Chapter 1

Introductory Chapter: Science Education - Research and New Technologies

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.70258

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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Chapter 2

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

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.68437

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.

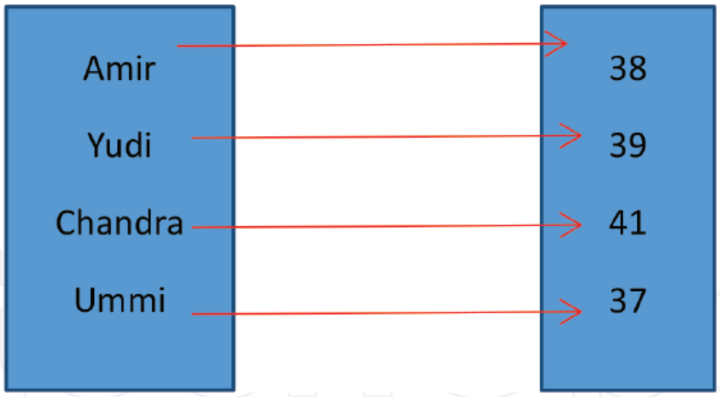


Figure 2. Example of relation between name and shoes number.

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,

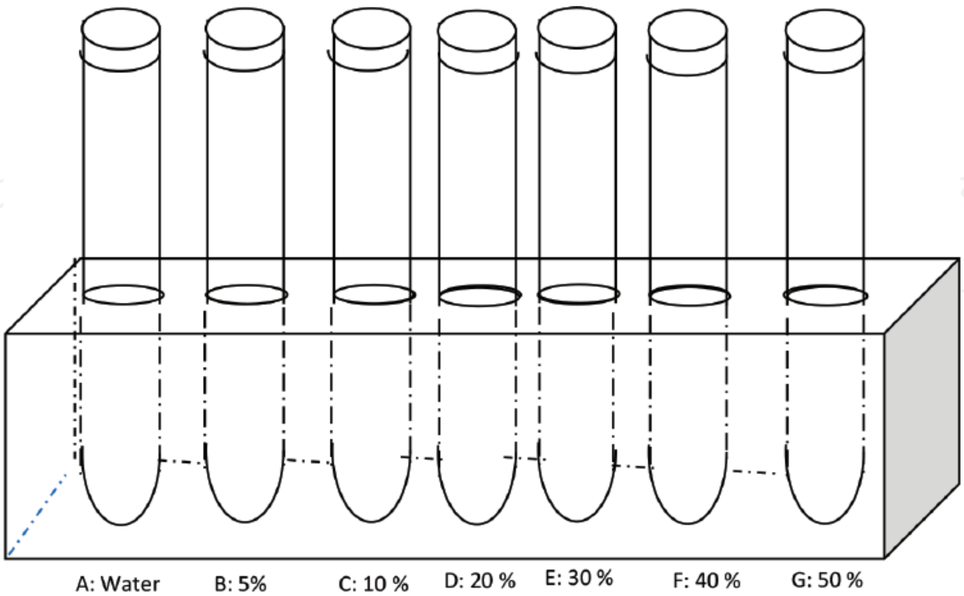


Figure 3. Solutions of sugar cane in percents.

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.

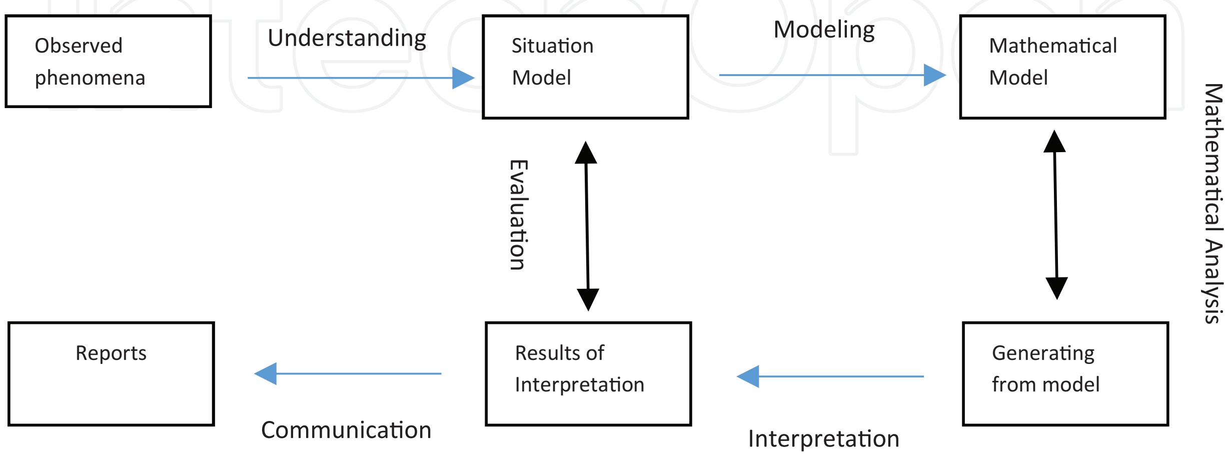


Figure 4. Diagram of mathematical modeling process.

http://dx.doi.org/10.5772/intechopen.68437

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

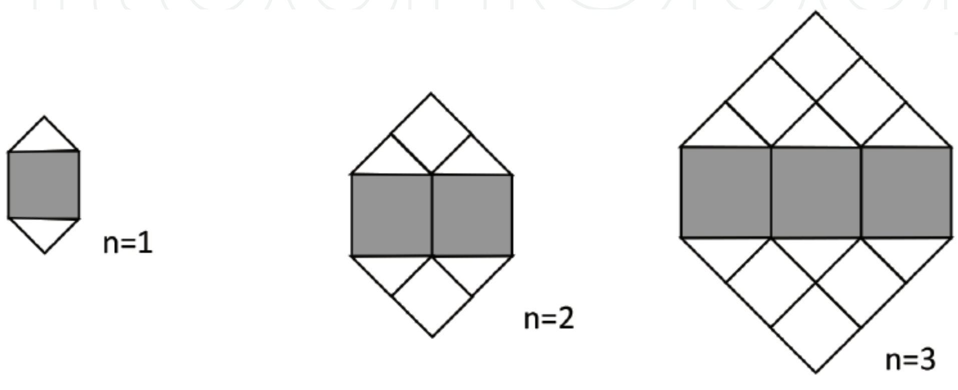


Figure 5. Patterns of floor in JICA-FPMIPA building.

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:

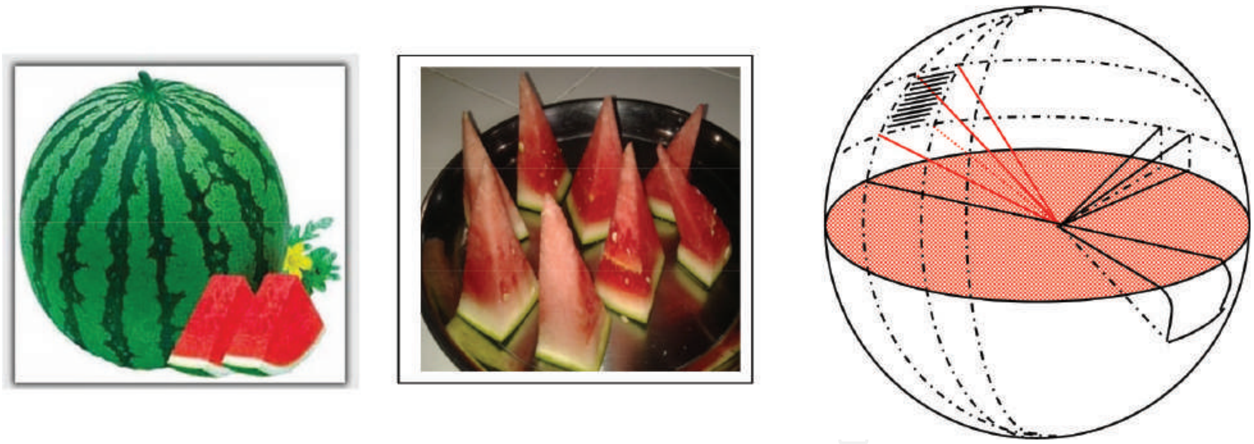


Figure 8. Watermelon ball to show the formula of sphere volume.

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

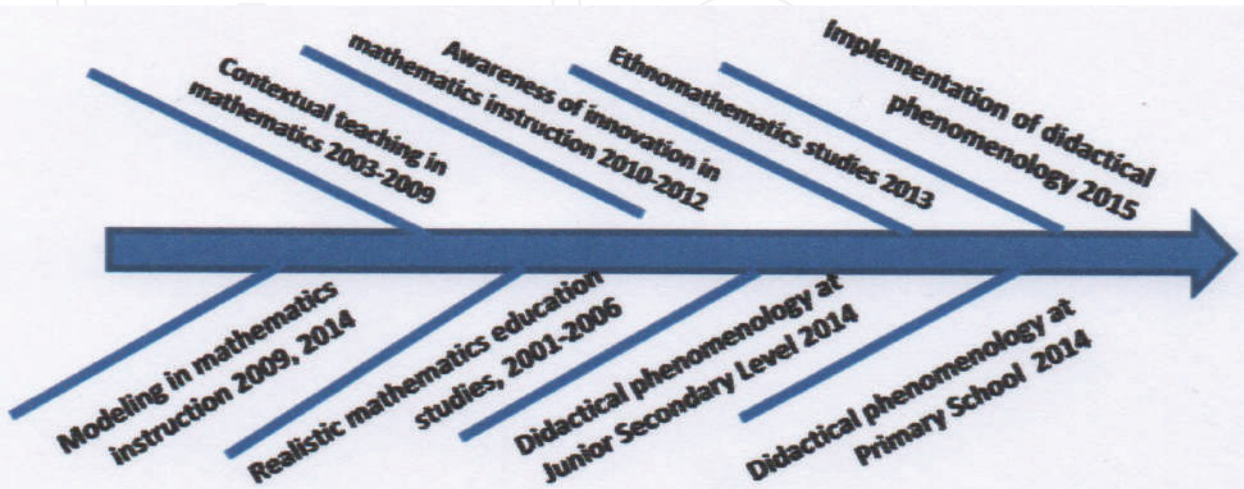


Figure 9. Fish backbone of research roadmap.

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

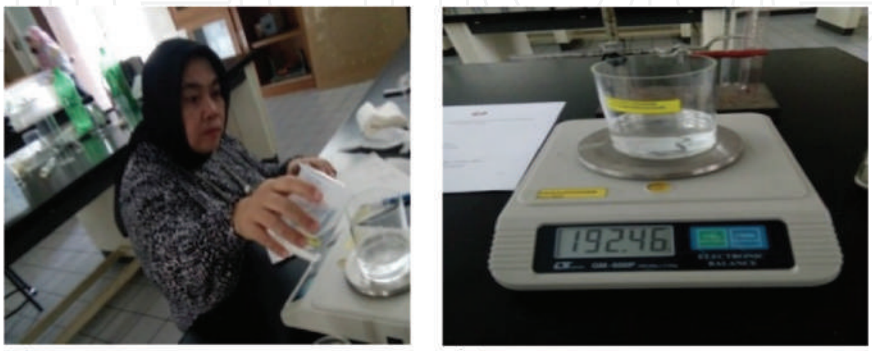
Teaching materials designed in the planning of learning include sugar solution, water fountain with various sized holes, burning fireworks, and opening faucets (various sizes of angle) to record the time of flowing for a certain volume of water. However, because of limited space for reporting in this 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.

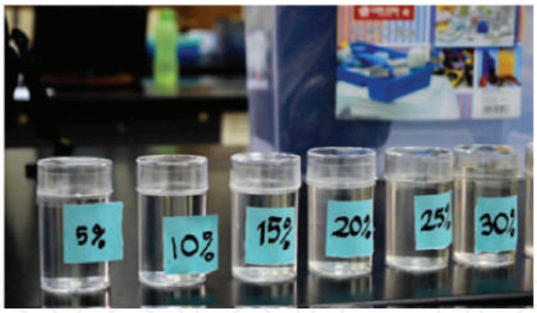


Figure 11. Sugar solutions with various concentrations.

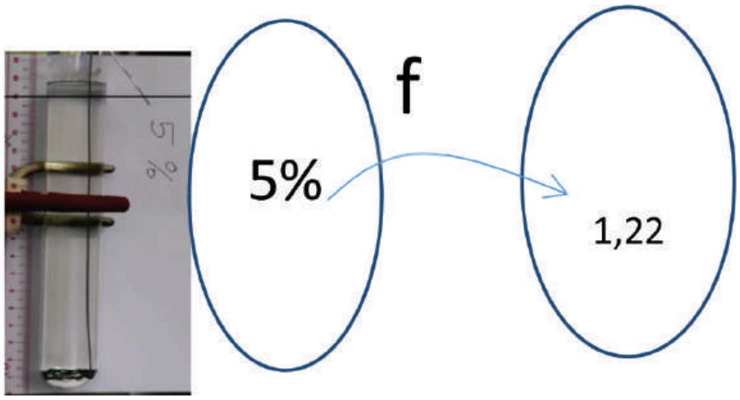


Figure 12. Five percent sugar solution with "time sneaking".

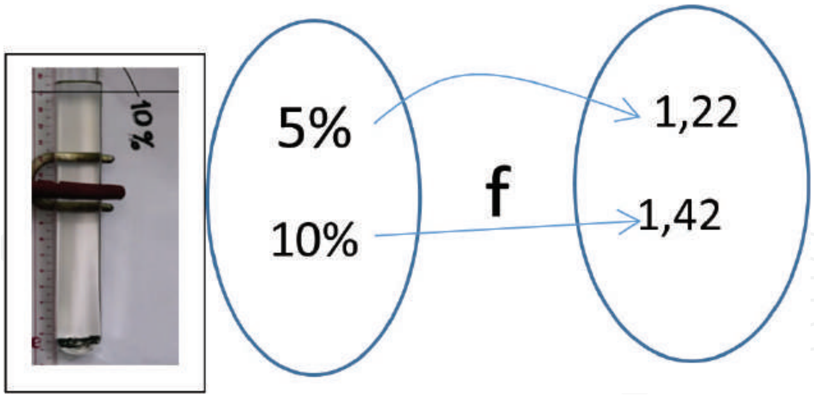


Figure 13. Five percent and 10% sugar solutions with "time sneaking".

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

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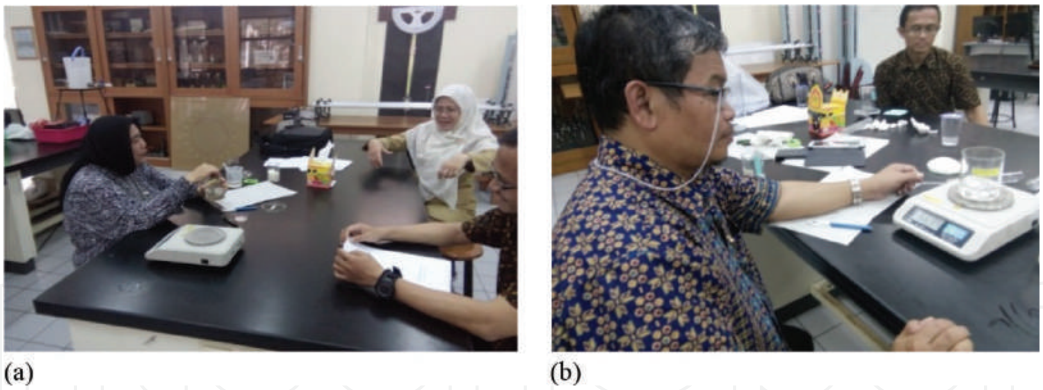

Figure 14. (a) Discussion in Sci Lab, (b) working in Sci Lab.

"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

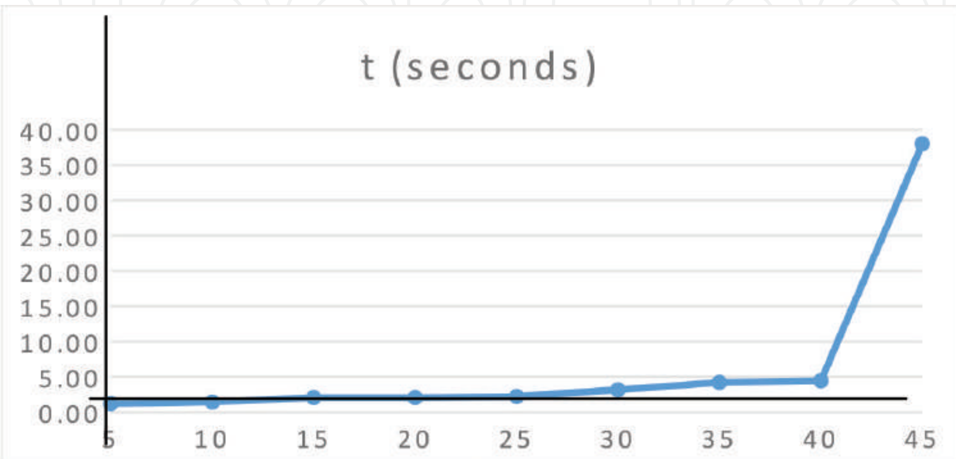

Figure 15. Graph prediction of the sugar solutions.

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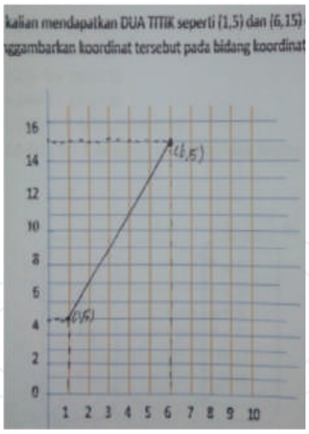


Figure 16. Incorrect graph {(1,5), (6,15)} graph.

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.

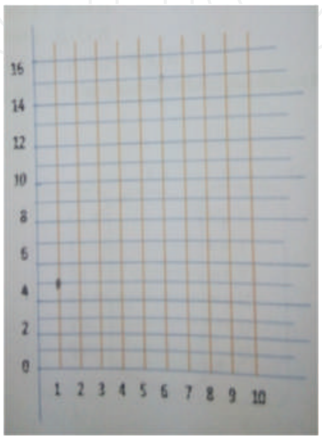


Figure 17. {(1,5), (6,15)} correct graph.

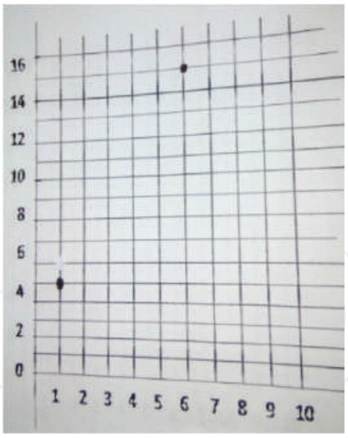


Figure 18. {(1,5), (6, 15)} correct graph.

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	~

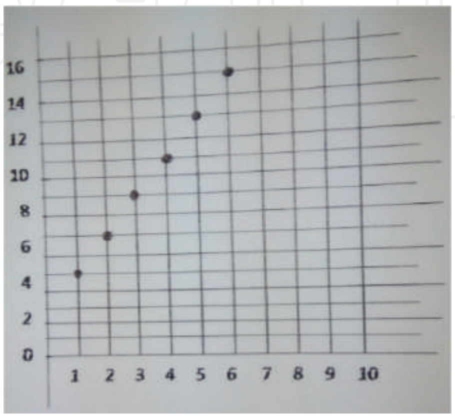


Figure 19. {(1,5),(2,7), (3,9) (4,11), (5,13), (6,15)}.

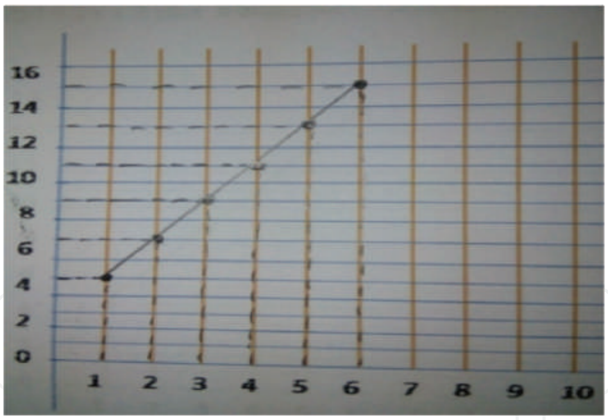


Figure 20. $\{(x,y)\ y = 2x + 3,\ x$ dan y real dengan $1 \leq x \leq 6\}$.

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).

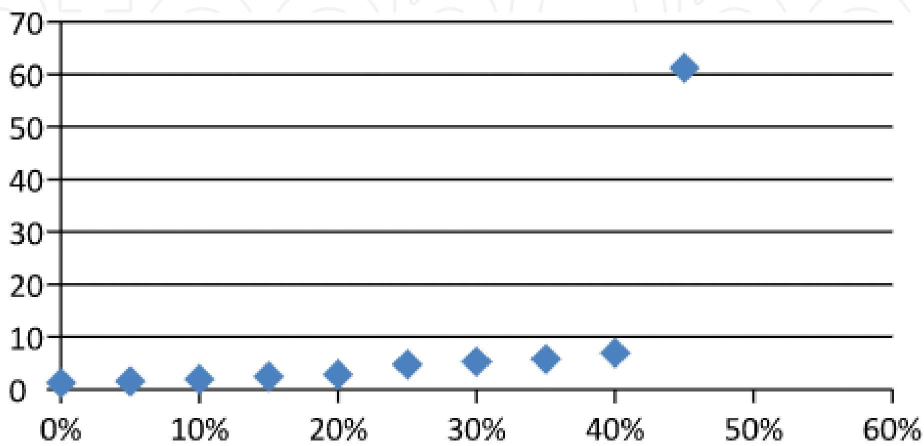


Figure 21. Plotting graph of sugar solution to sedimentation time.

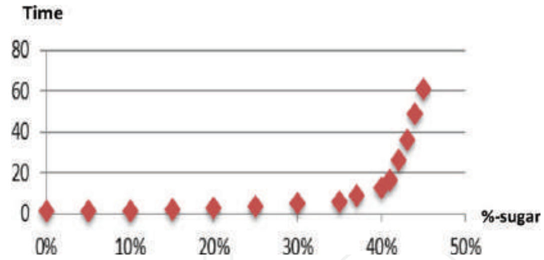


Figure 22. Plotting the percentage of sugar solution versus sedimentation time of plasticine ball.

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:

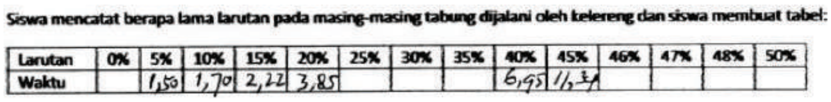
Students above (**Figure 27**) understood the relationship, as they wrote "A Member of A is only be paired with one quantity," even though, in fact, the relationship is "a very simple relationship among two sets," as far as the two sets are associated. In a particular association, this relationship was 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.

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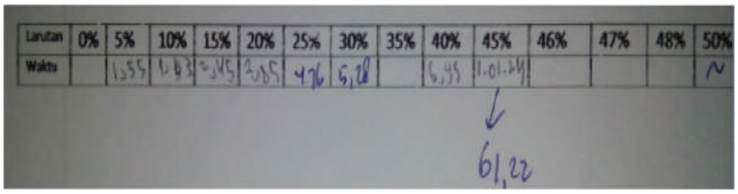
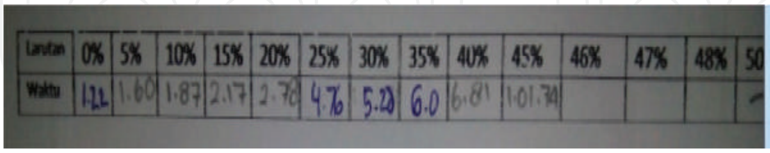


Larutan	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	46%	47%	48%	50%
Waktu		1,55	1,63	2,45	3,85	4,76	5,28		6,45	1.01.24				~

61,22

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



Larutan	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	46%	47%	48%	50
Waktu	1.22	1.60	1.87	2.17	2.78	4.76	5.23	6.0	6.81	1.01.74				–

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:

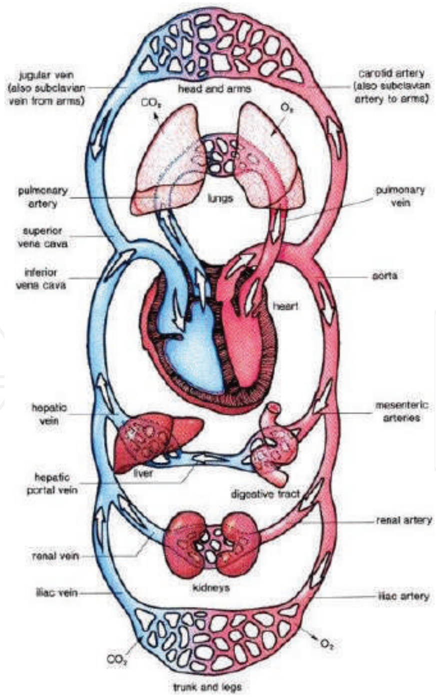


Figure 26. The circulatory system [53].

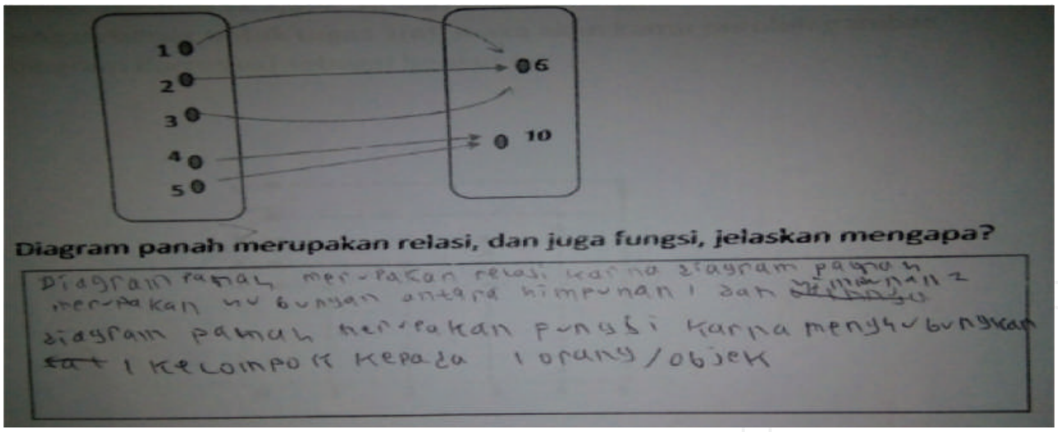


Figure 27. Students' work of function definition.

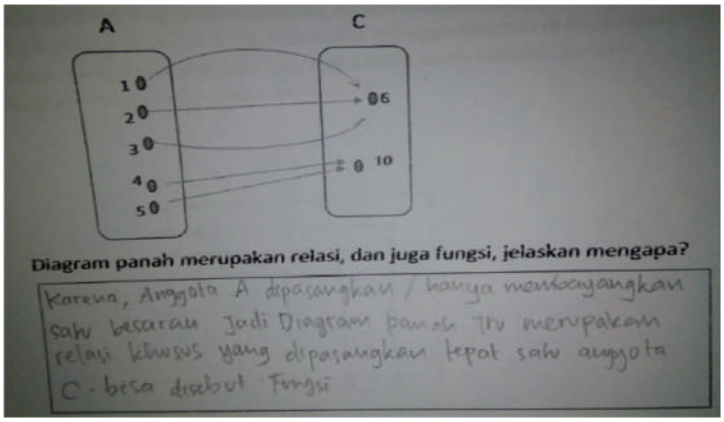


Figure 28. Students' work.

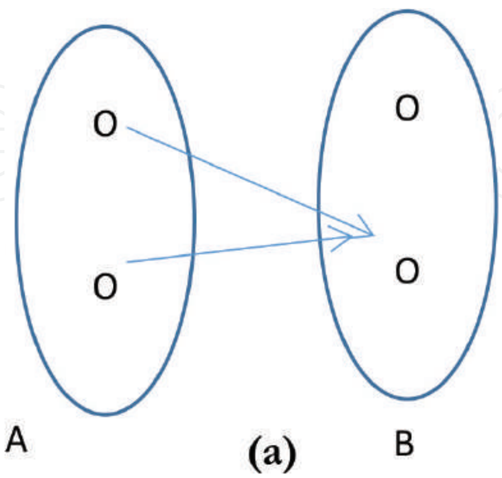


Figure 29. Relation as function.

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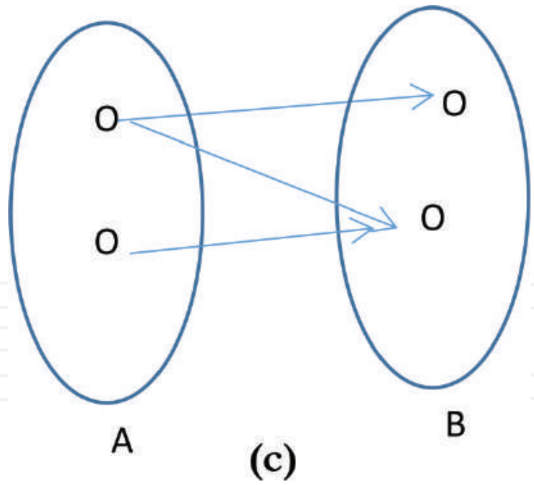

Figure 30. Relation not as function.

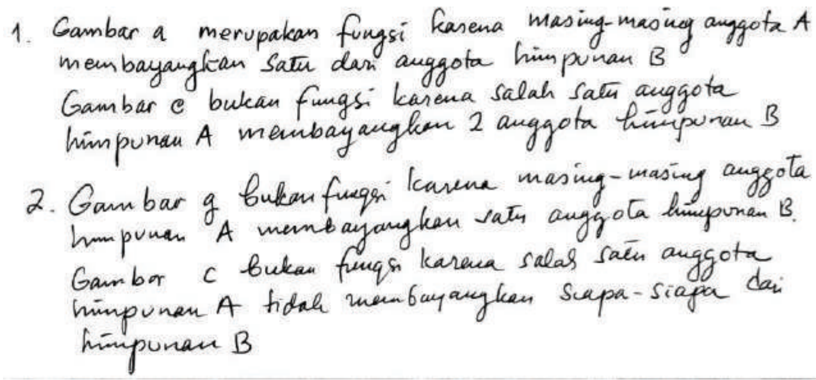

Figure 31. Reason for a function and not a function.

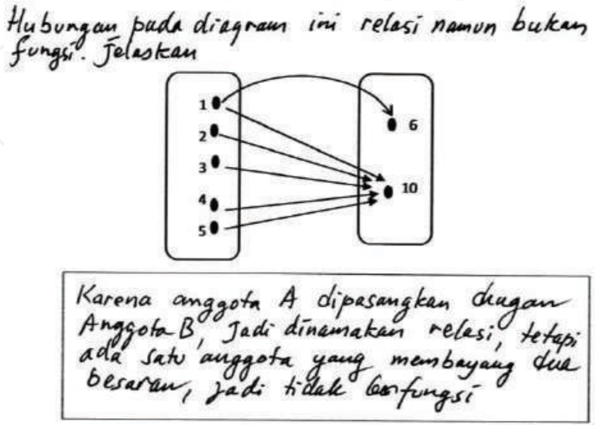

Figure 32. Students' work and reason why this relation is not function.

“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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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

http://dx.doi.org/10.5772/intechopen.68218

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.

http://dx.doi.org/10.5772/intechopen.68218

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?

http://dx.doi.org/10.5772/intechopen.68218

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Chapter 4

Teaching and Learning Primary Science for Marginalised Children

Kamisah Osman and Cindy Wong Chyee Chen

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.68577

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

http://dx.doi.org/10.5772/intechopen.68577

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

http://dx.doi.org/10.5772/intechopen.68577

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.

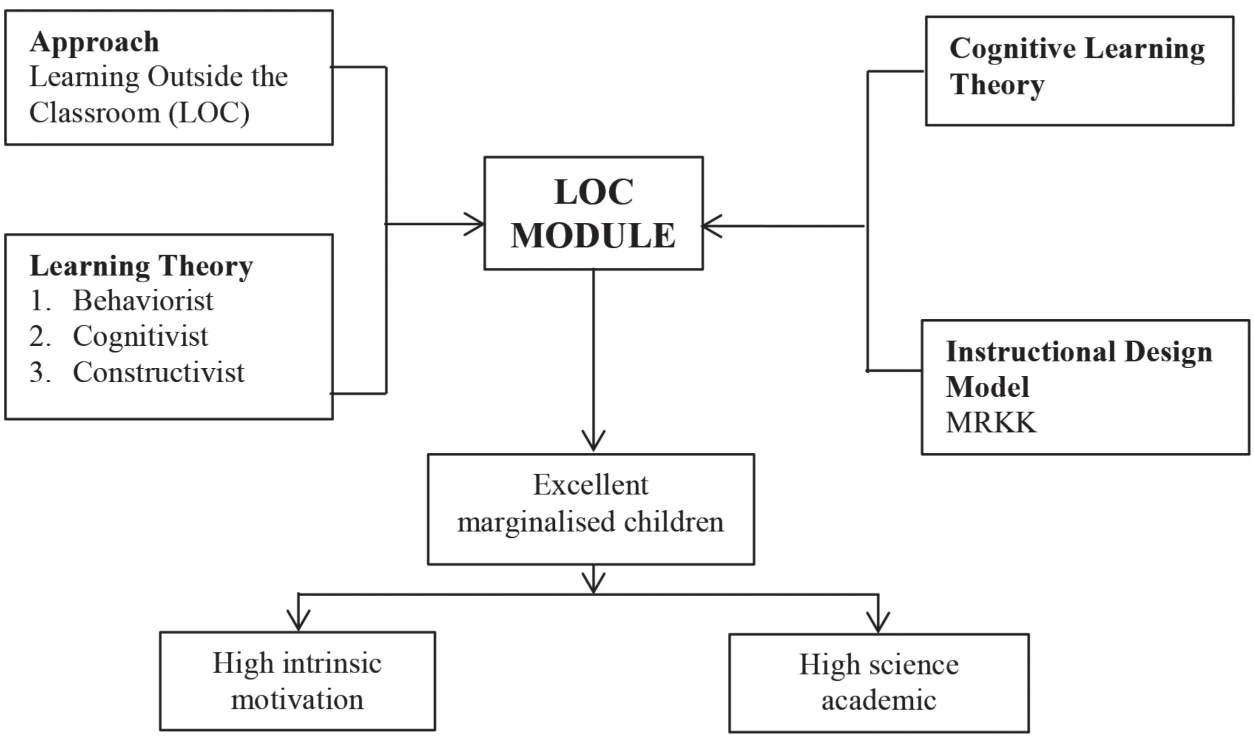

Figure 2. Conceptual framework.

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.

http://dx.doi.org/10.5772/intechopen.68577

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

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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.

http://dx.doi.org/10.5772/intechopen.68577

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

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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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Chapter 5

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

Leandro Duso

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.68182

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

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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;

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(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.

http://dx.doi.org/10.5772/intechopen.68182

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,

http://dx.doi.org/10.5772/intechopen.68182

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

http://dx.doi.org/10.5772/intechopen.68182

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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