each element. GUI allows better comprehension and clearer vision to analyze the performance of each electric machine, thus, a complementary educational tool. In addition, GUI permits optimal collaborative learning situations when linked with the theoretical expansion and, thus, is a teaching process that forges the connection between traditional subjects and science education.

Keywords: MATLAB, GUI, educational tool, science education, electric machines, ferromagnetic material, transformers, DC machines, induction machines

1. Introduction

There are several ways to generate electricity which are burning fossil fuels, converting water into steam, and using the steam to spin a turbine that is connected to an electric generator. In hydroelectric power plants, generators are turned by water and via wind in wind turbines. In all cases, the electricity generated at these facilities flows across the transmission and distribution system to where it is needed to meet customer demand in cities and rural areas. The electric system is an interconnected network for generating, transmitting, and delivering electricity to consumers [1].

The conventional view of studying electric machines concentrates on concepts. The graphical user interface provides direct contact with the content, provokes curiosity, and implements the science education through scientific knowledge based on facts, laws, theories, and models. The integration of this new structure improves science comprehension and helps students to learn better and more efficiently.

The study of an efficient power system starts with understanding the behavior of each component that develops this system. Electric machines used in power systems (generators, motors, and transformers) will be examined through analytical expressions and computer simulation. The importance of simulation is that these components could be studied before it is manufactured; thus, the consequences of changing dimensions and parameters can be assessed.

This simulation will be implemented in an educational tool, going from the basic operation principles, through developing models and equations toward the solution. The graphical user interface of MATLAB allows the students to study and analyze the effect of each parameter in order to understand its electric behavior with respect to its electric model.

This chapter will discuss the implementation of ferromagnetic core using graphical user interface taking into consideration the effects of air gap and fringing of a ferromagnetic core. Then, a detailed study of output power and losses with voltage regulation and efficiency of a single- and three-phase transformer will be established. In addition, a special survey will be accomplished concerning the types of DC motors and generators. Finally, this chapter will be concluded by providing an adequate research on the induction machines including their parametric study, and it will be achieved by a general conclusion of this work.

This chapter presents learning situations going from the theoretical expansion to the graphical interpretation. It is a teaching methodology toward the science education.

2. Ferromagnetic core

Magnetic fields are the essential means by which energy is converted from one form to another in motors, generators, and transformers. The most important class of the magnetic materials is the ferromagnetic materials such as iron, cobalt, nickel, and manganese [2].

There are four basic principles which describe how magnetic fields are used [2]:

1. A wire produces a magnetic field in the area around it when current passes through it.
2. A change in magnetic field, by mutual inductance, induces a voltage in the coil of wire: this is the principle of transformer action.
3. In the presence of a magnetic field, a current-carrying wire has a force induced on it: this is the principle of motor action.
4. In the presence of a magnetic field, a moving wire has a voltage induced in it: this is the principle of generator action.

2.1. The magnetic field

The magnetic field is produced by induced current in Ampere's law:

$$\oint H.dl = I_{net} \tag{1}$$

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where I_{net} produces magnetic field intensity and H and dl are the length integration along a path. If the core is produced from ferromagnetic material (**Figure 1**), then all the magnetic field produced within the core will remain inside the core. Therefore, the path of integration dl in the Ampere's law is the mean path length l_c [2].

The current passing in the path of the integration I_{net} is NI since the coil of the wire divides the path of integration into N times when the current passes through it:

$$H.l = NI \Rightarrow H = \frac{NI}{l} \tag{2}$$

The magnetic field intensity H is the effort in which a current is applying to establishment of a magnetic field. Strength of the magnetic field depends on the material of core. There is a relationship between the magnetic field intensity, the material magnetic permeability μ, and the magnetic flux produced within the material as shown in Eq. (3):

$$B = \mu H \tag{3}$$

The permeability of free space is called μ_0 and equal to $4\pi \times 10^{-7}$ H/m, and the relative permeability is the permeability of any other material compared to the free space permeability:

$$\mu_r = \frac{\mu}{\mu_0} \tag{4}$$

In the core (**Figure 1**), the magnitude of the flux density is given by

$$B = \mu H = \mu \frac{NI}{l} \tag{5}$$

Therefore, the total flux in a given area is expressed in Eq. (6). This equation reduced if the flux density vector is perpendicular to any plane of area, and if the flux density is constant throughout the area, then to

$$\int_A \phi = B.dA \Rightarrow \phi = B.A = \mu HA = \mu \frac{NI}{l} A \tag{6}$$

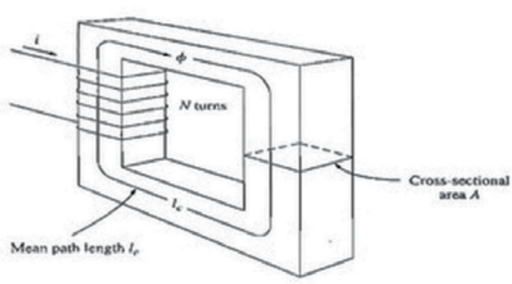

Figure 1. Ferromagnetic core.

2.2. Magnetic circuits

Magnetic flux is produced when the current in a coil of wire is wrapped around a core. This is similar to a voltage in an electric circuit producing a current flow. Thus, a "magnetic circuit" is defined by equations that are similar to that of an electric circuit. In the design of electric machines and transformers, the magnetic circuit model is used to simplify the complex design process [2].

The voltage or electromotive force drives the current flow in the electric circuit. The magnetomotive force of the magnetic circuit is denoted by where is the magnetomotive force in ampere-turns. In the magnetic circuit, the applied magnetomotive force causes flux (ϕ) to be produced (**Figure 2**).

The relationship that governs the magnetomotive force and flux is given by

$$\mathfrak{F} = NI = \phi\mathfrak{R} \tag{7}$$

The permeance of a magnetic circuit is the reciprocal of its reluctance. Therefore, the relation between magnetomotive force and flux can be expressed as

$$\phi = \mathfrak{F}P \Rightarrow \phi = \mathfrak{F}\frac{1}{\mathfrak{R}} \tag{8}$$

It is easier to work with the permeance of a magnetic field than with its reluctance.

The resulting flux and reluctance of a core are shown in Eqs. (9) and (10), respectively:

$$\phi = \mathfrak{F}\frac{\mu A}{l} \tag{9}$$

$$\mathfrak{R} = \frac{l}{\mu A} \tag{10}$$

The equivalent reluctance of a number of reluctances in series is just the sum of the individual reluctances:

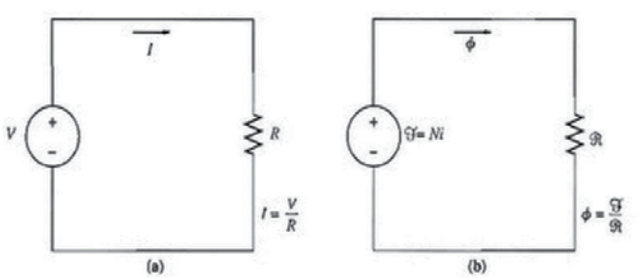

Figure 2. (a) A simple electric circuit. (b) The magnetic circuit analogue to a transformer core.

$$\mathfrak{R}_{eq} = \mathfrak{R}_1 + \mathfrak{R}_2 + \mathfrak{R}_3 + \ldots.. \tag{11}$$

The equivalent reluctance of a number of reluctances in parallel is just the sum of the individual reluctances:

$$\mathfrak{R}_{eq} = \frac{1}{\mathfrak{R}_1} + \frac{1}{\mathfrak{R}_2} + \frac{1}{\mathfrak{R}_3} + \ldots.. \tag{12}$$

The reluctance of each leg of a ferromagnetic core is

$$\mathfrak{R}_x = \frac{l_x}{\mu_r \mu_0 A_x} {}^{A.t}/_{wb} \tag{13}$$

The air-gap reluctance at leg X is

$$\mathfrak{R}_{xa} = \frac{l_{xa}}{\mu_0 A_{xa}} {}^{A.t}/_{wb} \tag{14}$$

The total flux of the ferromagnetic core is

$$\phi_{TOT} = \frac{\mathfrak{F}}{\mathfrak{R}_{eq}} wb \tag{15}$$

2.3. Implement in MATLAB GUI

When implementing in MATLAB, the user will add certain input which will then be calculated, and the result will be displayed. Below is a block diagram of the system.

The user fills the number of regions with availability of air gap indicating which leg is available and the details for core type such as relative permeability of the material and number of turns with the current (**Figure 3**). The results of the calculated parameters such as total flux and total reluctance and magnetomotive force of ferromagnetic core are displayed (**Figure 4**).

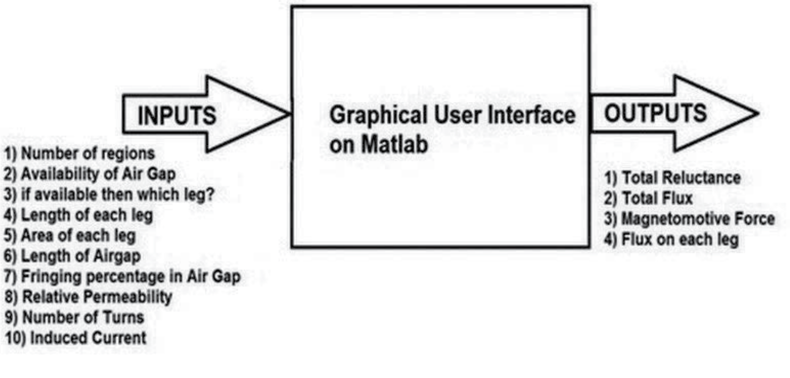

Figure 3. Ferromagnetic core GUI block diagram.

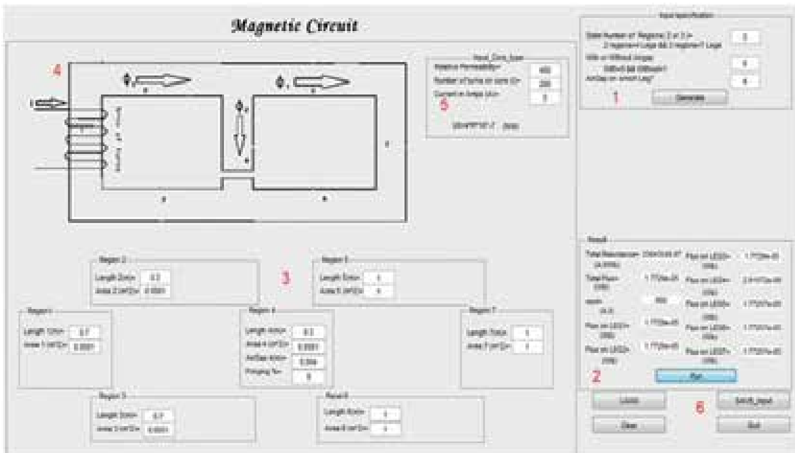

Figure 4. Graphical user interface for ferromagnetic core.

Also, the user should add the parameters of the ferromagnetic core such as length, area, air gap, and fringing percentage of each leg of the core; the ferromagnetic core is displayed after entering the inputs. Push buttons are added to load, save data, clear, and quit.

3. Single- and three-phase transformer

3.1. Introduction

Transformer allows developing different voltage levels across the system for the most cost-effective price. Transformer functioning principle is based on the idea that energy can be transferred by means of magnetic induction from one winding at the primary side to another winding at the secondary side. This is done by varying the magnetic field produced by alternating current [2, 3].

In this section, graphical user interface (GUI) on MATLAB software will be used to calculate the circuit parameters, efficiency, and voltage regulation of single-phase and three-phase ac transformer. The MATLAB results have been verified and compared with manual calculation in order to ensure they are correct and reliable.

Using GUI in electrical simulation, the instructor/teacher could show the effect of variation for different parameters and then permit to analyze and conclude without the need of manual solving.

3.2. Single-phase transformer model

A single-phase transformer consists of one primary winding and one secondary winding. The exact equivalent circuit with its parameter is shown in the figure below [4].

The parameters of this transformer are as follows (**Figure 5**):

Primary side:

a. Primary voltage terminal (V_P)

b. Primary current (I_P)

c. Primary resistance (R_P)

d. Primary leakage reactance (X_P)

e. Core resistance (R_C)

f. Magnetize in reactance (X_M)

g. Number of turns (N_P)

Secondary side:

a. Secondary voltage terminal (V_S)

b. Secondary current (I_S)

c. Secondary resistance (R_S)

d. Secondary leakage reactance (X_S)

e. Number of turns (N_S)

These parameters can be calculated by open-circuit test and short-circuit test procedure.

3.3. Transformer test

Two tests are applied on the transformer in order to determine its parameters: short-circuit and open-circuit tests [2].

The results permit to determine the equivalent circuit of the transformer, its voltage regulation, as well as its efficiency.

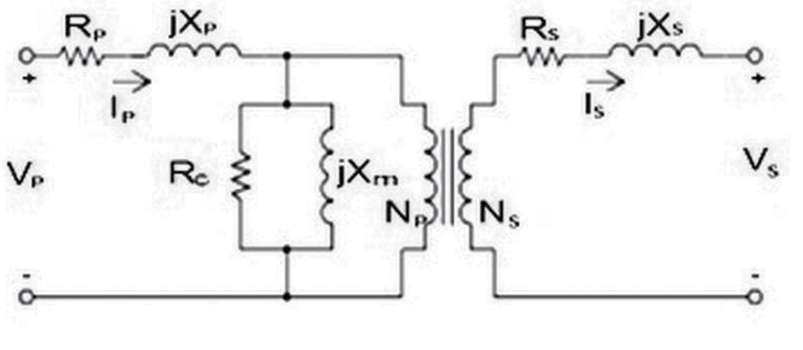

Figure 5. Exact model of transformer.

3.3.1. Short-circuit test

A voltmeter, ammeter, and wattmeter are connected in the HV side of the transformer. Then, the voltage at rated frequency is applied to that HV side using a variable ratio autotransformer. We will then short circuit the LV side of the transformer. Keep increasing the applied voltage, slowly, till reaching the rated current of the HV side (ammeter reading).

Once the rated current is reached on the HV side, the readings extracted on all three instruments, voltmeter, ammeter, and wattmeter, are recorded. The full-load current equivalent corresponds to the ammeter reading.

The transformer core losses could be neglected in this test. In fact, the voltage applied during the short-circuit test on the transformer is very small when compared to the rated voltage of the transformer.

The copper losses in the transformer could be read on the wattmeter. In fact, the wattmeter indicates the input power during the short-circuit test, when the voltmeter is showing the short-circuit voltage V_{SC}. At this time, no output power will appear (short circuited), the core losses are neglected due to the low applied voltage, and, thus, the copper losses in the transformer correspond to the input power.

The extracted values, when the test is accomplished on the transformer's HV side, are referred to the HV side. We can also refer these values to the LV side dividing by the squared turn ratio of the transformer.

Let us consider that the wattmeter reading is P_{SC}:

$$P_{SC} = R_e I^2 \tag{16}$$

If Z_e is the equivalent impedance of the transformer, then

$$R_e = \frac{V_{SC}}{I_L} \tag{17}$$

Therefore, if the equivalent reactance of transformer is X_e, then

$$X_e^2 = Z_e^2 - R_e^2 \tag{18}$$

Power factor of the current and angle of power factor are shown below:

$$PF = \cos\theta = \frac{P_{SC}}{V_{SC} I_{SC}} \Rightarrow \theta = \cos^{-1}\frac{P_{SC}}{V_{SC} I_{SC}} \tag{19}$$

3.3.2. Open-circuit test

The open-circuit test consists of connecting an ammeter, a voltmeter, and a wattmeter to the LV side of the transformer. At rated frequency, a voltage is applied to the LV side using a variable ratio autotransformer.

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Increasing this applied voltage until the LV side rated voltage is reached (using the voltmeter readings). The HV side of the transformer is kept open. Now, the three readings, voltage, current, and power, are recorded.

The recorded current is the no-load current I_e. It has a small value when compared to the transformer's rated current, and, thus, we can neglect the voltage drop due to this electric current. The recorded voltage V is now equal to the transformer's secondary induced voltage.

The wattmeter indicates the input power, which corresponds to the core and copper losses in the transformer, since no output power will appear (open circuit). Copper losses could be neglected since the no-load current is very small compared to the full-load current, and, thus, the core losses in the transformer are considered equal to the wattmeter reading, P_o:

$$P_o = \frac{V_1^2}{R_m} \tag{20}$$

where R_m is the transformer's shunt branch resistance.

If Z_m is the shunt branch impedance of the transformer, then

$$Z_m = \frac{V_1}{I_e} \tag{21}$$

Therefore, if shunt branch reactance of transformer is X_m, then

$$\left(1/X_m\right)^2 = \left(1/Z_m\right)^2 - \left(1/R_m\right)^2 \tag{22}$$

The test is applied on the LV side of the transformer, so the calculated values are referred to the LV side. We could calculate the referred HV side values by multiplying these values with the squared turn's ratio of the transformer. The open-circuit test on transformer is used to determine the parameters of the shunt branch of the equivalent circuit of transformer:

$$PF = \cos\theta = \frac{P_{OC}}{V_{OC}I_{OC}} \Rightarrow \theta = \cos^{-1}\frac{P_{OC}}{V_{OC}I_{OC}} \tag{23}$$

The excitation admittance is therefore

$$Y_E = \frac{I_{OC}}{V_{OC}} \angle -\theta_{OC} \tag{24}$$

The equivalent series impedance is therefore

$$Z_{SE} = \frac{V_{SC}}{I_{SC}} \angle \theta_{SC} \tag{25}$$

The voltage regulation is

$$VR = \frac{V_P/a - V_{s,fl}}{V_{s,fl}} \times 100\% \tag{26}$$

And the efficiency is

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \tag{27}$$

3.4. Three-phase transformer

A three-phase transformer is made of three transformers that are either separated or combined in one core. The primary side and secondary side of any given three-phase transformer can be connected independently in either delta (Δ) or wye (Y) [2].

3.5. Implementation on GUI MATLAB

The user will enter certain values into the GUI interface, and then the result will be displayed with respect to this flow chart (**Figure 6**).

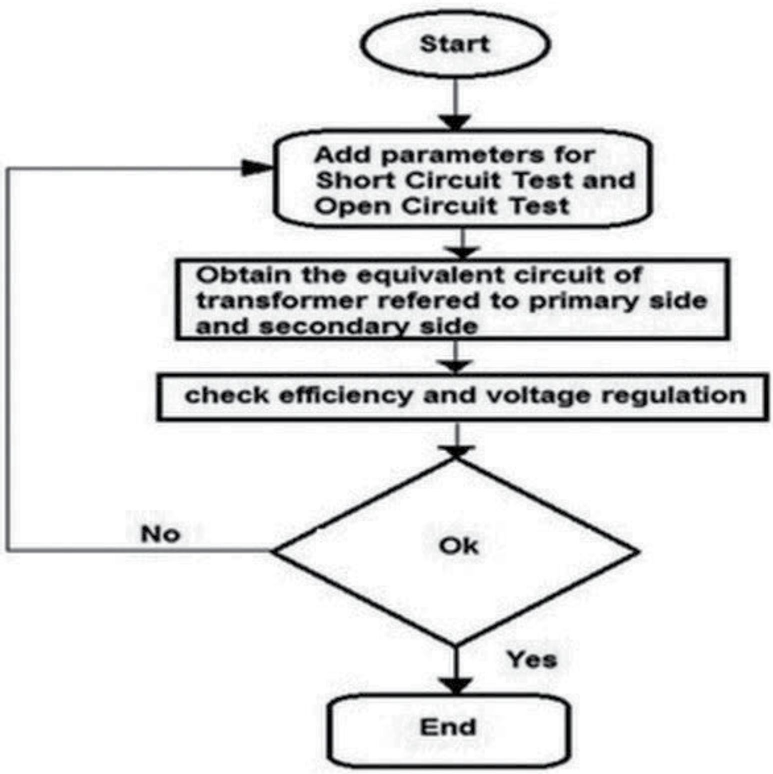

Figure 6. Flow chart for GUI.

The graphical user interface for single-phase transformer is shown in **Figure 7**.

The user will add the inputs which are values of short-circuit test and open-circuit test. And then, choose between leading and lagging load. The results of the equivalent circuits referred to primary and secondary side are displayed after adding the parameter and clicking on to calculate the equivalent circuit, and the equivalent circuit of the transformer referred to the primary side and secondary side are displayed with their parameter.

The user may also choose the type of core of the transformer whether circular or rectangular in shape (**Figure 8**).

Push buttons were used to load and save data as well as to display the performance of the transformer (**Figure 9**).

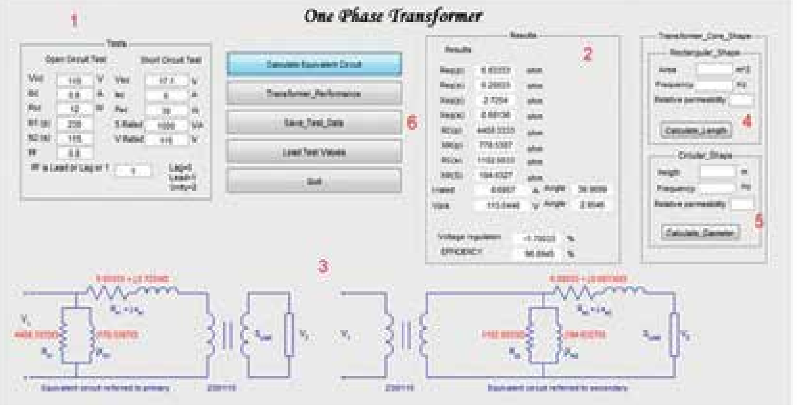

Figure 7. Graphical user interface for single-phase transformer.

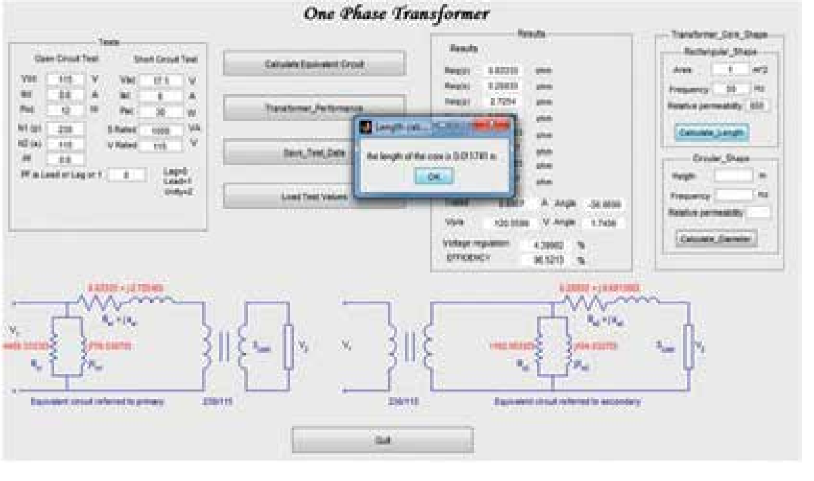

Figure 8. Transformer core shape calculated.

The graphical user interface for three-phase transformer is shown in **Figure 10**.

Here, the user has to choose the type of connection. An example of calculation is shown in **Figure 11**.

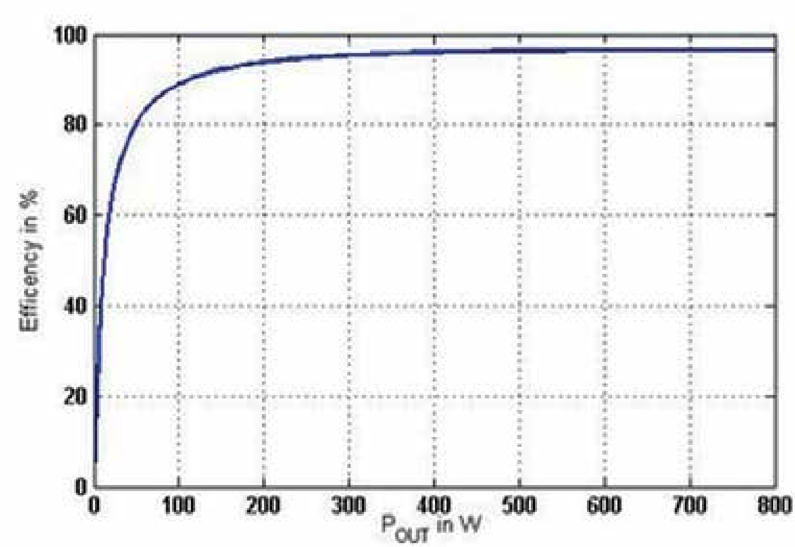

Figure 9. Single-phase transformer performance.

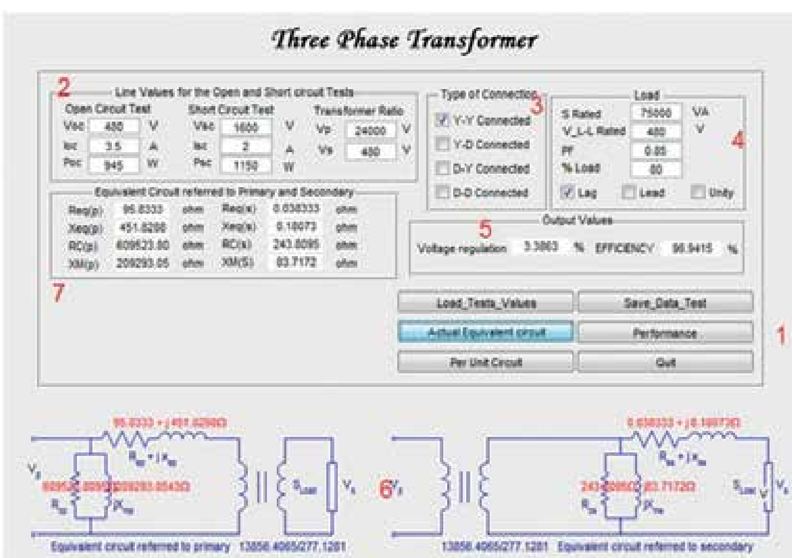

Figure 10. Graphical user interface for three-phase transformer.

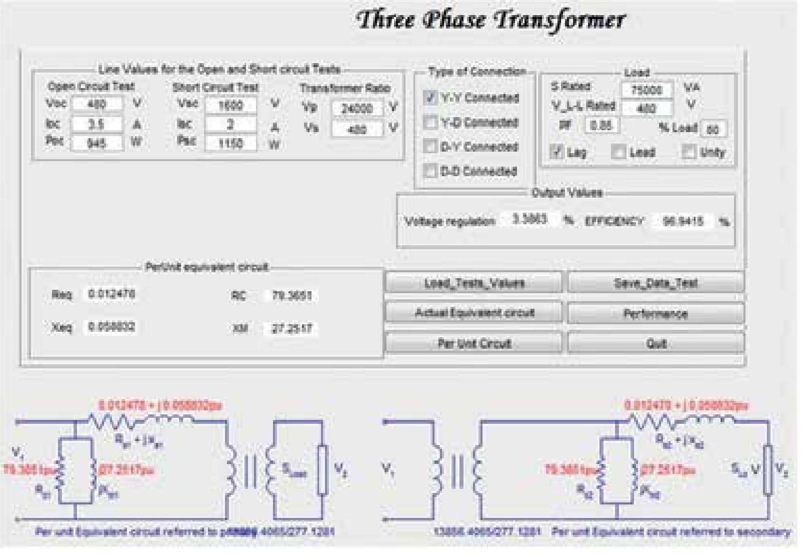

Figure 11. Per unit equivalent circuit of three-phase transformer.

4. DC machines

4.1. Introduction

This chapter discusses the types of DC machines with implementation of graphical user interface and plotting the torque speed characteristics and terminal characteristic for each DC machine [5].

In DC machines, the armature or loops of the rotor can be connected in many ways to the segments of the commutators. The rotor output voltage and the number of parallel current paths are affected by these several ways of connection [2, 5].

In any given machine, the voltage induced in E_A depends on three factors:

- **i.** The flux ϕ in the machine
- **ii.** The speed ω_m of the rotor of the machine
- **iii.** A constant K that depends on the construction of the machine

The voltage of the real machine armature is given by

$$E_A = \frac{ZP}{2\pi a}\phi\omega_m = \frac{ZP}{2\pi a}\phi\frac{2\pi}{60}n_m \tag{28}$$

In any DC machine, the torque depends on three factors:

- **i.** The flux ϕ in the machine
- **ii.** The armature current I_A of the machine
- **iii.** A constant K that depends on the construction of the machine

The torque on the armature of a real machine is

$$T_{ind} = \frac{ZP}{2\pi a}\phi I_A \tag{29}$$

4.2. DC motors and DC generators

DC machines can be used as DC motors or DC generators. The difference between the motor and generator is the power flow direction. The equivalent circuit of DC motors and DC generators is similar to each other, but the direction of the current flow of the DC motors is opposite to the direction in DC generators [2].

In a DC machine, the induced voltage is directly proportional to the flux and the speed of rotation of the machine. The magnetomotive field force is produced by field current, which in turn produces flux along with its magnetization curve.

As long as the field current is proportional to the magnetomotive field force and the induced voltage is proportional to the produced flux, it is usual to present the magnetization curve as a plot of E_A-induced voltage with respect to the current of the field for a constant speed ω_0.

4.2.1. Types of DC motors

a. **Separately excited DC motor**: is a DC motor where the field circuit is supplied by a separate voltage supply.

b. **Shunt DC motor:** is a DC motor whose field circuit gets its power directly across the armature terminals of the motor.

c. **Series DC motor:** is a DC motor where the field windings consist of few turns that are connected in series with the armature circuit.

d. **Compounded DC motor:** is a motor that consists of both a shunt and a series field. It consists of two types: cumulative and differential compounded DC motor.

   In cumulative compounded motor, the current flows into the dots of both field coils. The resulting magnetomotive forces add to produce a larger total magnetomotive force.

   In differential compounded motor, the current flows into the dot on one of the field coils and out of the dot of the other field coil, the resulting magnetomotive forces subtract.

4.2.2. Types of DC generators

a. **Separately excited generator:** a separate power source, independent of the generator, supplies the field flux to the DC generator.

b. **Shunt generator:** the field circuit is connected directly to the generator terminals in order to produce the field flux to the DC generator.

c. **Series generator**: the field circuit is connected in series with the generator armature to produce the field flux to the DC generator.

d. **Cumulatively compounded generator:** is a DC generator in which both the shunt and the series fields are available, and their effects are added.

e. **Differentially compounded generator:** is a DC generator in which both the shunt and the series fields are available, but their effects are subtracted.

4.3. Implementation on GUI MATLAB

A graphical user interface is implemented for DC machine with types of generators and motors. The first GUI will obtain the armature resistance for any DC machine (**Figure 12**).

The user will determine the type of winding and enter the inputs which are pole number. Coil numbers and turn numbers with the plex and resistance per turn then calculate results. The armature resistance (RA) is expressed by

$$\mathrm{RA} = \frac{\mathrm{Turns} \times \dfrac{\mathrm{coils}}{\mathrm{current\,path}} \times (\mathrm{resistance\,per\,turn})}{\mathrm{current\,path}} \tag{30}$$

The results will be displayed with armature resistance included. This value will be installed in the other part of the graphical user interface for DC generators and DC motors.

The graphical user interface for the types of DC generators and DC motors is shown in **Figure 13**.

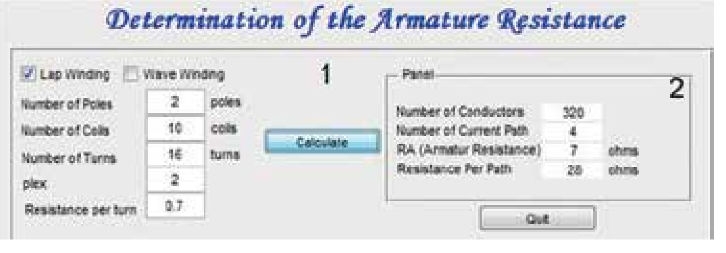

Figure 12. GUI to determine the armature resistance of DC machines.

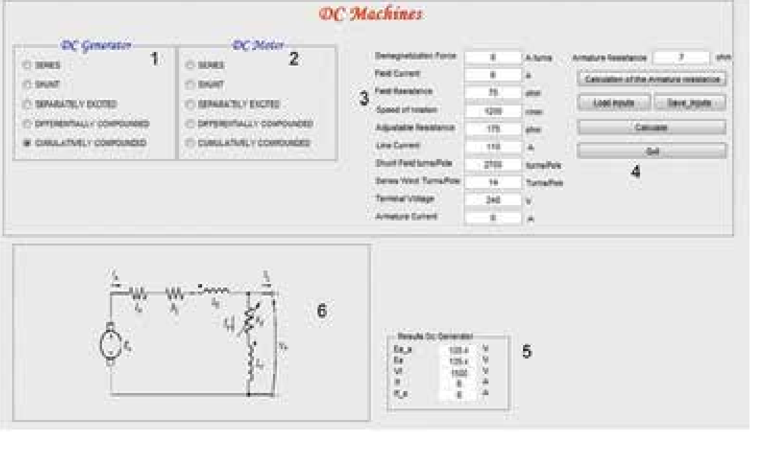

Figure 13. Graphical user interface for the types of DC motors and DC generators.

The user will choose the type of DC generator/motor and enter the corresponding parameters. Push buttons are available to load and save the data, calculate the armature resistance, and quit the program. Results will be displayed with the terminal characteristic and torque speed characteristics (**Figures 14** and **15**).

The equivalent circuit of the type of motor or generator will be displayed after calculating the result.

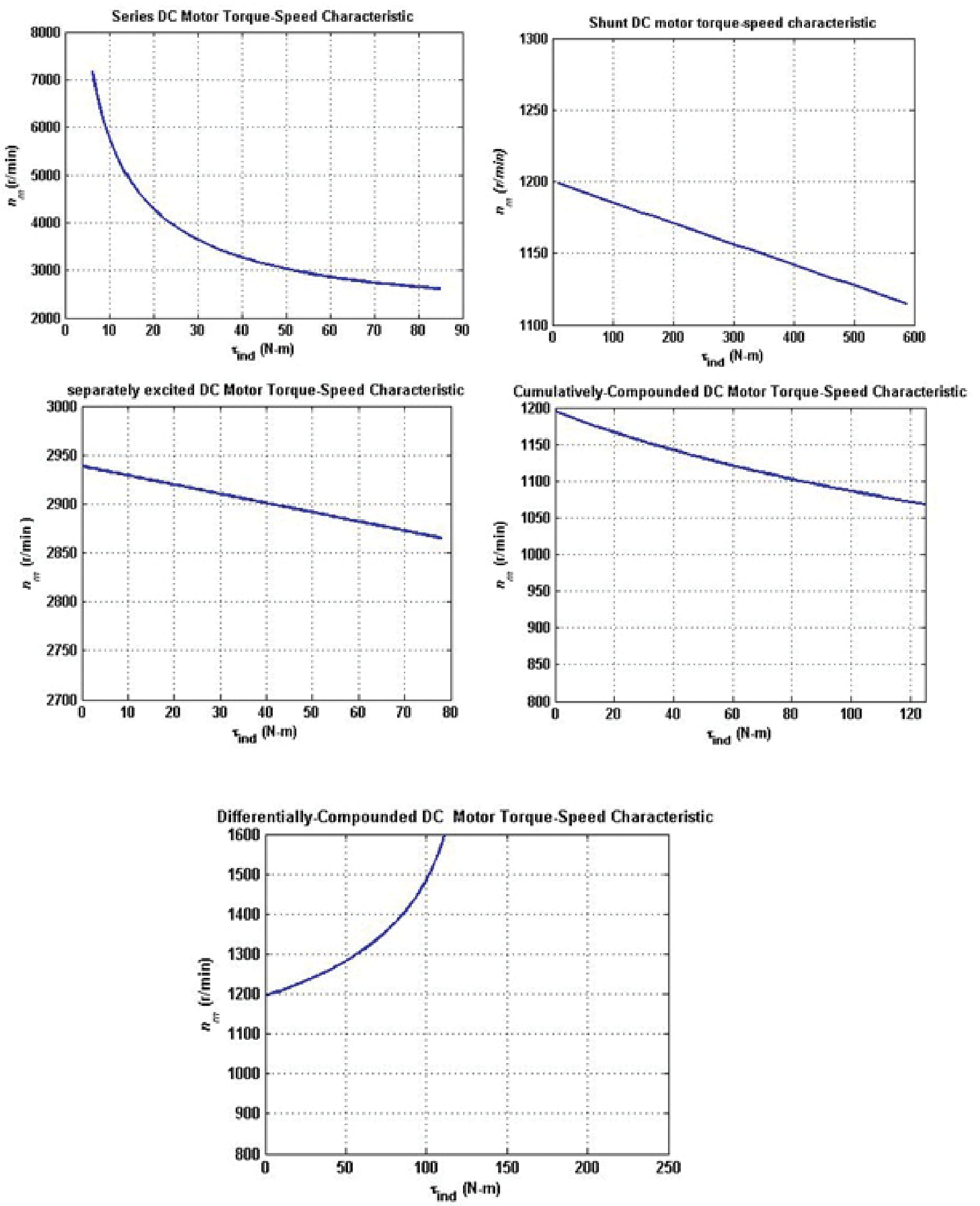

Figure 14. DC motor terminal characteristics.

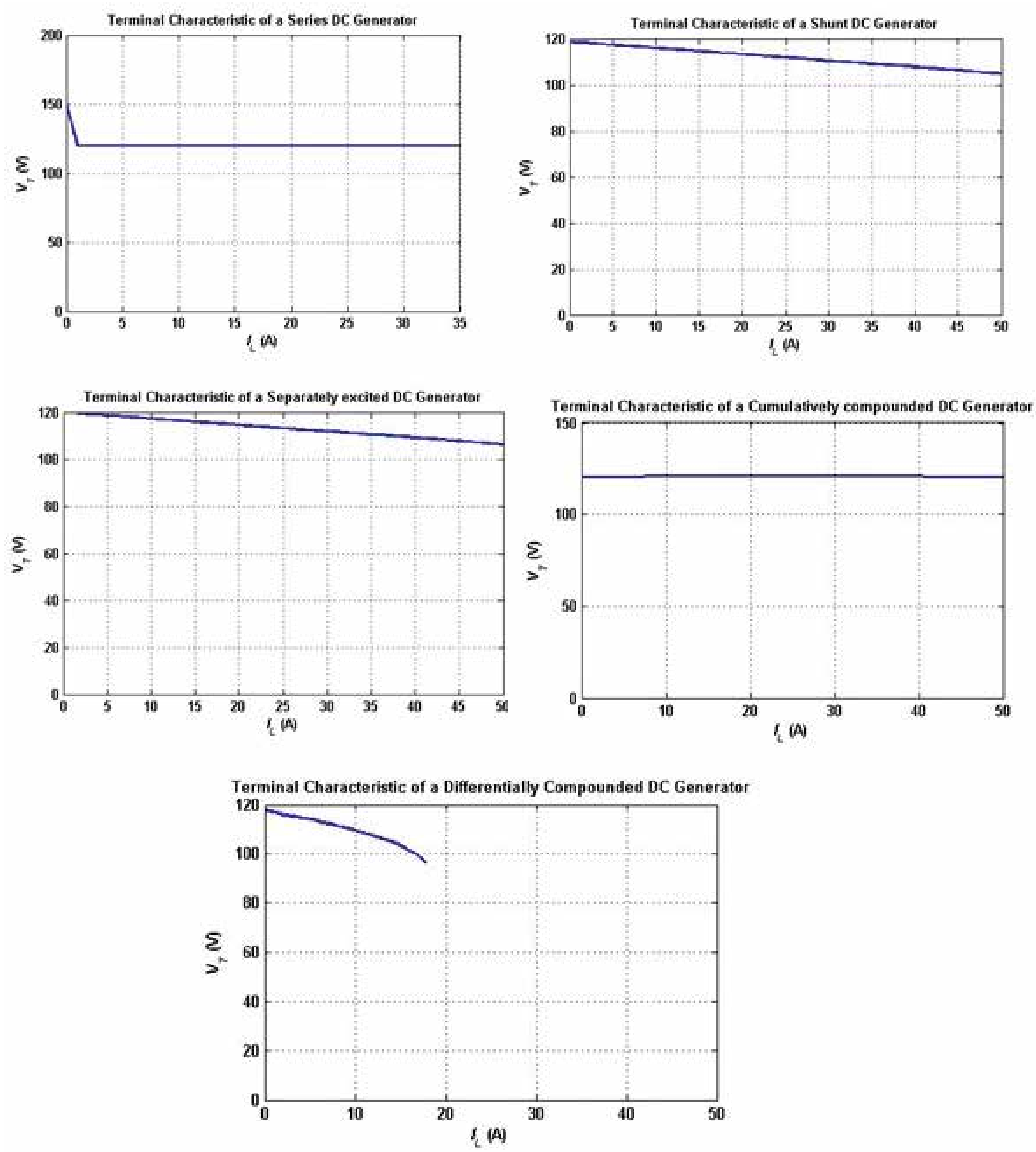

Figure 15. DC generator terminal characteristics.

5. Induction machines

5.1. Induction motors and induction generators

An induction machine is a machine with only a continuous set of amortisseur windings. They are induction machine because the voltage of the rotor is induced in the rotor winding instead of being physically connected with wires. To run the machine, it does not require a DC field current. Induction machines can be used as either generators or motors. Induction machines are not used as generators except in some special applications due to their disadvantages. Therefore, induction machines are most of the time referred to as induction motors [2].

After applying a three-phase voltage to the stator, current flows into the stator which produces magnetic field that rotates in a counterclockwise direction. The rotation speed of the magnetic field is expressed by

$$n_{sys} = \frac{120f_{se}}{P} \tag{31}$$

The relative motion of magnetic field and rotor is defined with two terms, which are

a. **Slip speed:** It is the synchronous speed minus rotor speed.

b. **Slip:** It is the relative speed expressed as ratio of slip speed to synchronous speed in a percentage basis.

$$n_{slip} = n_{sync} - n_m \tag{32}$$

$$s = \frac{n_{slip}}{n_{sync}} \times 100\% \Rightarrow s = \frac{n_{sync} - n_m}{n_{sync}} \times 100\% \tag{33}$$

Note that the rotor turns at $s = 0$, whereas at $s = 1$, the rotor is stationary.

5.2. The equivalent circuit of an induction motor

The equivalent circuit of an induction motor is similar to that of the transformer, with a difference between the magnetization curve of the transformer and induction machine (**Figures 16** and **17**).

5.3. Implementation on GUI MATLAB

A graphical user interface is implemented on MATLAB for induction machines (**Figure 18**).

The user has to enter details related to the induction machine:

1. In this part the user can calculate and display the result of induction machine torque characteristics (**Figure 19**).
2. Single- and double-cage rotor characteristic (**Figure 20**).

As we noticed, the double-cage design, when compared to the single-cage rotor, has a high starting torque with smaller maximum torque and a slightly higher slip in the normal operating range.

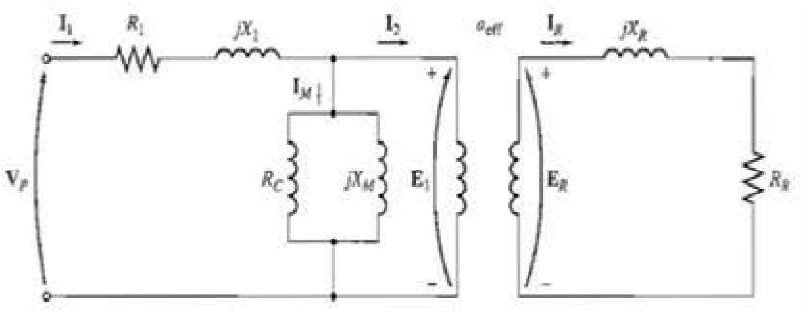

Figure 16. The transformer model of an induction motor, with rotor and stator connected by an ideal transformer of turn ratio a_{eff}.

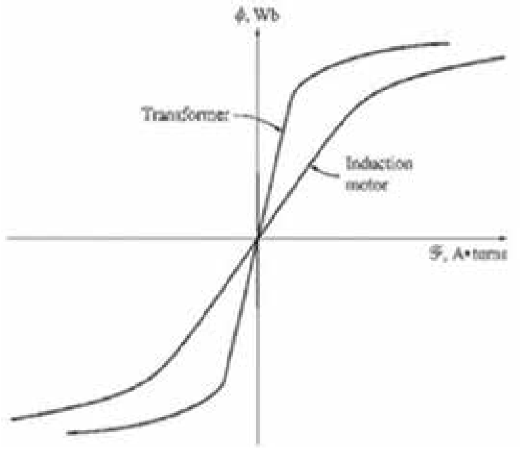

Figure 17. The magnetization curve of an induction motor compared to that of a transformer.

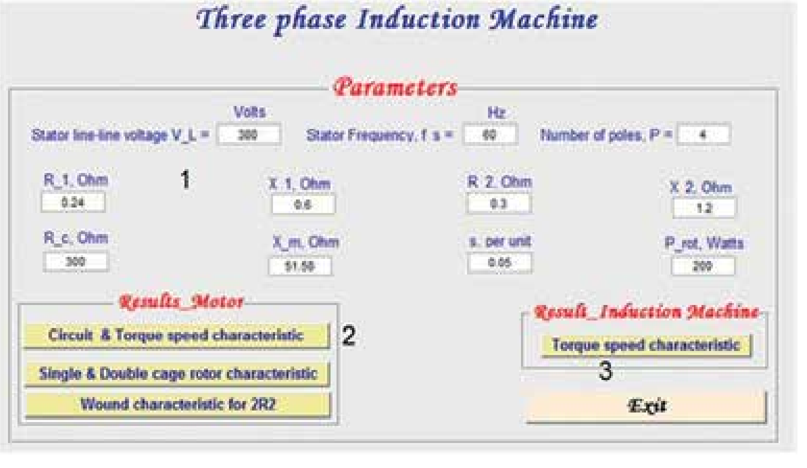

Figure 18. Graphical user interface for three-phase induction machine.

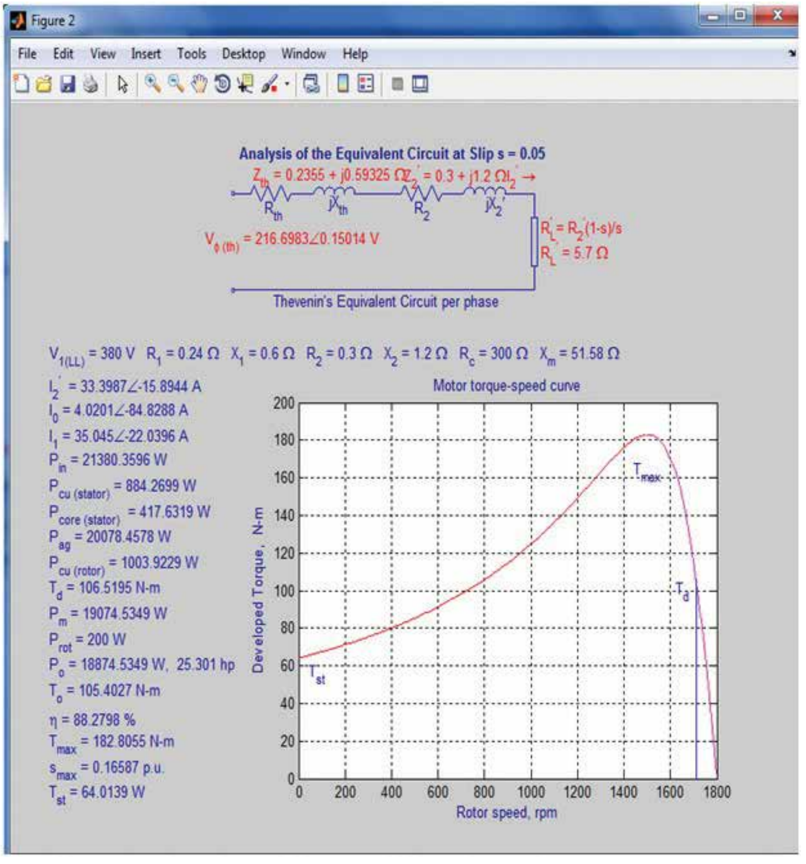

Figure 19. Equivalent circuit and torque speed characteristic.

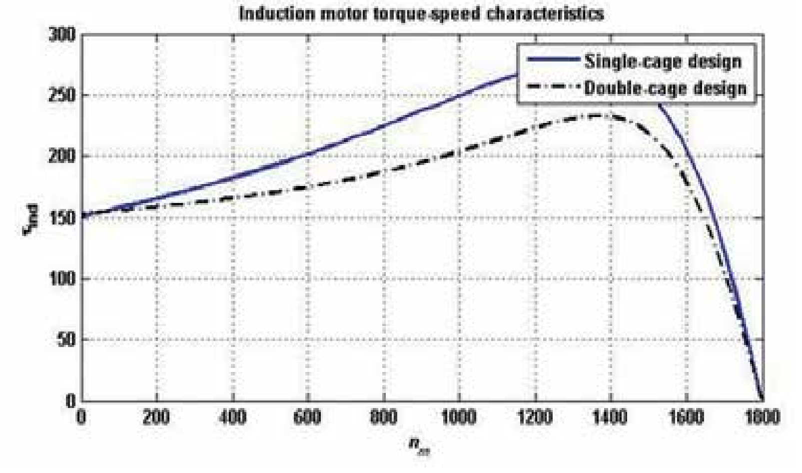

Figure 20. Single- and double-cage rotor characteristic.

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6. Conclusion

Ferromagnetic materials were discussed and implemented with respect to its magnetic model in graphical user interface using MATLAB.

Single-phase and three-phase transformers were discussed with implementation of transformer model in GUI on MATLAB. We also checked the parameter referred to secondary and primary side with the effect of load of the transformer.

DC machines were discussed with implementation of different types of DC motors, obtaining the plots of torque speed characteristic. Different types of DC generators were also implemented on GUI, and the terminal characteristics were also obtained.

Induction machines were examined through implementation of the parameters of induction motor in the GUI on MATLAB, obtaining the torque speed characteristics and the terminal characteristics.

Implementing an educational model on GUI MATLAB for the ferromagnetic core, single- and three-phase transformer, DC machines, and induction machines allows the students to study and analyze the effect of each parameter in order to understand its electric behavior with respect to its electric model.

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References

[1] Afsar MN, Birch JR, Clarke RN, Chantry GW. The measurement of the properties. Proceedings of the IEEE. 1986;**74**:183-199

[2] Chapman SJ. Electric Machinery Fundamentals. 4th ed. New York: McGraw-Hill; 1991

[3] Coltman JW. The transformer [historical overview]. Industry Applications Magazine. 2002;**8**(1):8-15

[4] Winders J. Power Transformers: Principles and Applications. New York: CRC Press; 2002 ISBN 9780824707668

[5] Fitzgerald AE, Kingsley C Jr., Umans SD. Electric Machinery. 6th ed. New York: McGraw-Hill; 2003

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