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CONTENTS

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Resources Used by Lebanese Secondary Physics Teachers' for Teaching Electricity: Types, Objectives and Factors Affecting their Selection

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Abstract

The purpose of this research was to study the system of resources, the objectives of their use and the factors that affect the selection and integration of the different resources by Lebanese secondary physics teachers in their teaching in general and for teaching Electricity in particular. For this aim, a qualitative approach was used and the research was designed as a collective case study where four teachers were purposefully selected. Interviews and classroom observations were the main data collection tools. Results showed that teachers used different types of resources: Paper resources, audio-visual resources, object resources, and evoked resources to elaborate their teaching activities. They paid a particular attention to the experimental activity using object and audio-visual resources to enhance students' comprehension of Physics concepts. Moreover, teachers referred to the virtual laboratory to be more efficient than the real lab at the level of precision, clarity and management, in addition to its importance for illustration at the microscopic scale. Results also revealed that the school setting, time constraints and teachers' professional knowledge are the main factors that affect the selection and the integration of resources.

Introduction

Teaching is a complex activity where teachers are obliged to present specific content with a specific approach in order to facilitate the learning process and enhance students' understanding. (Shulman, 1987) Learning and teaching processes are affected by many factors some of which are related to the teacher qualifications and personality, while others are related to the content taught and students' capacities. Teaching science encounters more obstacles than other teachers since most of the scientific concepts are abstract and difficult for students to learn. Moreover, secondary physics teachers may face other difficulties such as the lack of school equipment and materials, as well as, the lack of initial and continuous teachers' training courses in general and those concerning new technologies in particular (i.e., Interactive White Board , educational software, etc.). Lack of material can have a direct influence on teaching of science since the experimental activities usually require a well-equipped laboratory especially when teaching quantitative physics. Even computer rooms become a necessity to install software and to project instructional videos in order to integrate the Information and Communication Technologies (ICTs) in education. All of these constraints form gaps for teachers' professional work in preparing and teaching scientific content. To fill these gaps, teachers are left with the obligation to search for teaching resources that enable them to produce new documents of teaching for later use in their classrooms. These resources should be well selected, adapted and transformed to be integrated within the content taught in class (Gueudet and Trouche, 2008).

In the last decades, the progression of technology and the proliferation of the usage of internet led to the creation of a wide range of online resources in the domain of education. In addition to the traditional resources (curriculum material and books), these resources come to stand as additional support for teachers in their profession. Those resources include digital textbooks, websites, software, online exercises, online courses, audios, videos, photos and simulations. The resources can help teachers prepare and present the content to be taught, thus leading to a change in their professional work (Sabra, 2011). Moreover, the resources can help teachers in approaching difficult concepts to their students (Flick & Bell, 2000). Due to the abundance and the diversity of resources, science teachers should make their selection among a large number of resources varying between traditional, (books, textbooks, scientific magazines, encyclopedia, etc...), digital and online resources (texts, websites, simulations, videos, etc...).

In the twenty first century, technology becomes an essential factor in the progression of many domains in the human jobs. In education, technology and digital resources played an essential role in the field of pedagogy such as teaching and learning process (Spring, 2011). Despite of the presence of many technological tools and many educational digital resources (in the private schools in particular), their use in the classroom remained not well developed (Jacobsen, 2001). The investigation about the reasons behind the lack of effective technology integration forms the purpose of an empirical science education study conducted by Zgheib (2013). Zgheib showed that the availability of technologies and the proliferation of its use is not sufficient for the development of teachers' use of technology, however, a major shift should occur at the leadership level. To shift teacher's attitudes towards an effective use of educational technology, an organizational support of technology should be integrated through professional development in the whole school culture (Zgheib, 2013).

According to Boujaoude and Abd-El-Khalick (2004) and Boujaoude and El Hage (2009), who analyzed 116 empirical science education studies conducted in Lebanon between the years 1992 and 2008, only three studies conducted in Lebanon were about resources in general and using technology in particular. Shihab (2000) investigated the effect of using web-based hypermedia as an alternative to textbooks on student achievement in a unit about the classification of animals. In 2007 and 2008, two studies were published in the category of technology-aided instruction. The first one is about the mathematization in physics laboratories that incorporated inquiry-enhancing technologies (Jurdak, BouJaoude, & Ghumrawi, 2007) and the second one investigated the views of both students and teachers of the advantages and limitations of using Information and Communication T0echnology (Eid, 2008). Hammoud (2012) studied the professional work of Chemistry teachers on the resources they realize in order to perform their teaching, particularly with respect to Inquiry-Based Science Teaching. Shaaban studied the interaction between resources, particularly digital resources, and Biology teachers' conceptions during their teaching preparation and teaching practices of Genetics determinism. She showed that teachers referred to different types of resources to update their scientific knowledge and to enhance student's understanding of some difficult topics like Genetics (Shaaban, 2014).

The professional activities of teachers and the interaction with colleagues affect teachers' practices and their development (Grangeat & Gray, 2007). Moreover, the implementation of ICT in teaching sciences presents new affordances for science education. In fact, using computer simulations allows teachers and students to explore phenomena that cannot be done experimentally (Webb, 2008). For example, in teaching Physics and with the help of simulation and computers' software, students are able to explore some phenomena that cannot be experienced in the laboratory such as nuclear reactions at microscopic scale or the observation of astronomy at large scale. Thus, technology becomes more relevant for science education.

Therefore, to prepare their teaching activities, teachers should select the convenient resource that they think is important in the teaching process and enhances students' understanding of a specific content. Therefore, the variety of the available resources and the proliferation of technology and digital resources provided physics teachers with a new important category of educational aids. These resources in addition to the traditional ones form a wide range of resources, from which physics teachers selected an adaptable resource to present specific physics content. Since, the unit of Electricity is found in almost all intermediate and secondary classes, this unit is seen as one of the important units in physics. In this study, the researchers aimed to explore teachers' resources, the objectives of their use and the factors affecting the selection and the integration of these resources in teaching preparation and practice in general and in teaching Electricity to grade ten students in particular. For this purpose, the researchers in this study intended to answer the following questions:

1. What are the different resources used by the Lebanese Secondary Physics Teachers in their teaching preparation/ teaching practices in general and in teaching Electricity for grade ten students' in particular?
2. What is the objective of the experimental activity (real and virtual) in teaching Physics in general, and what are the factors that affect the selection and the use of different resources in teaching preparation/ teaching practices of Secondary Physics Teachers?

Theoretical Background

This study attempts to explore the system of pedagogical "Resources" that secondary physics teachers selected and integrated in their professional work and to investigate the objectives of their use and the factors that affect the selection of these resources.

The common meaning in education of "*resource*" refers to material resources. With time and due to the progression of technology and the development of the educational aids, the term resource covered many domains and different meanings. Adler (2010) conceptualized the term "resource" as both a noun and a verb. As a verb "*re-source*" means to source again or differently where source presents the origin or the place from where a thing comes. She has offered a broad conceptualization of resources that exceeds the material resources and distinguished between several categories of resources: material resources (such as technological tools: table, overhead projector ..., real objects, books, documents, software etc.), human resources (professional and subject knowledge of teachers), social and cultural resources (language) and time.

Based on the proposition of Adler (2010), Gueudet and Trouche (2010) defined the word "resource" as what is likely to re-source the work of teachers. In their work, they distinguished between these resources based on their characteristics: some are "material" (such as manuals, files, real objects etc.) and others are "non-material" (such as interactions with colleagues, students, communities etc.).

During their professional activity, physics teachers develop their teaching content based on various resources. Therefore, they could use bookish resources (textbooks and programs, documents, encyclopedia etc.), educational software and online resources (Artigue & Gueudet, 2008) or the real objects (physical objects or everyday life objects) which still form the main resource that promotes the work of experimental science teachers. Furthermore, Gueudet and Trouche (2009) found that the collective work plays an important role in the documentation system of teachers. It is based on direct communication between people (teacher-teacher, teacher-student, teacher and others ...). This type of communication which takes place in the educational meetings inside the institutions, associations, networks and society, leads to a new proposition to define a document as "a contract between men " (Pédauque 2006, p.13; as cited by Gueudet & Trouche, 2009).Physics teachers may also use examples of physics applications from students' everyday life during their practice. Thus, in order to elaborate a comprehensive activity and enhance learning process, physics teachers should make a selection from a wide range of available resources. These resources are presented either concretely in class by a material support or presented by a non-material support. Based on Gueudet and Trouche (2010) this study has adopted the definition of the term *resource* and distinguished between material and non-material resources:

- The material resources (MR) include the resources used by physics teachers that are present in their work environment. We categorize this type of resources according to the nature of the appropriate materials carrying (bearing) them, and we distinguish between three categories of material resources: the objects resources (OR) that consist of physics and real life objects, audio-visual resources (AVR), that correspond to videos, DVDs, CDs, Photos, simulations, software, etc. finally the paper resources (PR), refer to books, extra sheets, documents, magazines, etc.

- The non-material resources (NMR) or what Adler (2010) called knowledge resources or human resources cover the verbal discourses indicating applications of physics concepts in the real life like the principles of functioning of some machines, natural phenomena etc. Another example concerning Electricity, physics teacher may evoke the functioning of the electric heater or the iron in order to explain the principle of conversion of energy in a resistor. These resources are evoked in class without being presented concretely. Therefore, the teacher could illustrate the principle of conversion of electric energy into other forms of energy by using non-material resources that are called "*Evoked Resources*" in this study.

In their professional activity, physics teachers may interact with a wide range of resources; these interactions and their consequences hold a central place in teachers' professional development. This work according to Gueudet & Trouche (2009) is called documentary work, which is the work of the teacher on different resources and what it produces to form the subject or the document of his teaching. According to Gueudet and Trouche (2010), the document prepared by the teacher does not live isolated; it develops over time because of interactions with resources and with other documents. The process of evolution of the documentary system develops over time new documents that can play the role of new resources. In this sense, a resource produced in the classroom is not a document, with time and after revision and modification, it may result in a document. Since this study focused on the teaching of physics, therefore, its particular interest goes to the resources that physics teachers use to teach specific content in the field of physics. In this study secondary Physics teachers' use of resources is studied during their teaching Electricity part in grade ten.

According to Gueudet & trouche (2008) studying a system of resources or a document requires taking into consideration three intertwined components:

- The material component: Corresponds to the type of the used resources.

- The physics content component: Involves physics notions, tasks and techniques.
- The didactical component: Corresponds to the organizational elements ranging from mapping over the whole year to planning a session.

Concerning the first component the type of the resources is studied based on the categorization of the material and non material resources.

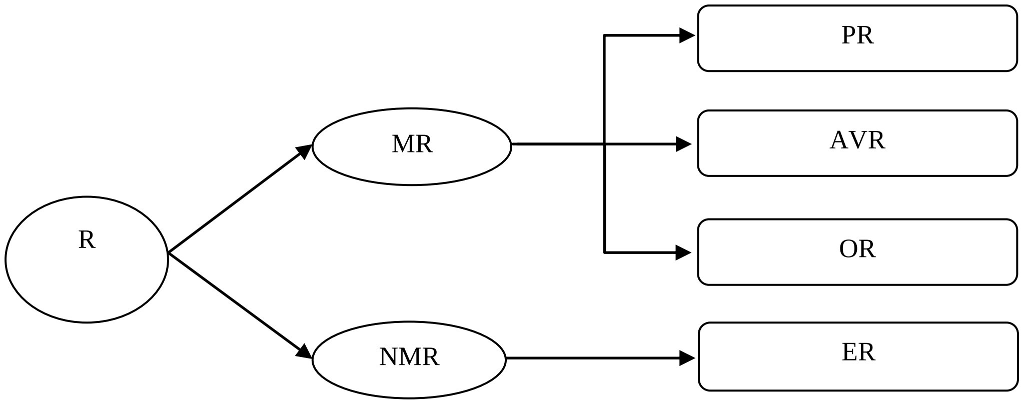

Figure 1. The relation between different types of the teachers' resources

Figure 1 shows the categorization of the system of resources of the teachers (coded, R) as a combination of four categories: paper resources (coded, PR), object resource (coded, OR), audio-visual resource (coded, AVR) and the evoked resources (coded, ER). In summary, this section presented some elements of the theoretical framework adopted in the following research to identify the selected resources of physics teachers and the integrated ones. Gueudet and Trouche presented a frame to study the mobilized resources and the work of the teachers on these resources to build their teaching activities. Through the documentational approach this study interested in the characterization of different types of resources forming the system of resources of physics teachers.

Method

Research Design

This study follows a qualitative approach to explore the resources used by the Lebanese secondary physics teachers in their teaching in general and particularly for teaching Electricity for grade ten students. Moreover, it aimed to explore the objectives of use of resources and the factors affecting their selection and integration in the teaching-learning process.

Participants

This research was designed as a collective case study where four teachers were purposefully selected, from 101 Physics teachers attending the annual meeting to discuss the answer key of the official exams. The four teachers where given the pseudonyms Mark, Salam, Moustafa and Amir were selected for in-depth investigation. They had different profiles they all taught grade ten students and they integrated resources in their teaching. Table 1 shows a comparison between the different profiles and work environments of the selected participants. The four teachers had a Bachelor of Science (BS) in physics except Amir who has a BS in Electronics, while Salam and Moustafa had also a Teaching Diploma (TD) from the faculty of education. They all teach secondary classes in English or in French and have teaching experience ranging between 8 and 17 years. The four teachers worked in public or private schools of different level of setting and equipment.

Table 1. Comparison between the selected teachers' profiles and school settings

	Mark	Salam	Moustafa	Amir
University's Diplomas	BS	BS + TD	BS + TD	BS
Major	Physics	Physics	Physics	Electronics
Teaching Experience	13 years	8 years	8 years	17 years
Language of Teaching	English	English	English	French
School Type	Private	Public	Public	Public
Level of Equipment	Acceptable	Poor	Poor	Poor

Data Collection Tools

The data collection tools were the interviews and the classroom observations. The interviews were two semi-structured interviews, one general (GI) and the other specific (SI), that aimed to explore the system of resources mobilized by the teachers in their teaching in general and in teaching Electricity in particular. This system of resources claimed by teachers during the interviews about their teaching is called system of Stated Resources (SR). To enhance credibility, the interviews were video-taped and transcribed then the participants read the transcript by themselves to ensure that their ideas were well expressed. These two interviews (GI & SI) were monitored before the classroom observations.

The classroom observations were all about the chapter of "generators and receivers" in the unit of Electricity. The number of observations varied between five and nine sessions according to the teacher progression. In addition to videotaped observations, the first researcher took notes for all observed details in the class. Thus, he is said to be the data-collection instrument (Johnson & Christensen, 2008). Therefore, videos of the observed sessions allowed the partially reconstruction of the studied situation and allowed for viewing and reviewing of the video-taped sessions. Besides that, the videos provided access to verbal and non-verbal interactions between the different speakers in the classroom (teacher-student, student-student). Moreover, it allowed studying the resources implemented by teachers in class in order to present specific topic. These resources are called Integrated Resources (IR). Thus, the classroom observation formed an essential part in the educational research particularly to monitor the professional work of teachers in the classroom (Gueudet & Trouche, 2010) and to explore teachers' system of integrated resources. All the observed sessions were videotaped by two cameras from two different angles to collect maximum data of verbal and non-verbal behavior of the teacher and of the students. During the classroom observations, notes and reflections were taken excessively in order to clarify more the global image of the teaching learning process. The recording devices give the opportunity for the researchers to replay as many times as they desire in order to validate the captured data and other researchers can also have the chance to watch and to listen and to discuss.

Method of Data Analysis

The interviews and classroom observations were analyzed in three steps: first the interviews and videos were transcribed. Second the discourse was segmented into meaningful analytical units, coded and categorized into themes. Finally, the types of the stated and the integrated resources (SR & IR) were identified. To analyze the resources and their objectives of use, a grid of analysis was adopted from the work of Gueudet and Trouche, (2007) and Hammoud, (2012). This grid of analysis of resources (R) is mainly based on three categories related to: the type of the resources, the content presented in the resources and the didactical organization.

Regarding the type of resources (R), teachers may refer to many *material resources* (MR) and *non-material resources* (NMR). Material resources included three sub-categories: paper resources (documents, books, copybook...), object resources (lab tools, real life tools) and audio-visual resources (videos, CDs, software, images...). The non-material resources, also called *Evoked resources* (ER), were the examples about natural phenomena, features or any material situation related to the taught subject that teachers could use it in their professional work.

Concerning the second category about the physics content organization, the researchers detailed, from a physics point of view, the knowledge included in the content and the predictable learning difficulty related to it. In addition, the researchers tried to analyze, in terms of the content specification, the relevance of the choice of the teacher for a specific resource.

The third category was about the didactical organization of the implemented resource of how and when the teacher integrated a specific resource to present specific content. In order to deduce the objective of usage of the resource, the researchers detailed the strategy by which the teacher organized the progression of knowledge in his teaching activity and the role of the used resource.

Results and Discussion

Concerning the resources used by the four teachers in their professional work, the analysis of data collected from the interviews, showed that they used many types of resources (OR, PR, AVR and ER) in their teaching. In the interviews, teachers specified the use of these resources (SR) according to the content (specific physics topics) they intended to teach and the objectives of their use. These objectives, stated by the four teachers, presented many elements of similarity in terms of pedagogical goals. Table 2 presents the main common objectives associated by the four teachers for the use of each type of resources. It shows that teachers referred to the real objects when they perform experiments about the taught subjects or when they introduce specific physics content. In addition, they also used OR to enhance learning and remove misconceptions. Due to the lack of materials and equipments in the school setting, teachers stated that they mobilized the other types of resources i.e. the visual and the evoked resources to compensate this lack.

On the other hand, the evoked resources (ER) were the most useful resources that the teachers mobilized in their teaching. This kind of resources was related to teachers' knowledge about the application of some physics principles in the practical life and about some phenomena or features related to the taught topics in their classroom. The audio-visual resources (AVR) were mainly used for illustrating some concepts and to show some phenomena. Concerning the paper resources (PR), all the teachers used the official textbook to prepare their course according to the curriculum objectives. Moreover, they relied on PR to find exercises of application and to solve problems about the topic.

Table 2. The objectives of usage associated to the stated resources (SR)

Types of resources	Objectives of usage
Object resources (OR)	1. Introduce content 2. Explain or clarify a law 3. Facilitate learning and remove misconceptions
Audio-Visual resources (AVR)	1. Replace real objects 2. Show some phenomena 3. Illustrate physics principle
Paper resources (PR)	1. Prepare course 2. Find exercises and problems
Evoked resources (ER)	1. Replace real objects 2. Relate physics to the real life 3. Introduce content 4. Illustrate physics principle

One of the aims of this research was to study the specificity of teaching Electricity in grade ten in terms of the integrated resources and the objectives of their usage. The four teachers were observed in their classrooms during their explanation of the chapter of "generators and receivers". The explanation of the chapter done by each teacher showed that they all followed the same progression presented by the curriculum. This chapter about generators and receivers is divided according to the official textbook to three main parts: Electric generators and its characteristics, electric receivers and its characteristics, and some particular cases (generators in oppositions and blocked motor). The analysis of data collected from the classroom observations, showed that Mark referred to the real objects to perform experiment about the different parts in the chapter. He used the experimental activity to determine the characteristics of an electric generator and an electric receiver and to explain Ohm's law relative to them. He also referred to the evoked resources by giving examples from the real life about generators and receivers to illustrate the principle of conservation of energy responsible of how they function. The other three teachers (Salam, Moustafa, and Amir) referred mainly to the evoked resources and the audio-visual resources to explain the main ideas of the chapters. On the other hand, Salam used materials that he brought by himself to introduce electric generators, while, to determine the characteristics of generators and receivers, Salam and Moustafa referred to the virtual lab. Salam used different simulation software for the three different parts of the chapter. The software that Salam and Moustafa used was given to them from their colleagues and from the Faculty of Education when they were preparing their Teaching Diploma (TD). Thus, Salam's system of integrated resources was rich, as he has used real objects, evoked resources, three simulations software and the official book. Moustafa and Amir did not use any object resources (OR) during their explanation. Amir referred only to the evoked resources (ER) during his explanation where he tried to relate physics knowledge to their application in the real world by giving examples from students' real life. However, to solve exercises and problems the four teachers referred to the textbook (PR). Table 3 summarizes in terms of the main taught ideas the different types of the integrated resources (IR) used by the four teachers during the explanation of the chapter of generators and receivers.

Table 3. The objectives of usage associated to the integrated resources (IR)

Progression	Mark	Salam	Moustafa	Amir
To introduce Electric generators	OR	OR	ER	ER
To introduce Electric receivers	OR	ER	ER	ER
To show Ohm's law related to generators	OR	AVR	AVR	ER
To show Ohm's law related receivers	OR	AVR	ER	ER
To explain generators in oppositions	ER	AVR	AVR	ER
To solve exercises	PR	PR	PR	PR

Concerning the role of the experimental activity in their teaching, the four teachers stated that it formed the most important strategy for teaching and learning physics. According to their declarations, Mark, Salam and Moustafa appreciated the role of the experiment in teaching physics because it put theory into practice and students had the opportunity to construct their knowledge by themselves and enhance their understanding. Furthermore, they believed that experiments are irreplaceable, but due to lack of materials, they referred to the practical examples (ER) and to the virtual laboratory (AVR). However, Mark had the chance to perform laboratory experiments since he taught in a private school where the needed materials in Electricity were present in school laboratory. Otherwise, he would be obliged, like the other teachers, to find other resources to replace the object resources (OR). Salam and Moustafa taught in public schools, which were poor in equipment and laboratories, thus they used the virtual experimental activity and some of their own materials. Moreover, Salam found that the virtual lab is more efficient at the level of time saving, precision, clarity and management. In addition, Salam added that the audio-visual resources are more efficient when topics are not applicable in school's laboratory (e.g., radioactivity). These two teachers Salam and Moustafa were comparable from their profile in three main points: the diplomas, the teaching experience and the school setting. They had their teaching diploma at the same year from the faculty of education at the Lebanese University where they got the simulation software. They have been teaching for eight years and were observed in public schools where there was lack of materials and equipment. In spite of this, Salam developed his documentation and his system of resources as well as his teaching practice more than Moustafa did. As a result, the lack of materials in public schools did not encourage teachers to choose real experimentation as instructional strategy in the chapter of "Generators and Receivers". However, physics teachers ranked the experimental activity as the first in teaching strategies due to its importance in the teaching learning process. Therefore, school setting affected the teacher's choice of resources, i.e. those teaching in public school were obliged to look for a replacement to the object resources. Moreover, all the four teachers appreciated the role of the evoked resources to relate the world of theory to the real world in particular, during the teaching of the unit of Electricity thus, the choice of resources is content dependent.

On another side, Amir also worked in a public school which was unequipped, and he believed that physics is better taught through practical knowledge. He used to draw diagrams illustrating the principle of functioning of some applications of physics contents in the real life. These diagrams showed proliferation in physics applications in the domain of Electricity. This level of knowledge and of accuracy presented in his classroom was not present in any of the other teachers' classroom, which could be explained by his long teaching experience in comparison with the others as well as his major (BS in Electronics). Therefore, all of his teaching activities in the chapter of generators and receivers were based on the evoked resources (ER). Thus, teaching experience and major are of the factors that influence teacher's practice, in addition to teacher's preparation and his professional knowledge about teaching physics.

As conclusion, the main results and findings of this study can be summarized by the following points:

- Secondary physics teachers used different types of resources in their teaching in general where the evoked resources (ER) formed the main common type.
- Secondary physics teachers referred mainly to the experimental activity (real lab or virtual lab) using object resources (OR) or audio-visual resources (AVR) in teaching Electricity.
- Secondary physics teachers paid particular attention to the importance of performing real experiments to enhance learning and remove students' misconceptions.
- Virtual laboratory could be more efficient than the real experiment in teaching some physics topics as it is less time consuming, more accurate, better organized and more precise, particularly at microscopic level.
- Concerning the factors that affect the selection and the integration of resources, the choice of the resource to present a specific content depends on:
  - The content itself and its particularity
  - The availability of materials and equipment
  - Time constraints
  - Teaching experience and diplomas
  - Teacher's professional knowledge

Discussion of the Results

The results of this study showed that during their teaching preparation/teaching practice, teachers had access to a variety of resources (OR, PR, AVR and ER). The availability of these resources in teacher' work environment (laboratories, library, computers, internet, technological tools...) enhanced the selection and the integration of such resources. This is consistent with Hammoud (2012) who found that teachers did not have a unique system of resources; they referred to different types of resources to elaborate their teaching activities. Nowadays, the access of physics teachers to the internet and the use of some audio-visual resources to present specific topics became easier with the development of technology.

During their explanation of Electric Generators, Salam and Moustafa were obliged to modify the used simulation software to differentiate between real and ideal generators. Thus, the integration of technology in education required proliferation in its use to adapt it to specific content. This is in line with Sabra, who showed that the development of the integration of technology in education required development in teacher's skills about its use (Sabra, 2011). According to Abd-El-Khalick (2005), the integration of technology in education required a development in the curricular goals and approaches. Nevertheless, Mounsef (2005) found that the integration of ICT is not emphasized in Lebanese science curriculum. Furthermore, the result showed that the visual resources of Salam and Moustafa were enriched by their collaborative work with other colleagues and from the Faculty of Education during their preparation for the TD (Teaching Diploma). They used during the explanation of the chapter of "Generators and receivers" the simulation software they brought from their colleagues. Therefore, the collective work developed their documentary work. This is consistent with Hammoud (2012), Sabra (2009) and Shaaban (2014) who showed that the collective work leads to an evolution of teacher's documentary work and their practices.

This study also showed that the physics teachers believed that the experimental activity in general and the real laboratory in particular were the best ways to teach physics in general and Electricity in particular. During interviews, Mark, Moustafa and Amir claimed that the experimental activity using real objects and tools is irreplaceable in the teaching/learning process. While Salam found that, the virtual laboratory is more efficient than the real one due to many reasons such as the time saving, the organization, the accuracy and microscopic scale of observation. Moreover, simulation software could be a solution for the lack of materials and laboratories, and for some topics such as astronomy and radioactivity. This is consistent with several previous studies like Bajpai and Kumar (2015) who found that the virtual laboratory in physics played an essential and significant role to develop students' science process skills. They found also that the virtual lab is useful when experiments involved hazardous chemicals or risky equipment. Other researchers (Redish *et al.,* 1997; Svec & Anderson, 1995; Zoubeir, 2000) revealed that computer simulation experiments are more effective for students' understanding than traditional experiments. In contrary, some researches revealed no difference in the effectiveness between real and virtual labs (Bayrak *et al*., 2007; Miller, 1986). The inconsistency between the results could be related to the specificity of the topic included, in particular when real experiment is inadequate, which limits the real experiment in developing some concepts (Yager *et al.,* 1969).

Furthermore, this study revealed that many factors hindered the integration of resources in the teaching process. These factors were related mainly to the content itself, the school setting and the teacher's professional knowledge. Moreover, Mark and Salam claimed that there is no sufficient time to perform experiment and integrate resources in their teaching in a continuous way due to the condensed curriculum. This is in line with some researchers who found that one of the factors affecting the use of resources is their availability in teacher' work environment (Haney, Czerniak, & Lumpe, 1996; Nargund-Joshi, Rogers, & Akerson, 2011). Some other researchers revealed that the time constraint is one of the factors hindering the implementation of resources (Bodzin, Cates, & Price, 2003; Keiser & Lambdin, 1996).

Conclusion

This paper presents a study about the system of resources used by Lebanese secondary Physics Teachers during their teaching preparation/teaching practice in general and for Electricity in particular. It aimed to study the different types of used resources, their objectives and the factors that may affect their selection and their use. The analysis of data showed that, in order to elaborate and present their teaching activity, Secondary Physics Teachers referred to different types of resource (OR, VR, PR and ER) depending mainly on the availability of these resources in teachers' work environments (school setting and equipment) and the content to be taught. The school setting and its equipment had a direct influence on the type of selected resources and teaching activity.

Most of the resources were mobilized to compensate the lack of materials (OR) and to illustrate specific physics topics. Teachers believed that the experimentation is the most important instructional strategy to enhance students' understanding and to remove misconceptions in learning physics in general and Electricity in particular. Using virtual laboratory through VR could be more efficient at the level of time consuming, accuracy, management and teaching at the microscopic level (e.g., Radioactivity). In addition to the content itself and its particularity and the availability of materials, the time constraint and teacher's pedagogical knowledge affect the selection of resources of different types. Furthermore, the major (Electronics, pure Physics...), the diploma (BS, TD, Master...) and the years of experience affected the selection and the integration of resources in general and the evoked resources (ER) in particular.

Recommendations and Implications

Future studies/interventions could arise from the discussion of the results of this study. This study showed that the selection of resources is content dependent, thus other research could test this result by choosing Physics topics other than the Electricity to explore if the selection and the integration of resources is different. Furthermore, future researchers can investigate how teachers' professional knowledge affects the selection and the use of resources such as the technological and the pedagogical content knowledge.

The integration of resources in general and the ICT in particular required organizational support and change in the whole school culture (Zgheib, 2013) and re-examining curricular goals (Abd-El-Khalick, 2005). Therefore, physics curricula, their objectives, the approaches and the required skills should be revised by the curriculum designers and educators and by the educational websites developers to support teachers in efficiently integrating resources in their professional work.

Acknowledgment

The current study presents some limitation related to the small number of case studies, the specification of one subject and one topic in science curriculum and the time constraint that prevent analyzing deeply the quality of used resources.

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Environmental Education in the Science Curriculum in Different Countries: Turkey, Australia, Singapore, Ireland, and Canada

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Abstract

This study aimed to compare the objectives of environmental education topics in various countries. The present study is a qualitative study and content analysis was used to analyze the data. The results revealed that the categories of the objectives regarding the environment topic in the primary education were found to be higher in Turkey compared to other countries. The concept of the ozone layer in chemistry curricula and the concept of biodiversity in biology curricula were intensively included. No country had objectives regarding all subcategories in primary education. There are no objectives regarding field trip in physics subject in all countries. Objectives regarding the category of identifying issues and research question were included only in Australia. However, the activities for environmental education were determined to be at a low level in all the countries.

Introduction

Humans have to change their attitudes toward the environment to sustain their lives in this world (McMillan, 2003). Based on the assumption that there is a relationship among knowledge, attitude, and behavior (Bradley, Waliczek & Zajicek, 1999; Gayford, 1998), there is a need for environmental education (McMillan, 2003) to positively influence society's attitude, awareness, and interest toward the environment and to equip individuals with eco-friendly behaviors (Bogner, 1998; Grodziéska-Jurczak, Stepska, Nieszporek & Bryda, 2006; Zelezny, 1999). This is because there exists a direct relationship between environmental education and the attitudes and behaviors toward the environment (Vlaardingerbroek & Taylor, 2007). Environmental education has a strong history in shaping studies of nature, experiences with nature, and environmental science studies (Kyburz-Graber, 1999). The deterioration in the structure and quality of the environment in the 1960s and the fact that it has been verified by scientists made it possible for the environmental education to take a place in the formal education (Gough, 2002).

Environmental education has received more attention in science education since it provides solutions for many environmental problems by taking advantage of science education departments and provides scientific explanations for solutions to environmental concerns (Shin, 2000). Since the 1970s, studies of the natural environment began to be more involved in environmental education concepts (Gough, 2002; Kyburz-Graber, 1999). In the meantime, science educators (in particular, biology) have undertaken the responsibility of providing environmental education when natural events and environmental problems were addressed and measured by technological and biological methods (Kyburz-Graber, 1999). Science educators put more emphasis on environmental education than on other disciplines in science education to make a positive change in society's attitudes and behavior toward the environment and to protect and develop the environment (Duvall & Zint, 2007; Kyburz-Graber, 1999).

Most science educators point out two factors causing students' failure in science courses: limited teaching methods and inadequate teacher qualifications. Teachers' efficiency in classrooms and ability to manage the curriculum have a considerable effect on student attainments (Onwuachu & Nwakonobi, 2009) and influence students' achievement (Darling-Hammond, 2000). Teachers' ability to bring up environmental problems in the classroom using various strategies and methods enables students to face these problems and revise their values, attitudes, knowledge, and perspectives, and to contribute to producing more rational and precise solutions in everyday life (Wals & Alblas, 1997). Education overall—and therefore teachers— have a considerable role in the development of students' responsibility toward the environment (Kaya & Tomal, 2011). Teachers with inadequate qualifications lead to students' limited knowledge acquisition regarding environmental education. Equipping teacher candidates with adequate skills in environmental education in teacher training programs will contribute to the preparation of more qualified environmental education programs in the future (Tuncer et al., 2009). However, published studies have revealed that environmental education in teacher training programs is ineffective and underdeveloped.

In addition, the qualifications of the teachers who provide environmental education were determined to be inadequate (McKeown-Ice, 2000; Moseley, Reinke & Bookout, 2002). Therefore, teachers' conceptual, procedural, and multidisciplinary competencies should be enhanced by undergraduate education and inservice and public training (Benedict, 1999). An increase in the knowledge level regarding EI, problems, and consequences makes a great contribution to the upbringing of responsible, aware, and sensitive individuals: students will find opportunities to recognize the factors behind environmental problems and deterioration (Korhonen & Lappalainen, 2004) and actively participate in the environmental decision-making and implantation of processes to avoid environmental problems (Palmer, 1999; Potter, 2009; Ruskey, Wilke & Beasley, 2001).

Curricula are at the core of education worldwide, and the curricula are necessary instruments for achieving the desired education (Alade, 2011). It can be proposed that the society developed scientifically based on the rapid advancements in technology and economy. Accordingly, a curriculum that meets the needs of the information society is needed for every country. To meet those requirements, a more contemporary curriculum should be implemented (Delibaş & Babadoğan, 2009; Gökmenoğlu & Eret, 2011). The needs of the current society should be considered while developing a curriculum. In addition, evaluations that determine whether a curriculum fully performing its functions are needed to ensure the sustainability and development of the current curriculum. Evaluations will contribute to the determination of the advantages/disadvantages of a curriculum in practice. While performing these evaluations, it will be of great benefit to consider the curricula of the countries that are assumed to be successful in education at the international level in addition to the curriculum in our country (Demirel, 2010; Demir & Demir, 2012; Kaya, 2007; Yüksel & Sağlam, 2012a). Many countries have benefited from observing the curricula of different countries while developing their own curricula (Eş & Sarıkaya, 2010). However, only a limited number of studies have been published about the role of environmental education in the curriculum.

Much national and international research in the published studies compares objectives, determines EI (Environmental Issues) in teaching materials, compares environment policies, and determines the role of environmental education in the curriculum. These studies revealed that the objectives in the curriculum related to environment remain at the level of knowledge; that very few objectives regarding skills are included; that the objectives are not sufficiently qualified to increase students' attitudes, behavior, and awareness; that more objectives related to environment are included in the biology curriculum compared with physics and chemistry curricula and that environmental issues is included in only a limited number of courses in those curricula. Further, in primary and secondary education curricula, there is no systematic approach toward environmental issues; the approach differs according to grade level and is not included in some grades; more objectives are included in science and technology subjects compared with life sciences and social science in primary education. Activities regarding environmental education are mostly included in science studies, and the updated curricula have a higher level of environmental education compared to previous programs but teaching materials for environmental education are insufficient.

Environmental education is included in only a limited number of courses in teacher training programs; therefore, teachers are not gaining increased competence in environmental education. (Abdullah, Halim, & Shahali, 2011; Adedayo & Olawepo, 1997; Alım, 2006; Bakırcı & Artun, 2011; Bodlalo, Sabbaghan, & Jome, 2013; Cebesoy & Şahin, 2010; Eames, Cowie, & Bolstad, 2008; Hamalosmanoğlu, 2012; Jóhannesson, Norðdahl, Óskarsdóttir, Pálsdóttir, & Pétursdóttir, 2011; Maravic, İvkovic, Segedinac, & Adamov, 2014; Srbinovski, Erdoğan, & Ismaili, 2010; Tanrıverdi, 2009; Taylor, 1998). Previous studies made comparisons based on listing the objectives in the curricula mostly of a single country or several countries; there is no detailed study on the curricula of a single subject or comparing the curricula of many countries. Therefore, this study aims to compare the objectives of environmental topics in the curricula of Turkey, Australia, Singapore, Ireland, and Canada. In the present study, answers to the following questions were sought:

1. What are the similarities and differences in the primary education of these countries in terms of;
   1.1 Environmental issues (EI)
   1.2 Environmental science and health (ESH)
   1.3 Environmental activities (EA)

2. In the secondary education of these countries,

2.1 What are the similarities and differences regarding physics in terms of;
- 2.1.1 EI
- 2.1.2 ESH
- 2.1.3 EA

2.2 What are the similarities and differences regarding chemistry as a subject in terms of:
- 2.2.1 ESH
- 2.2.2 EA

2.3 What are the similarities and differences regarding biology as a subject in terms of:
- 2.3.1 EI
- 2.3.2 ESH
- 2.3.3 EA

Method

The present study is a qualitative study and adopts a comparative education approach. Single-country, multiple-country (≤ 20), and many–country approaches are used in the comparative education studies. The comparisons of fewer countries are recommended in detailed studies (Aynal, 2012; Yüksel & Sağlam, 2012b). The scale developed by Hungerford, Volk, & Ramsey (1994) to analyze environmental education was adapted based on primary education in the subjects of physics, chemistry, and biology and used as data collection tool. The sequence followed in collecting data is as follows:

1. Determining which documents to include
2. Accessing those documents
3. Translating the documents (fully translating curricula and selecting objectives regarding environment)
4. Organizing data based on the research questions
5. Analyzing the data

Descriptive and content analysis was used to analyze the data. Data is first systematically and clearly described in the descriptive analysis. Then, these descriptions are explained, the cause-effect relationship is investigated, and some results are derived. The main purpose of the content analysis is to evaluate concepts and relationships that can explain the data. In the content analysis, the data that is summarized and interpreted in the descriptive analysis are subjected to a deeper processing; concepts and themes that are not identified by a descriptive approach can be discovered through that analysis (Yıldırım & Şimşek, 2008).

Content Analysis Process

Two approaches are used in the content analysis: induction and deduction. Both approaches can be applied to quantitative and qualitative data. The purpose of a study determined the approach that is adopted. Induction is recommended if there is insufficient knowledge of concepts because concepts only become evident as the texts are read in this approach. The existing concepts are used to proceed in the deductive approach. The preparation processes of both approaches are similar. These processes take place in three phases in both approaches: preparation, organization, and reporting.

However, there is no systematic analysis in content analysis. Generally, text-driven concepts are categorized into groups (Elo & Kyngas, 2008). The analysis units in content analysis can be evaluated in terms of either meaning or frequency. This decision is made in accordance with the purpose (Gökçe, 2006). In the present study, the frequency of the concepts or symbols regarding environmental education was considered.

Findings

The distribution of EI in primary education curricula on a country basis was presented initially. The findings as related to physics, chemistry, and biology are presented in the secondary education section.

Table 1. Category and subcategory of subjects in the curricula of primary and secondary education

	Category	Subcategory
Primary Science Curriculum	Environmental Issues	8 concepts
	Environmental Science and Health	21 concepts
	Environmental Activities	4 concepts
Physics and Chemistry Subjects	Environmental Issues-Environmental Science and Health	10 concepts for Physics Subject, 12 concepts for Chemistry Subject
	Environmental Activities	4 concepts
Biology Subject	Environmental Issues	8 concepts
	Environmental Science and Health	20 concepts
	Environmental Activities	7 concepts

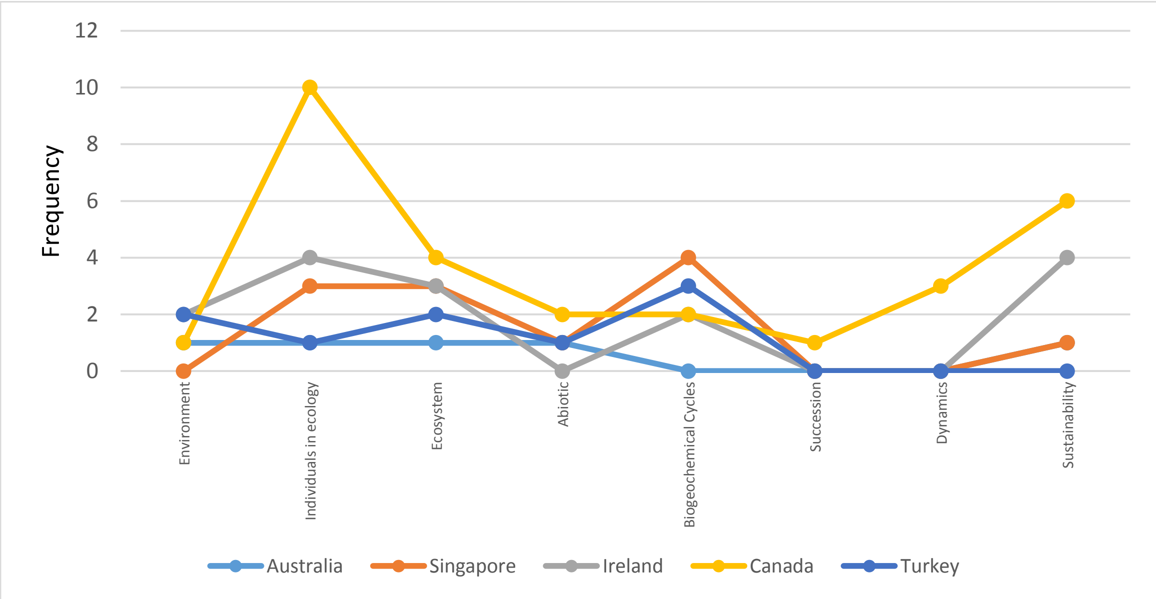

Figure 1. The distribution of environmental issues in primary education curricula

Figure 1 reveals a similar tendency across countries. The attainment frequency values of the countries regarding EI were clustered at a value of 4 and below. Among the EI investigated, the issue of individuals in ecology had the highest value, and Canada seemed to give more weight to this issue than other countries. In addition, Canada included objectives for all EI in its curricula. The frequency values for Turkey and Australia were determined to be 2 and below.

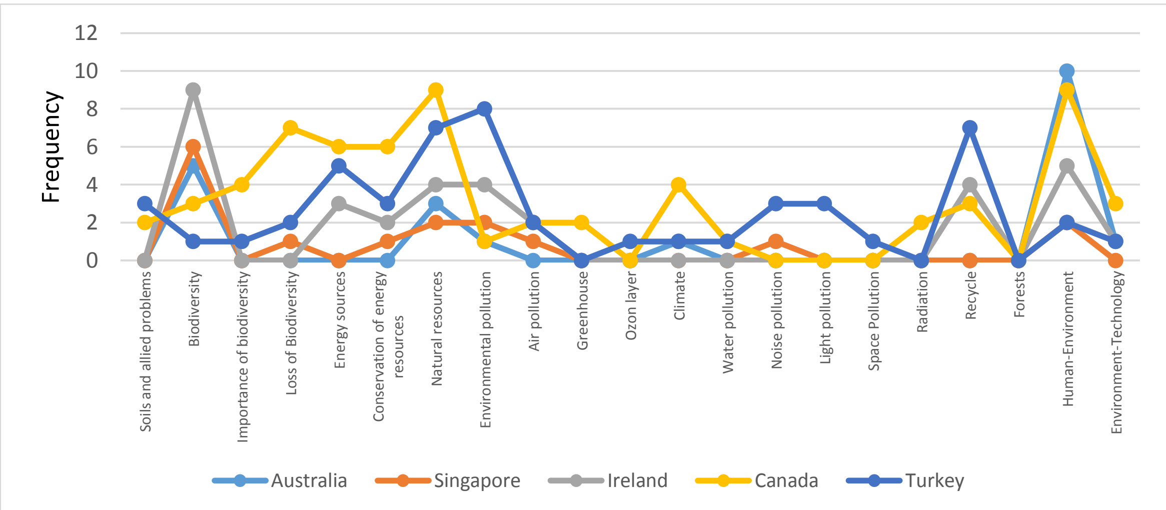

Figure 2. The distribution of environmental science and health in primary science curricula

There are many differences among the countries regarding ESE. Whereas there is no country with frequency value for all issues, the issue of forests that does not receive any frequency value in all countries that were examined. Biodiversity, Natural resources, Environmental pollution, and Human Environment are among the issues that have recorded frequencies in all countries. Singapore has the lowest frequency distributions because of its score of 2 and below in all issues except Biodiversity.

The Human-environment issue has the highest frequency among all issues examined and was highest in Australia. Singapore is the only country that does not have the highest frequency regarding any issue compared with other countries studied. However, most of the highest frequencies pertain to Canada. Canada also has the highest frequencies for nine issues: Importance of biodiversity, Loss of biodiversity, Energy Sources, Conservation of energy sources, Natural resources, Greenhouse, Climate, Radiation, and Environment-Technology (Figure 2).

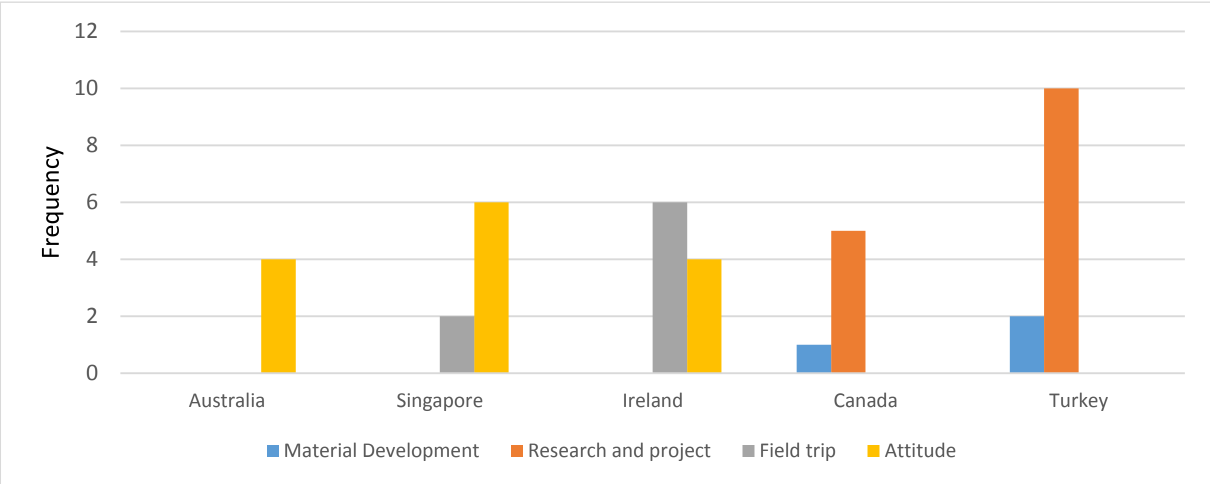

Figure 3. The distribution of environmental activities in primary science curricula

The headings of Material development and Research and project were included only in Canada and Turkey; the heading of Field trip was only included in only Singapore and Ireland; the heading of Attitude, sensitivity, and responsibility was included in only Australia, Singapore, and Ireland. There is no country with all headings. The most differences in primary education are in the EA section. There is no similarity among the countries: the subcategories in some countries are not included in others. There is no attainment for all subcategories.

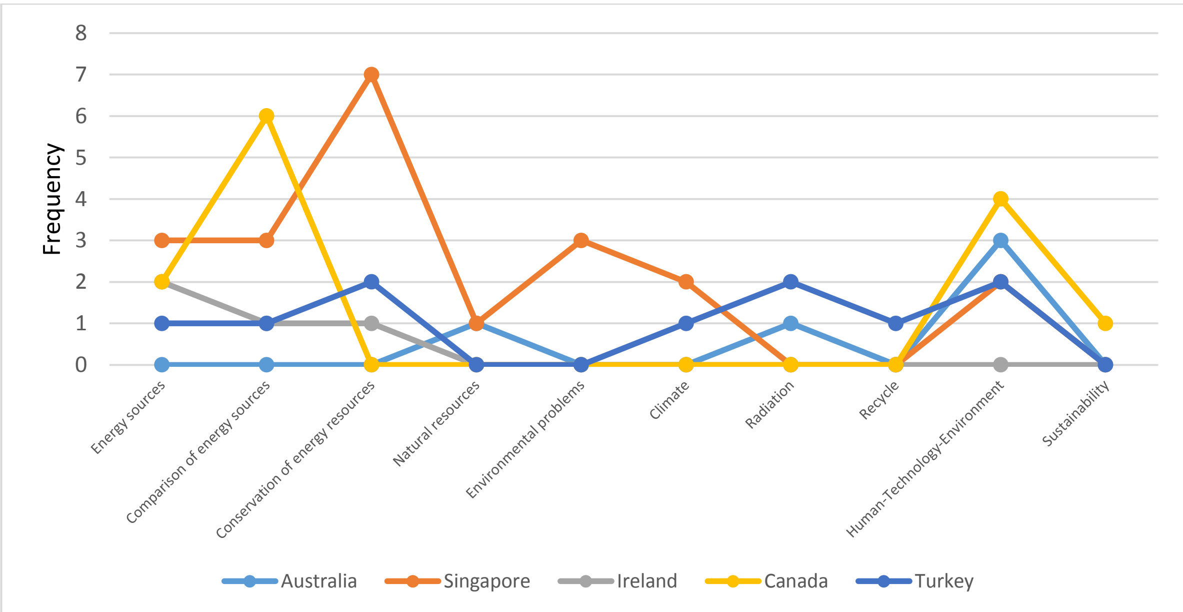

Figure 4. The distribution of environmental issues-environmental science and health in physics subject

As seen in Figure 4, there are different tendencies in the EI and ESH subcategories in physics subject of secondary education. The categories of Conservation of energy sources, Comparison of energy sources, and Human-technology has the highest frequencies. The lowest frequencies were found for Ireland and Australia, and mostly at a value of 1 or below. There are general differences on a country basis. Ireland is seen to have lower frequencies compared to other countries.

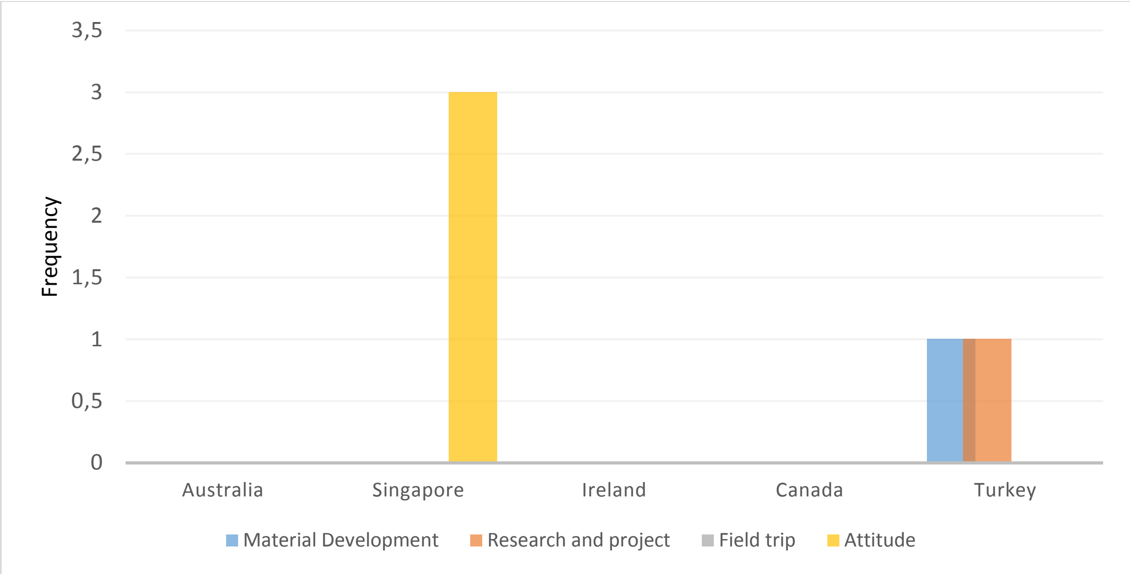

Figure 5. The distribution of environmental activities in physics subject

Figure 5 shows that the objectives regarding EA were not included in Australia, Ireland, and Canada. There were no attainments in the category of Field trip in any country, the category of Attitude, sensitivity, and responsibility was found in only Singapore; and the categories of Material development and research and project were found only in Turkey. EA in physics subject is not at a satisfactory level in the curricula of most countries. As in primary education, most of the differences are in the EA section. There is no similarity among countries: the subcategories in some countries were not included in others, and there is no objective for all subcategories.

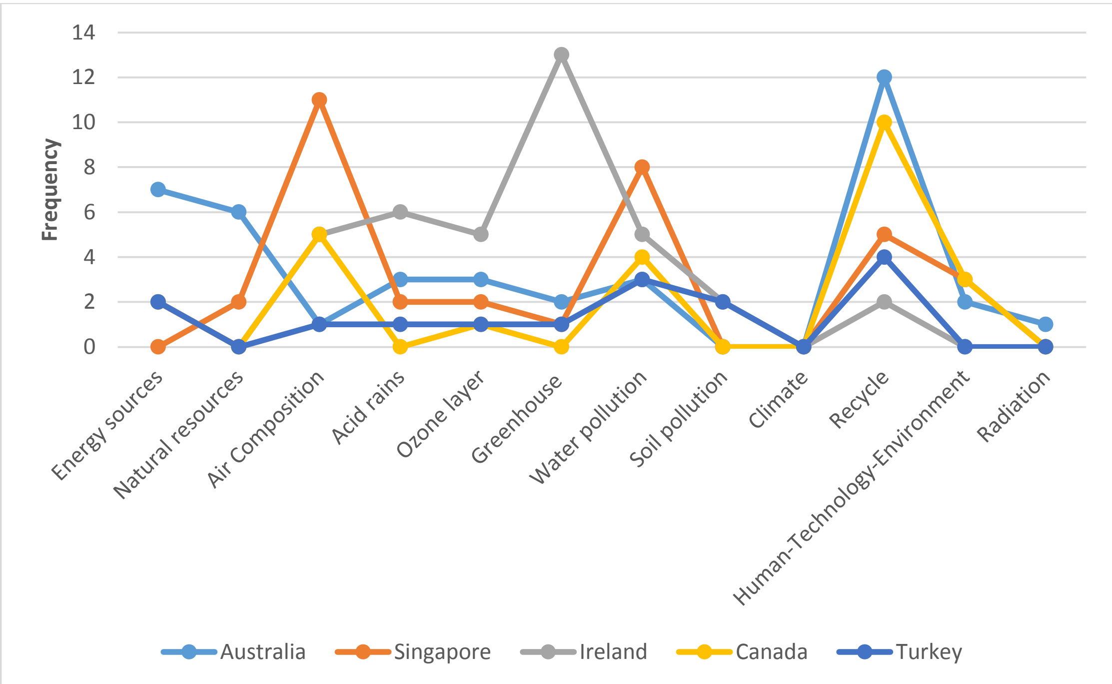

Figure 6**.** The distribution of environmental issues-environmental science and health in chemistry subject

It is noteworthy that the countries had different tendencies and that there were fluctuations at different points. Turkey generally received a value of 2 and below. The most favorable distribution occurs in the Recycle category, where Australia, Ireland, and Singapore have higher frequencies. The highest frequencies on by country basis based on issues are Australia in Energy sources and Natural resources; Singapore in Air composition and Water pollution; Ireland in Acid rains, Greenhouse, and Ozone layer; and Ireland and Turkey in Soil pollution.

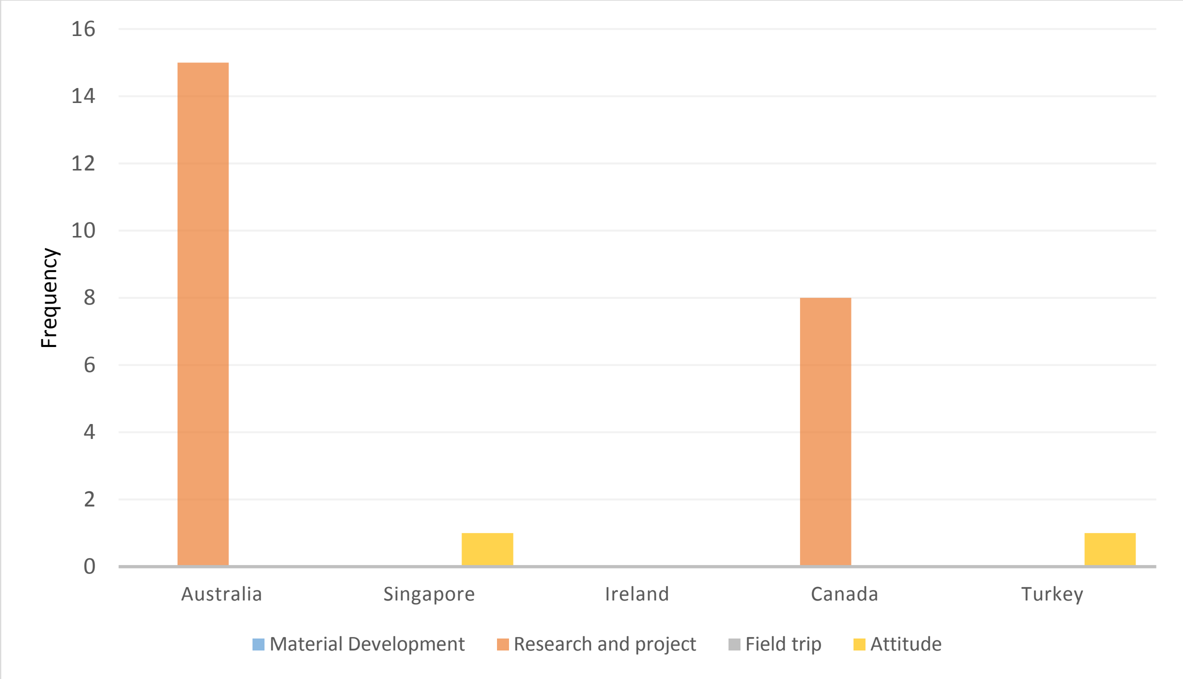

Figure 7. The distribution of environmental activities in chemistry subject

Figure 7 shows no objectives regarding Research and projects in Ireland. There were no attainments regarding the category of Material development. The category of Material development was highest in Australia and Canada, the category of Attitudes, sensitivity, and responsibility was low in Singapore and Turkey.

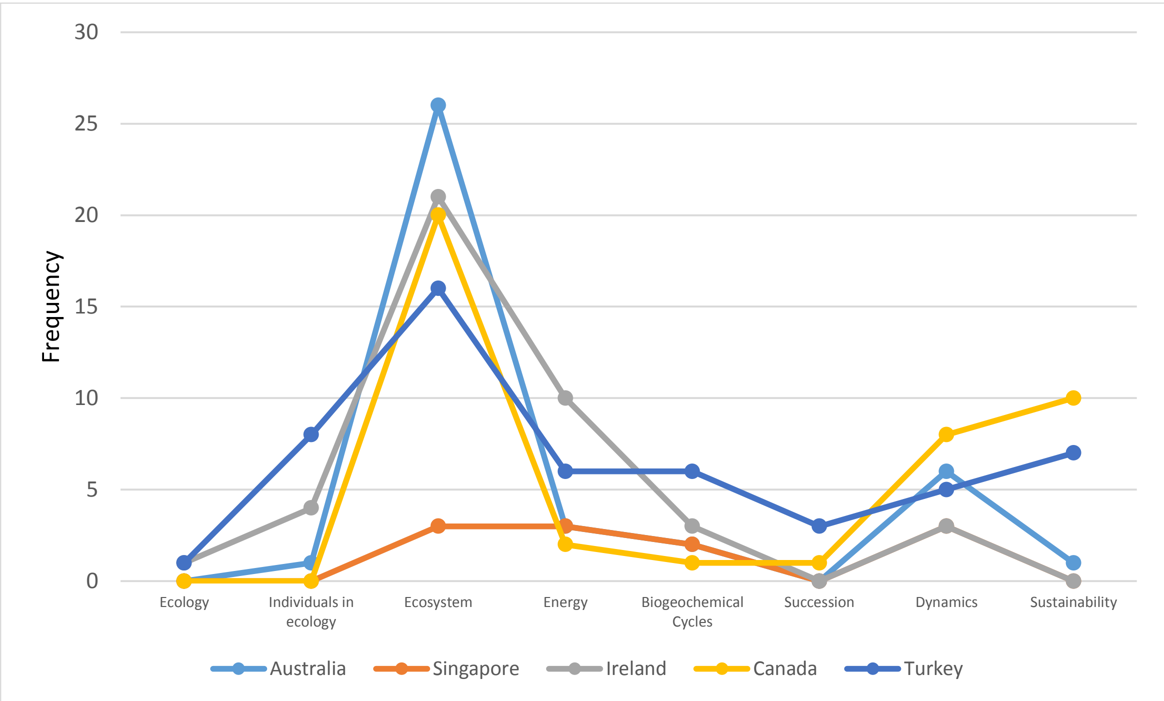

Figure 8. The distribution of environmental issues in biology subject

There is a similar fluctuation in EI categories in biology subject. The Ecosystem category has the highest frequency among the countries. Singapore has lower frequencies compared to other countries, and Turkey is the only country that has frequency values in all categories. The highest frequencies by country based on issues are Turkey and Ireland in Ecology; Turkey in Individuals in ecology; Australia in Ecosystem; Ireland in Energy; Turkey in Biogeochemical cycles and Succession; and Canada in both Dynamics and Sustainability.

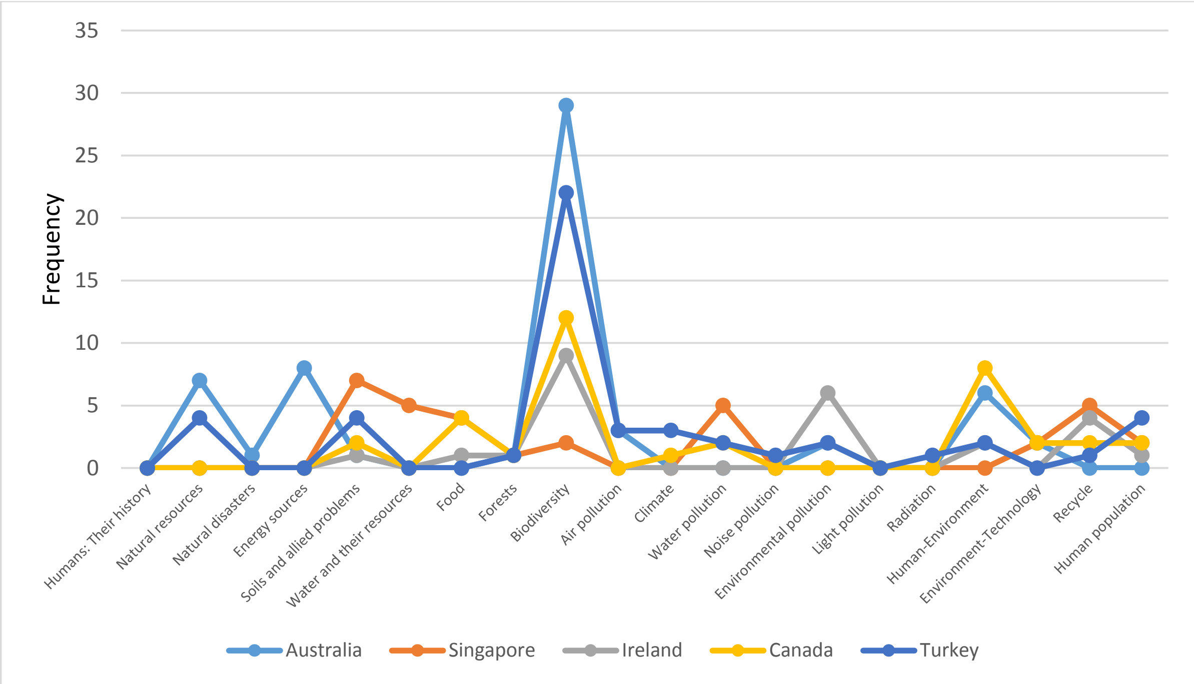

Figure 9. The distribution of environmental science and health in biology subject

Figure 9 shows that ESH in biology subject differs among the countries. The highest frequencies are encountered in the category of Biodiversity in most of the countries. The highest frequencies by country based on the issues are: Australia in Natural resources, Natural disasters, Energy sources, and Biodiversity; Singapore in Soils and allied problems, Water and their resources, Water pollution, and Recycle; Ireland in Environmental pollution; Canada in Human-environment; and Turkey in Climate, Noise pollution, Radiation, and Human population.

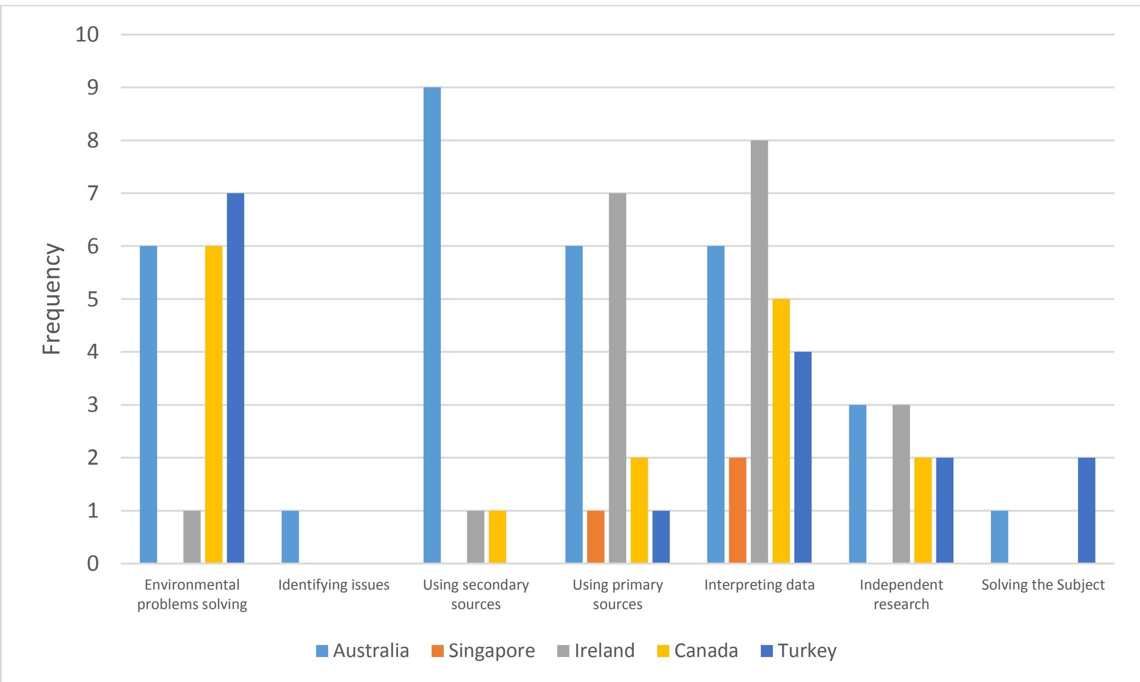

Figure 10. The distribution of environmental activities in biology subject

Figure 10 shows that Australia is the only country that has frequency values in all categories. The highest frequencies by country based on the issues are: Turkey in both Environmental problems solving and Solving the subject; Australia in Identifying issues and Using secondary sources; and Ireland in Using primary sources and Interpreting data. The categories of Using primary sources and Interpreting data were included in all countries.

Conclusion and Discussion

Findings regarding EI

The distribution of objectives in the primary education was found to be homogeneous only in Canada, which has the highest frequencies in many subcategories. We concluded that Canada has approached all attainments in curricula regarding EI, and that Canada has a systematic approach to EI. The issues of Ecologic succession and Population and its dynamics are included only in Canada. All objectives regarding biology subject were determined to be included in the curricula. The category of Ecologic succession was found to have a lower role. It was determined that there are no objectives regarding these issues in physics and chemistry subjects. Having EI at a low level and only in biology is insufficient to ensure a sustainable future. According to McMillan (2003), a qualified environmental education should be approached in education in a multidisciplinary way rather than in only one discipline to have enforce strong educational values and ensure a sustainable life. However, the desired knowledge, skills, and attitudes are provided through biology and geography in both primary and secondary education (Stevenson, 2007). A qualified environmental education should cover a wide range of subject areas, from the social sciences to “hard” sciences (Monroe, Andrews, & Biedenweg, 2008). EI should be included in the curricula with a wide range of issues and a multidisciplinary approach, according to Hassan & İsmail (2011).

Findings regarding ESH

The categories of the attainments in primary education were found to be higher in Turkey compared with other countries. Generally, there was a systematic distribution of subcategories in Turkey and Canada. The category of Forest did not receive a frequency value in any of the countries studied. Tsekos & Matthopoulos (2008) have pointed to a similar result in their study, which investigated EI in Greek newspapers. The results of that study revealed that the forest category is not included in Athens and included in Sparta by only 4%. Similarly, Vlaardingerbroek & Taylor (2007) listed the loss of forests, air pollution, and the pollution of beaches among the biggest environmental problems in Lebanon.

Ozone depletion, Light pollution, and Space pollution are included only in Turkey, and that Greenhouse and its effects are included only in Canada. Being knowledgeable about the effect of greenhouse gases on climate change, the extinction of dinosaurs, ozone depletion, and the change in weather events provides a more comprehensive awareness about global warming (Chaineux & Charlier, 1999). There are no objectives regarding Light pollution in biology subject. The distribution of subcategories is: Natural disasters and their effects and Energy sources (renewable and non-renewable, its conservation, importance, and effects) in Australia; Water and allied problems (World’s water resources, increasing water resources, management strategies, water conservation) in Singapore; Noise pollution (Sources and their levels, its effect on humans, control); and Radiation in Turkey.

The distribution of subcategories regarding physics subject is Wastes and their control in Turkey; Sustainability (Healthy environment) in Canada; and Environmental problems in Singapore. Educational systems need to be intensively revised to create ecologically sustainable societies (Smyth, 2006). Australia, Singapore, and Ireland include more objectives regarding chemistry subject, whereas Canada and Turkey include fewer attainments. In addition, the attainments in Turkey were determined to be mostly at a lower level compared to other countries. There were no attainments regarding the category of Climate and seasonal variation. The category of Radiation was only included in Australia (NSW).

Findings regarding EA

No country had objectives regarding all subcategories in primary education. The distribution of subcategories are Material development and Research and projects in Canada and Turkey; and Field trip and Attitude, sensitivity, and responsibility in Australia, Singapore, and Ireland. Stevenson (2007) indicated that teaching materials about the environment are mostly used in the Australian and US educational systems.

There are no objectives regarding Field trip in physics subject in all countries. The categories of Material development and Research and project were included only in Turkey. There are no objectives regarding the categories of Material development and Field trip in chemistry subject in all countries. On the other hand, Wilson & Monroe (2005) in their study of writing skills regarding biodiversity found that the materials and activities in line with the curricula have a significant effect on students' attitudes and skills.

Objectives regarding the category of Identifying issues and research question (the identification of the issue, variable and writing research questions) in biology subject were included only in Australia. EA was found to be included at a low level in all subjects and levels except biology subject. In parallel with similar studies, the increase of out-of-class activities in environmental education enables students to directly observe various environmental events and cases. Thus, individuals directly interact with real problems to develop values, knowledge, and skills to find solutions to environmental problems (Stevenson, 2007; Ajiboye & Olatundun, 2010). However, environmental education cannot be moved out of the classroom in primary and secondary educations. Environmental education is neglected by teachers, curriculum designers, and researchers. Financial difficulties and transportations problems, such as the cost of field trips, can be listed among the factors that bring teachers to adhere to textbooks (Biggs and Tap, 1986; Martin, 2003). Curriculum designers should include field trips and research and project activities at a sufficient level when designing a curriculum to equip students with knowledge and skills that will contribute to the solution of environmental problems (Olatundun & Adu, 2013). Farmer, Knapp, & Benton (2007) in their study asserted that students indicate that students remember the places they saw and experienced in an interview one year after the field trip.

Note

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Candidate Classroom Teachers' Perceptions about being Scientific in the Context of Pseudoscience

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Abstract

The current study, aiming at investigating the perceptions of candidate classroom teachers for being scientific and examining the effect of the intervention comprising particular characteristics of demarcation on those perceptions, was interpretative in nature. Two data sources were utilized in order to determine their pre and post perceptions. Candidates performed poorly in the process of concluding on the status of pseudoscientific knowledge claims. But, after the intervention that based on pre-determined characteristics, the guided participants were seemed to reason more validly and able to evaluate the status of the cases they investigated for being scientific or not.

Introduction

Scientific and technological developments such as genetic copying, journeys to deep inside the space and even colonizing in different planets increase the prosperity level and life quality of human being, thus making science an indispensable part of our social life. It is even suggested that it will not be possible to argue values, socio-economic issues and objectives of education without considering the role of science (Hurd, 1998). But, it still seems controversial to define science as a way of knowing at least philosophically. Various philosophers and schools of thought such as logical positivists, Popper, Kuhn, Lakatos and Feyerabend had developed their definitions of science and tried to establish boundaries for it but their perceptions with regard to the processes, validity criterions and even credibility of science were seen diverged (Dilworth, 2006; Mahner, 2007; Nickles, 2006). On the other hand, apart from philosophical debates, some researchers tried to reveal general definitions of science in order to construct a common platform of dialogue and cited science as the techniques to have an access to knowledge in a secure way (Feder, 2014) or as the activity of revealing valid/reliable generalizations, explanations that attempt to answer the questions regarding the natural word which are open to criticism (McComas, 1996). The related literature on nature of science (NOS) and the proposed aspects of it can also be viewed in this manner (Gauch, 2009; Lederman, 1998). So talking about science and its common characteristics such as having empirically based data and etc. across the well-known scientific disciplines and constructing boundaries for science seems unproblematic, at least for scientists (Bauer, 2001; Derry, 1999).

The demarcation issue should be tackled as the distinction of science from pseudoscience or nonscience, but the extensive meanings of these concepts must be clarified. The concept of nonscience has been clarified by the use of fields such as the humanities disciplines, arts, religion and literature (Laudan 1983; Mahner 2007). These fields are not usually considered scientific; also their ontological and epistemological presuppositions vary from those of the natural sciences (Turgut, 2011). Hence nonscience is to be understood as an inclusive concept involving various fields of knowledge which do not allege to be scientific. Pseudoscience is quite different that is, disciplines in this category often claim to be scientific, although they do not meet the various standards set by science philosophers (Preece and Baxter 2000).

However, when the issue of being scientific is handled in the context of pseudoscientific knowledge claims and disciplines, the criteria to be used become fuzzy. The issue of demarcation of science and pseudoscience requires criteria that would be valid for all disciplines of science without any debate which seems to be not achieved yet (Gillies, 1998; Nickles, 2006). Many of the criteria proposed by various philosophers of science were marked as either too narrow or too broad, or found to be generally unsatisfactory. Indeed, some have argued about the impossibility of identifying certain criteria for a clear-cut demarcation of scientific areas of inquiry from nonscientific ones (Laudan 1983; Mahner 2007). It is widely argued that to define science in a simple way or to draw the borders of science with strict lines cannot be possible because of the complexity of scientific enterprise (Turgut, 2011). For some instances, controversies (as a processes) themselves would be more valuable than their results. Then the problem is not just related with the criteria of demarcation to be used; (i) recent inquiries and data can change the opinions and, (ii) some psychological factors can much more be determinant than the accepted criteria. There exist some historical cases for the first one, such as acupuncture, which was previously considered as pseudoscientific (Allchin, 1996), but then was partly accepted as scientific after particular controlled experiments performed (Ulett, Han & Han, 1998). The well-known pseudoscientific astrology can be viewed for the second one, dealing with the effect of heavenly bodies on human psychology and hence claims the tasks of astronomy and psychology, which still seems accepted as scientific in many circles (Francis & Robbins, 2007; Lundström, 2007; Losh & Nzekwe, 2011). On the other hand, in order to overcome the difficulties at least partially in the context of the issue of demarcation, the approach of Smith and Scharmann (1999) can be adopted since the proposed criteria are debatable. In that approach, the problem is seen as 'What are the features that make the field of research more scientific or less scientific?' instead of 'Is this field of research scientific or not?' by rejecting the idea of strict demarcation. Smith and Scharmann (1999) provided a reflective synthesis and draw some implications of these proposals for teacher preparation. Their suggestions can be thought as a continuous distribution that there is science, on one side, and non-science, on the other. In addition to this, they proposed the characteristics that make a field of study more scientific or less scientific. They classified the characteristics that make a field of study more scientific as "The Objects and Processes of Study" and "Values of Science". On the other hand the same researchers stated that "Espousing a Theological Position", "Valuing Authority over Evidence", and "Fideism" as the characteristics that make a field of study less scientific. Based on the literature about the demarcation problem, it is considered that Smith and Scharmann's approach is more suitable than drawing the borders of science with strict lines. Additionally, individuals are faced with various pseudo-scientific claims and need to make a decision or judgement about these claims. So using some characteristics or criteria is an inevitable necessity in the demarcation process when considering the frequency of encountering pseudoscientific claims in daily life. Therefore, teaching the characteristics of science to learners is better than drawing the borders of science. Accordingly, in the current study we presented some characteristics of science to the participants to use in the demarcation.

The astrology type instances indicate that the credibility and public prestige of science leads to the emergence of many types of pseudoscientific claims in the guise of science that are presented especially with the label of *logy* as a marketing tactic (Turgut, 2009; Turgut, Akçay & İrez, 2010; Turgut, 2011; Uslu, 2011). Therefore, the problem of pseudoscience is not just a philosophical and/or technical issue; it has some public and economic dimensions that are to be considered (Nickles, 2006). It should be asserted that to demarcate scientific theories or research from pseudoscientific ones and conspiracy theories is crucial for also sociological motives (Turgut, 2009; Turgut, Akçay & İrez, 2010; Uslu, 2011). The public and sociological aspects of the issue require introducing pseudoscience to society at least conceptually. As a threshold matter, without ignoring the philosophical difficulties in formulating the strict criteria for demarcation, the phrase of pseudoscience can be presented in a simple way as a wholesome of the claims deprived of scientific proofs and cogency even though it appears with the claim of being scientific (Shermer, 1997). In other words, as mentioned above the pseudoscientific claims are proposed to be scientific by their proponents but they are mostly regarded as not scientific since they do not meet the scientific standards such as to be verifiable either experimentally or theoretically (Finn, Bothe & Bramlett, 2005; Jahoda, 1969; Preece & Baxter, 2000).

As stated above, since pseudoscientific claims are presented with the label of being scientific, they hide behind the prestige of science and therefore it becomes difficult for individuals to determine them (Tseng, Tsai, Hsieh, Hung & Huang, 2014). Related research showed that many pseudoscientific claims such as spacemen, telekinetic, astrology, lucky numbers and etc. are being approved by the society at non-ignorable level (Moore, 2005; National Science Board [NSB], 2006; Tobacyk, Milford, 1983) and media is assumed to play an important role in that approval by presenting them in an exciting fashion (Nickles, 2006). So, it is of crucial importance to train scientifically literate individuals who had developed qualified perceptions with regard to the pseudoscientific claims and the aspects of them which do not meet the standards of science (Turgut, 2009). The visions of modern educational reform movements and Elementary Science Education Curriculum of Turkey (Republic of Turkey Ministry of National Education [MEB], 2013) can also be interpreted in that way; scientific literacy was not put forward as a requirement for just particular professional groups and scientists, but aimed for all society and raising scientifically literate individuals was regarded as one of the significant objectives of science education.

The scientifically literate citizens of contemporary societies are expected to be aware of the scientific concepts, use scientific principles in an effective way, discuss scientific subject matters, make intended decisions and learn about the nature of scientific knowledge, while they are interacting with their environment (Murcia & Schibeci, 1999; Ryan & Aikenhead, 1992; Ryder, 2001). Developing those intended competencies require reflecting upon the learning environments and the search of meaningful contexts to be governed in order to provide individuals to practice them. Previous research performed with candidate teachers of science indicated that the context of the issue of demarcation of science and pseudoscience could be used effectively in this sense since standards and particular aspects of science were viewed in the scope and individuals were required to conclude with the use of the proposed criteria (Turgut, 2009; Turgut, Akçay & İrez, 2010; Turgut, 2011). Turgut (2009) pointed out that the science teacher candidates seem to lack skills necessary to examine science-pseudoscience difference critically which results in deficiencies in such an important demarcation. Also Turgut, Akçay & İrez, (2010) indicated that based on the results of their study conducted with 38 elementary science teacher candidates, the course design framed on demarcation of science from pseudoscience instead of a traditional NOS course involving broad discussions on all aspects of science could be used effectively in NOS instruction. In addition to these, Turgut (2011) suggested that a learning intervention based on the issue of demarcation of science from pseudoscience proved an effective instructional strategy, which a majority of teacher candidates claimed to plan to use in their future teachings. However, science courses of the Turkish Science Education Curriculum are planned from 3rd grade up to 8th grade and they are taught by classroom teachers at 3rd and 4th grades. Science teachers become a part of the curriculum at just 5th grade which means that students experience initial formal science practices with their classroom teachers. So, the role of classroom teachers seems crucial as the first step in the science curriculum (Akerson, Buzzelli & Donely, 2010) in the route of constituting an intellectual basis for perceptions of science in the scope of scientific literacy and related competencies in the early ages.

Research Questions

Given the importance of constituting an intellectual basis for individuals' perceptions of science in their early ages and the crucial role of classroom teachers in that process, the study was focused on Turkish pre-service classroom teachers' conceptions of being scientific in the context of pseudoscientific claims. It was asserted that in order to guide their students in developing informed perceptions of science, the classroom teachers initially themselves must have the required competencies. So the research questions of the study were as follows:

1) How do Turkish pre-service classroom teachers perceive "*Being Scientific*?"
2) How does the intervention based on the pre-determined characteristics of science affect Turkish pre-service classroom teachers' perceptions of "*Being Scientific*?"

Method

The current study, aiming at firstly investigating the perceptions of candidate classroom teachers for being scientific and then examining the effect of the intervention comprising particular characteristics of demarcation on those perceptions, was interpretative in nature. The methodology of the research was presented in terms of participants, intervention, data sources and analysis process under separate headings in detail below.

Participants and Course Context

The participants of the study were determined by purposeful sampling technique (Creswell, 2012) since the issue of the research was perceptions with regard to being scientific that questioned in the context of various pseudoscientific cases which requires having basic terminology of science to be understood. The primary criterion in the sampling process was to take fundamental science courses (physics, chemistry and biology) of the undergraduate classroom teacher education curriculum. Therefore, the research was confined to third grade teacher candidates in the context of the compulsory Science and Technology Education course that taught by one of the researchers for three hours a week. After the target group was determined, the secondary criterion of the sampling process was set as being volunteer to express perceptions and views with regard to the related issue. For this, an open-ended questionnaire developed by the researchers as data collection tool was introduced to 66 third grade candidate classroom teachers. They responded the questionnaire individually and after the overall analysis of their answers for content and explicitness, 60 of the candidates (26 males and 34 females, ages ranging from 20 to 25) were assigned to constitute the study group.

After the participants of the study determined, the researchers introduced the content and the objectives of the course (Science and Technology Education) to them and shared only the name of the cases. Then, the participants were asked to choose one of the cases from the pre-determined list comprising astrology, reflexology, healing stones, acupuncture, ufology, graphology, parapsychology and iridology in order to search for their fundamentals and basic claims for a period of one week. Multiple cases were preferred instead of just one, since it was aimed to allow participants to perform research into the subject matters that they were interested in. Each case was investigated by 4 to 10 participants voluntarily and to prevent any guidance, they were asked to investigate what the subject matter was, what kind of process it had, where and for what purposes they were used, by whom and when they were used. In order to prevent a guidance before the course, they were not asked to examine the status of the cases for being scientific or not and any discourse was not provided to them by the researchers before their research. Because we were wondering how they would evaluate being scientific of the cases when they searched for it on their own without any guidance.

The participants performed their research and prepared individually written reports with regard to the assigned cases. Then they were asked to conclude on the status of the cases and claims for being scientific or not with their rationales and warrants. As the next step, they were grouped according to the cases that they searched (e.g. the ones who searched astrology were Group 1, reflexology were Group 2 etc.) to discuss and re-evaluate the status of the cases within those groups. Following the group discussions, the characteristics of science (consistency, observability, being natural, predictability, testability, tentativeness - CONPTT) cited in the work of Dickhaus (1999) were presented one by one to participants and discussed with them in the class. In the presentation of the instruction about the meaning of the characteristics, question-answer and expository teaching methods were used by the researcher in the course of three lessons. In this process, some tasks were carried out and the assigned cases were partially examined by the participants through the presented characteristics. The intervention was comprised of three hours in addition to the research period and at the end of it, "Worksheet: Is It Science? Is It a Scientific Statement?" was applied to participants.

Data Sources and Analysis

In this research, two data sources were utilized in order to determine participants' pre and post perceptions about being scientific. The initial data source was a form that was used as pre-test in order to determine the participants' initial perceptions for being scientific. It was utilized after the participants completed their search for individually assigned cases (i.e. reflexology, acupuncture etc.) and therefore collected information with regard to their fundamentals. In the first question of the form, participants were asked to conclude for the case if it is being scientific or not and then in the second question they were invited to express their warrants and rationales. Based on their rationales and presented warrants, the characteristics that participants used in the process of evaluating any claim for its status of being scientific or not were tried to be determined. The data obtained through this form were analyzed qualitatively. In the analysis process, initially, the answer sheets of the participants were representatively renamed (as an example, the sheet of the first candidate teacher investigating the subject matter of astrology was renamed as A1). Then, the answers of each participant were reviewed in a way that they could allow to evaluate the expressions and particularly repeating concepts without breaking the unity inside them. For this, each answer sheet was read separately in order to code the potential concepts and thematic structures in short and the coding process was based on either just words or whole sentences, paragraphs (Bogdan & Biklen, 2007; Gay, Mills & Airasian, 2006).

The second data source of the research that was utilized to determine post perceptions of the participants for being scientific after the brief intervention was "Worksheet: Is It Science? Is It A Scientific Statement?". It was developed by Dickhaus (1999), adapted to Turkish by İrez and Turgut (2012) and constructed on a group of pre-determined characteristics such as consistency, observability, being natural, predictability, testability and tentativeness (CONPTT). With the help of that form, the participants were asked to re-evaluate the cases that they searched and evaluated with their own characteristics before the intervention. They filled the form and concluded on the status of the assigned cases for being scientific or not. In this process, the related cases meeting all the characteristics of science were qualified as scientific while those falling short in one or more of the characteristics of science were labelled as proto-scientific. Besides that, the cases that do not meet the characteristics despite having the claim of being scientific were classified as pseudoscientific. The category of non-scientific was also provided for the ones that do not meet the characteristics of science and do not have any claim of being scientific differently from the pseudoscientific ones.

Findings

The findings of the study presented in this section were organized according to the research questions and data collection procedures detailed previously. Hence, firstly the participants' initial perceptions with regard to status of assigned cases were given. Then the characteristics of science that they used in evaluating the cases, the within group discussions and their post perceptions about the status of the cases for being scientific were viewed.

Participants' Initial Perceptions about the Status of Assigned Cases

After they performed research on the fundamentals and basic claims of the assigned cases, the participants tried to conclude about the status of them for being scientific or not. The first question of the initial data source, the open ended form, was used for this aim and without any interpretation the participants answered it by labeling the case they searched as scientific or not. Some of the participants strictly labelled their cases as either scientific or pseudoscientific whereas some of them talked about the possibility of being scientific. The perceptions of participants and their distribution along the cases were presented in Table 1.

Table 1. Participants' initial perceptions about the status of assigned cases

	Astrology (n=8)	Reflexology (n=7)	Healing Stones (n=10)	Acupuncture (n=9)	Ufology (n=7)	Graphology (n=8)	Parapsychology (n=7)	Iridology (n=4)	Total
Scientific		4	2	5	1	4	1	4	21
Possible		1		1		2			4
Pseudoscientifc	3								3
Non-scientific	5	2	8	3	6	2	6		32

As given in Table 1, three participants out of 8 labelled astrology as pseudoscientific while five of them pointed out that it is non-scientific. It was not accurate that they were aware of the difference between pseudoscience and non-science but none of them qualified astrology as scientific. It was seen that an important portion of the participants investigating reflexology (4 out of 7), acupuncture (5 out of 9) and graphology (4 out of 8) regarded that these cases were within the limits of science. In addition, all of the participants who searched the case of iridology labelled it as scientific. On the other hand, the great majority of the participants examining healing stones (8 out of 10), ufology (6 out of 7) and parapsychology (6 out of 7) evaluated them out of scientific limits and hence non-scientific.

Participants' Initial Perceptions about the Characteristics of Science

In the second question of the initial data source, the open ended form, the participants were asked to justify their conclusions with regard to the status of the cases for being scientific or not that they investigated. Their responses were analyzed for the characteristics they presented in evaluating the assigned cases and the findings revealed were given in Table 2.

Table 2. Participants' Initial Perceptions about the Characteristics of Science

Characteristics	Astrology	Reflexology	Healing Stones	Acupuncture	Ufology	Graphology	Parapsychology	Iridology	Total
Being Natural	3	3	6	3	4	2	8	1	30
Verifiable	4	2	7	5	6	1	2	1	28
Observability	4	6	-	4	3	-	3	2	21
Consistency	3	3	2	4	1	1	4	1	19
Expert Opinion	1	5	3	7	4	1	4	1	26
Institutionalism	3	1	5	3	1	3	1	-	17
Terminology	-	2	2	2	2	3	-	2	13
Persistency	-	2	3	2	-	1	1	-	9

It was seen that participants proposed several characteristics of science in the scope of the cases they investigated. Among these, ontological ones were in the forefront such as being natural, verifiable and observable. In addition participants also cited psychological characteristics such as expert opinion and rational/methodological characteristics such as consistency. The distribution of those characteristics across the cases indicated that being natural, verifiable and consistent were offered for all by the participants.

The criterion which was mostly cited (f=30) in evaluating the status of knowledge claims for being scientific was being natural. With that criterion participants focused on the ontology of the entities which were mentioned as the subject of the investigated case and limited the boundaries of science and hence being scientific to physical universe. In accordance, they also indicated being verifiable (f=28) and observable (f=21) as characteristics of science:

> Such things as changing of dimension by human being, reading them mind etc. are out of material today and things out of material are not a science but metaphysics (P 5).
>
> Astrology examines the effects of celestial bodies on human character and it cannot be proved. We cannot prove the effects of celestial bodies on human character (A 3).
>
> It is scientific if a spot is minimized in the eye of a human being and his disease is known, when we have a look at the symptoms of the diseases depending on the spot and the severity of it is decreased (I 2).

The approach of the participants with regard to the issue of being scientific was seen consistent at ontological level; they provided being natural, observable and verifiable. Although they did not detail the issues of being verifiable and observable in direct or indirect forms, they explicitly reflected the boundary and methodology of science.

As being natural and verifiable, participants also cited the criterion of being consistent (f=19) in all the cases. By consistency some of the participants referred to methodological procedures such as yielding same results in repeated treatments whereas some others mentioned being free of self-contradictions:

> Acupuncture treatments cause varying outcomes for different people. The effects of the treatment are not observed as they asserted for all the patients (AC 6).
>
> It is not rational and reasonable. Why people should arrange their lives according to astrology? It has contradictory aspects. Also astrologers contradict each other and astrology does not seem consistent (A 4).

It was seen that participants offered the criterion of consistency partially in parallel with ontological ones. Some of them claimed to be repeatable and the requirement of yielding the same results in repeated practices by independent researchers as criterion of being scientific. In addition some of them underlined the rational/logical unity and consistency of arguments that provided by the proponents of the investigated cases.

Another group of characteristics participants provided were based on the notion of authority. They cited expert opinion (f=26), institutional approval (f=17) and use of scientific terminology (f=13) in the process of concluding the status of the cases they investigated for being scientific or not. The common factor in those characteristics was seen to be their social emphasis, prestige and connotation of authority on people and hence participants:

> There are not enough experts in this field. The ones in the field are trained in very short time and it is not enough to become a specialist. They are not educated in the universities. Many doctors and academicians do not think that it is scientific (R 2).
>
> If it were scientific, modern medical institutions would approve and not try to produce drugs for the diseases instead of healing stones. They would easily heal the patients with those stones (HS 7).
>
> When we look at the formula of active elements of healing stones, we see scientific, chemical components. In addition their origin is explained scientifically by the movements of the magma (HS 10).

The concept of expert was associated with academic titles or diplomas by participants and hence having formal education on related topics was seen as requirement by them. Institutional approval was also thought in parallel and journals, university departments or organized congresses were offered with the idea of authority behind. In addition the prestige of widely accepted scientific terms and concepts were seen to be in their agenda because of their natural evocation of science.

An additional criterion which was presented by a group participants (f=9) for the status of knowledge claims for being scientific or not was persistency. The historical background and discourses ever since ancient times with regard to the fundamentals of the investigated cases were seen to provide credit for the participants:

> While searching the basics of graphology, I considered that the history of it goes back to the antiquity. A practice which continues to exist since ancient times would be scientific. If it was not scientific it would be denied (G 1).

It was seen that participants presented the criterion of persistency with the notion of being surviving for long periods of time and resisting to counter arguments successfully which meant being valid and hence scientific. Their approach was based on the assertion that just valid and reliable claims would proceed in the history whereas the ones that do not meet those qualifications would be denied inevitably.

Participants' Perceptions Following Group Discussions

After the individual evaluations were performed and reported by the participants, with regard to the status of the cases for being scientific or not, they were grouped according to the cases investigated. Within groups, participants shared their own opinions with other members and discussed the status of the common cases they investigated with their warrants. Following group discussions, participants' perceptions about the cases and characteristics of science were reviewed. It was seen that any change was not observed in the evaluations of the participants investigating the cases of astrology, reflexology, healing stones and iridology. However, a participant claiming that ufology is scientific changed his mind and labelled it as being out of science after within group discussions:

> It is not scientific as the existences of UFOs have not been proven, there is no official proof and no empirical observation has been carried out in this sense (U 2).

It is likely to see that the characteristics leading to the change in the ideas of that participant were being observable and verifiable, hence to be proved. Similarly, a participant investigating the case of graphology and once having a claim that it is scientific changed his mind and then expressed graphology as being out of science:

> It is not scientific since there is versatility in the tools and materials used in writing, in surrounding and how graphologists examine it (G 2).

As for the expression of the participant, the criterion leading to a change in his idea was consistency. Being consistent was also one of the characteristics for a participant who changed his mind with regard to the status of parapsychology:

> The subject matter of science is material but parapsychology has a content of metaphysics. There is a problem of repetition in the studies carried out. The studies carried out have not been supervised enough and have not been documented (P 6).

It was obvious that the participant changed his mind in line with the characteristics of being natural and consistent. In addition, a participant regarding acupuncture as possibly scientific beforehand changed his mind and claimed that it is within the limits of science after group discussions:

> It is within the science of medicine. It is a healing applied by trained experts. The application fields and rules of acupuncture were determined with the regulation of Official Gazette by the Ministry of Health in Turkey (AC 6).

It was seen that the participant altered his view in accordance with the characteristics of institutional approval and expert opinion. Based on those presented above, it could be stated that participants persist on their perceptions about the status of the cases for being scientific or not to a great extent in group discussions. Just four participants out of 60 changed their minds and the characteristics they used in that process were mainly ontological and rational/methodological ones.

Participants' Post Perceptions about the Status of Assigned Cases

As presented in the section of course context, after group discussions performed, the characteristics of science (CONPTT) cited in the work of Dickhaus (1999) were provided to participants and they discussed the cases in class with the help of those characteristics. At the end of this process they individually filled the "Worksheet: Is It Science? Is It A Scientific Statement?" form and concluded the status of the case they investigated for being scientific or not. The findings obtained through the analysis of those worksheets were given together with the findings of first questionnaire and group work in Table 3 in order to interpret the possible changes across the whole process.

Table 3. Participants' post perceptions about the status of assigned cases

		Pseudoscientific	Undecided	Proto-Scientific	Scientific	Non-Scientific
Astrology	First View	3	-	-	-	5
	Group-work	3	-	-	-	5
	Final View	8	-	-	-	-
Reflexology	First View	-	1	-	4	2
	Group-work	-	1	-	4	2
	Final View	6	-	1	-	-
Healing Stones	First View	-	-	-	2	8
	Group-work	-	-	-	2	8
	Final View	8	-	2	-	-
Acupuncture	First View	-	1	-	5	3
	Group-work	-	-	-	6	3
	Final View	3	-	5	1	-
Ufology	First View	-	-	-	1	6
	Group-work	-	-	-	-	7
	Final View	7	-	-	-	-
Graphology	First View	-	2	-	4	2
	Group-work	-	2	-	3	3
	Final View	8	-	-	-	-
Parapsychology	First View	-	-	-	1	6
	Group-work	-	-	-	-	7
	Final View	7	-	-	-	-
Iridology	First View	-	-	-	4	-
	Group-work	-	-	-	4	-
	Final View	1	-	3	-	-
Total	First View	3	4	-	21	32
	Group-work	3	3	-	19	35
	Final View	48	-	11	1	-

As given in Table 3, all of the participants (n=8) investigating the case of astrology concluded that astrology is a pseudoscience at the end of the process. Although none of them qualified astrology as scientific previously, it was seen that the ones who labelled it as non-scientific (n=5) shifted their terminology then to being pseudoscientific. Similarly, the majority of the participants examining the case of reflexology (n=7) decided that it is pseudoscientific at the end of intervention. Four participants who thought reflexology as scientific and two participants who thought reflexology as non-scientific concluded that it is pseudo-scientific. For the case of healing stones, the great majority of the participants (n=8) came to the point that it is pseudoscientific whereas two of them indicated that it could be proto-scientific. It was obvious that the ones (n=2) claiming healing stones as scientific gave up their opinion. One of the participants (out of 6) investigating the case of acupuncture persisted in his view that it is scientific while rest of them (n=5) regarded acupuncture as proto-scientific. Three participants in this group once regarded it as non-scientific then claimed that pseudoscience is the right concept to define acupuncture. All of the participants investigating the cases of ufology (n=7), graphology (n=8) and parapsychology (n=7) regarded them as being pseudoscientific in their final view. It was seen that most of the participants investigating ufology and parapsychology changed their views from being non-scientific to pseudoscientific. The participants' perceptions with regard to the case of iridology who previously indicated that it is scientific were also shifted but most of them (n=3 out of 4) did not labelled it as being pseudoscientific. Instead, they concluded that it could be viewed as proto-scientific.

To sum up, it was seen that participants' perceptions with regard to the status of the cases they investigated for being scientific or not were differed slightly along with group discussions. Just four participants (out of 60) changed their minds and 19 participants persisted in their views about the status of the cases that they are being scientific. However, a clear distinction became apparent after the intervention performed in the class that based on the pre-determined characteristics (CONPTT). Just one participant remained with the perception of being scientific (for the case of acupuncture) and nearly all the participants who claimed the cases they investigated to be non-scientific modified their perceptions to being pseudoscientific. In addition, it was determined that some of the participants (n=11) encountered the concept of being proto-scientific after the intervention. Similarly, while most of the participants did not cite the concept of being pseudoscientific previously (comprising also the perceptions after group discussions) except for astrology, a great many participants (n=48) changed their mind and eventually regarded the cases they investigated in the context of pseudoscience.

Discussion and Conclusion

Depending on the findings of the study, it is likely to see that an important portion of the participants (n=21) initially regarded the cases they investigated as being scientific and some of them (n=4) thought them as possible to be scientific. It reveals that even though some of the candidate teachers investigated that subject matter, they were not able to make a detailed reasoning. Such a result was in compliance with research indicating that various pseudoscientific claims as telekinesis, astrology, lucky numbers, or so have considerably been approved by the community (Tobacyk & Milford, 1983; National Science Board [NSB], 2006; Moore, 2005), expected reasoning skills cannot be used when encountered with paranormal claims (Wang & Lin, 2005) and even individuals having education in science could not apply scientific knowledge and skills adequately in the process of evaluating pseudoscientific claims (Afonsoa & Gilbert, 2010; Johnson & Pigliucci, 2004; Losh & Nzekwe, 2011; Walker, Hoekstra & Vogl, 2002). The approval of those pseudoscientific claims by the community and educated individuals such as university students was warranted partly with the impact of television programs (Tseng, Tsai, Hsieh, Hung & Huang, 2014). Also Mugaloglu (2014) indicated that learners are accepted existing pseudoscientific beliefs because of exposing to alternative constructions through social negotiation than to furthering their appreciation of science. However, it is well known that believing in pseudoscientific claims has mediate and immediate harms (Lindem, 2014) and to develop educational practices in order to create public awareness against them is crucial. For instance, Sagan (1996) expressed that ex US President Ronald Regan and his wife consulted to an astrologist because of their private and social problems which would cause possible negative effects on American community.

On the other hand, it was seen that just the participants investigating astrology regarded their case initially as being either pseudoscientific or non-scientific and hence none of them labelled it as being scientific. This finding was seemed in contrast with research carried out by citizens (Losh, Tavani, Njoroge, Wilke & Mcauley, 2003), teachers (Kallery, 2001) and candidate teachers (Turgut, 2011) since they revealed that there is a widespread belief for the status of astrology as being scientific. So that, Sugarman, Impey, Buxner, & Antonellis, (2011) indicated astrology is accepted being scientific by individuals who have strong performance on science knowledge indicators. However, when it was realized that participants searched related literature and viewed the increased popular/explicit claims identifying astrology as being pseudoscientific, it was thought as reasonable since just some of those participants (n=3) used the expression of pseudoscience. The issue that why rest of the participants (n=52 for other cases in total) did not cite pseudoscience would also be questioned for the sources they viewed but it can also be mentioned that majority of the participants used the phrase of non-scientific in their initial conclusions.

In terms of the findings of the study, participants were seen to put emphasis on ontological, methodological and psychological characteristics such as being natural (f=30), verifiable (f=28), observable (f=21), consistent (f=19) and persistent (f=9) while investigating the status of any claim for being scientific or not based on their individual research. The overall evaluation of that profile revealed that participants mainly focused on empirical aspects of science with the notions of being natural, observable, and verifiable in accord with various research results. For instance, Sperandeo (2004) pointed out that a great majority of physics teachers regarded physics as an accumulation of observation and explanation that was gathered in order to be proved and Tsai (2002) determined that a great majority of science teachers' views about science were based on realist perspective. Ayvacı and Er Nas (2010) indicated that scientific knowledge is asserted to be achieved just through experimental proving by half of the science and technology teachers who participated in their study and Turgut

(2009) expressed that although candidate teachers of science were seemed to perceive the dialectic of the controlled experiments in science, they had some misconceptions regarding the meaning of experiments in the formation and testing of scientific knowledge. Related research showed that similar perceptions were also observed in the forms of absolute knowledge based on experimental method, developing knowledge through process of proving and assumption of objective epistemology (Hofer, 2000; Roth & Roychoudhury, 1994). Nevertheless, if the notion of the improvability of the hypothetic theories (Martin, 1994) and basic presuppositions of modern science such as "objective external reality" and "causality" considered (Suchting, 1995), it can be claimed that the current perceptions of the candidates remained limited with traditional science paradigm. Those results obtained in related research in accordance with the ones in this study can be argued to be based on the fact that students perceive science mostly through the course books, teachers and laboratory practices in which the conception of science is limited to its experimental aspect and process of proving (Turgut, 2009; Ayvacı, Er Nas, 2010).

It was also found that some of the participants assumed expert opinion (f=26), institutional approval (f=17), use of scientific terminology (f=13) and being persistent in history (f=9) to be determinant for them in evaluating the status of knowledge claims for being scientific or not. It is known that pseudoscientific claims are supposed to be scientific by their proponents and various tactics are used by them in order to reinforce that conception even though those claims do not meet scientific criteria (Shermer, 1997). In this study, it was seen that the assertion of the approval of experts or institutions, inclusion of some scientific terms and having a long history back to ancient times caused to raise the perception of being scientific for the cases investigated in some of the participants' minds naively. That result was obvious to see the importance of psychological criteria for some of the participants either based on the notion of authority or the belief that true one survives in the history, despite the ones that indicate informed views such as being consistent (f=19) and natural (f=30).

Another striking result that revealed in this study was the ineffectiveness of the unguided group discussions, performed in the class, in adopting the perceptions of participants. Just three candidate teachers revised their opinions about the status of the cases they investigated from being scientific to non-scientific and one from undecided to scientific through the discussions within groups after they reflected on mostly cited characteristics of being verifiable, observable, consistent and natural. On the other hand, a considerable alteration was determined in the perceptions of participants about the status of cases they investigated following the intervention performed in the class by one of the researchers that based on pre-determined characteristics of CONPTT. Initially, an important portion of the participants (n=21) thought that their assigned cases were scientific whereas at the end of the process just one participant seemed to persist in his view. In addition, the participants (n=11) who did not previously mentioned the concept of proto-science introduced that concept after the intervention, particularly for the status of acupuncture. Similarly, it was seen that just three participants used the concept of pseudoscience in their evaluations before the intervention but then great majority of the participants (n=48) were able to cite it accurately in their worksheets for the cases they investigated. In fact, those participants were previously seen to adopt the concept of non-science for the cases and could not differentiate the non-scientific from pseudoscientific while labelling the claims as being out of science. So, it can be asserted that an important gain for the participants in this research was to develop awareness about the difference between pseudoscientific and non-scientific disciplines since the former is sometimes used pejoratively instead of the latter for various claims (e.g. religious ones) in some circles (Turgut, 2011).

To conclude on the status of various claims, for if they should take place within limits of science and hence if they should benefit from the public prestige of it, seems crucial when we consider the value and credit of science in modern society. In fact, that is the controversial demarcation problem and it must be noted that having strict positions in this context is claimed to be impossible at least philosophically (Nickles, 2006). However, as seen in this research, the cited difficulties in the issue of science versus pseudoscience can be possibly overcame to some extent if the approach of Smith and Scharmann (1999) is adopted to the context by rejecting the idea of strict demarcation and replacing the question of 'Is this field of research scientific or not?' by 'What are the features that make the field of research more scientific or less scientific?'. It was seen that candidate classroom teachers previously used the characteristics that dominantly based on the notion of being empirical and performed poorly in the process of concluding the status of knowledge claims. But after the intervention that based on pre-determined characteristics in line with the approach cited above was performed, the guided participants were seemed to reason more validly and able to evaluate the status of the cases they investigated for being scientific or not.

It is clear that it is not possible to define science in a simple way or draw the borders of science with strict lines. Whether science should take its place within the limits of science when we consider the value of science in the presence of community or how close these limits are is an important problem. Depending on the results of the research, it is likely to see that candidate teachers applied for the characteristics which are more suitable for the traditional conception of science in the process of decision making regarding the being scientific of a case. Similarly Metin, & Ertepinar (2016) indicated that teacher candidates would have difficulties to transfer their understanding about science into other issues and although they were aware of the scientific process, they had difficulties to demarcate science from pseudoscience. However, the present study results indicate that their reasoning abilities increased when they were given some characteristics of science that the candidate teachers could apply in determining being scientific. Also, it is suggested that using pseudoscientific cases is a useful tool to promote critical thinking (De Robertis, & Delaney, 2000; Metin, & Ertepinar 2016). For this reasons, it is of crucial importance that the candidate teachers be made to perceive the sense of modern science in educational process and be taught the characteristics of science they could use in evaluating being scientific.

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Improving Elementary School Teacher Candidates' Views of Nature of Science through Intensive Education

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Abstract

Elementary school teacher candidates' (student teachers or STs) views of nature of science are important for an effective science teaching that aims to improve children's scientific literacy. The purpose of this study was to improve STs' views of nature of science through an intensive intervention. The study group consisted of 65 third year STs who were attending a major university in Ankara Turkey during the 2015 – 2016 fall semester. An educational program with a variety of activities that were designed to help improve participants' views of nature of science was applied and the effect of this program was evaluated. The educational program included historical approach activities, generic activities, explicit-reflective approach activities, and media news analysis activities which were applied in three hour periods over the course of nine weeks. Both qualitative and quantitative data were collected in this convergent parallel mixed method study. At the beginning of the study, the participating STs had naive views of nature of science and some misconceptions. After the applied educational program, STs' views of nature of science improved and they adopted more contemporary views of science. As a result, a long-term intervention with multiple methods of teaching with different kinds of activities was found to be an effective approach for improving STs' understanding of nature of science.

Introduction

In the 21st century, the amount of scientific knowledge increases exponentially and technology advances very fast which pose challenges to the general public. These fast advancements in science and technology increase the importance of educating people with skills and experience to deal with such challenges. In Turkey and in many countries around the world, improving science education for the purpose of preparing citizens with the required skills of the 21st century is an ongoing effort. In today's world, using knowledge is a more important skill than searching or finding knowledge. Accordingly, the most important purpose of today's science education is to educate individuals to become scientifically literate (American Association for the Advancement of Science [AAAS], 1990; National Research Council [NRC], 1996, 2011; Ministry of National Education [MNE], 2013, 2017; NGSS Lead States, 2013; The Organization for Economic Co-operation and Development [OECD], 2015). Turkey, like other developing countries, ascribes importance to science education, which is seen as a key to develop the nation's economy. To serve this purpose, new science education curriculums are prepared to educate individuals who can create new knowledge and make important discoveries. The Turkish science education curriculum was renewed in 2013 and 2018 and in both curriculum documents, vision was stated as "all students to be trained as scientifically literate individuals" (MNE, 2013, 2018). Nature of science (NOS) is one of the most important dimensions of scientific literacy. For a person to be scientifically literate, his/her understanding of NOS has to be adequate (AAAS, 1990, Çepni, 2011; Lederman, 1992; McComas vd., 2000). However, Program for International Student Assessment (PISA) 2015 results showed that Turkish students' scientific literacy results are significantly lower than the OECD average (OECD, 2015). This is a strong indication that more should be done to improve students' NOS understanding and scientific literacy. Improving teacher education is an obvious place to start to this end.

One of the important subjects of NOS is to explain what science is. Science is an ever changing, developing, multi-dimensional, and complex phenomenon that to agree on a definition of science is very difficult. The 10^{th} grade biology textbook in Turkey define science as "regular knowledge accumulated through objective experiments and observations." This definition proposes a positivist science understanding by suggesting objective observations and experiments are possible. It does not mention scientists' prior knowledge, education, subjective point of view, creativity, and socio-cultural environment which are factors that influence their interpretation of observational and experimental data (Doğan et al., 2012). Similar positivist approaches to science and scientific knowledge in educational resources create misconceptions or scientific myths. McComas (1996) reported the following myths that students have about NOS: (i) hypotheses turn into theories, theories turn into scientific laws, (ii) there is a universal scientific method, (iii) scientific method provides certain evidence, (iv) scientific method can answer all questions, (v) scientists are objective, (vi) main way to reach knowledge is experiment, (vii) scientific results are verified experimentation, (viii) scientific knowledge is certain and it's correctness cannot be discussed, (ix) science and technology are similar to each other, (x) science is not a teamwork, it is an individual effort.

Lederman (1992) defined NOS as values and assumptions in the scientific enterprise. McComas and Olson (1998) explained that NOS is about answers given to the questions such as: What is science? How is it done? How do scientists work? What are the effects of scientific and cultural realm on science? Just like the definition of science, there is no consensus on what NOS is. However, to provide a framework for teaching and learning of NOS, a consensus has been reached among some science educators on what students and teachers should know about NOS (Bell et al., 2000; Deboer, 2000; Lederman, 1992; Matthews, 1996). Lederman (2007) listed seven themes to describe the so called "consensus view of NOS." These themes are:

1. Scientific knowledge is tentative: scientific knowledge is stable but it is never certain or absolutely true. Scientific knowledge changes through evolutionary and revolutionary processes. Scientific knowledge may change with new data or reevaluation of existing data.
2. Scientific knowledge is based on evidence: science is based on direct or indirect observation of the natural world. Science is not only based on scientific evidence, it's also based on logical inferences. Scientific knowledge is supported through experimental data but it is never proved. Observation and inference should not be confused with each other. Scientists may have different inferences of same observations.
3. Scientific knowledge involves subjectivity: Scientists' prior knowledge, experience, values and beliefs, education and expectations influence their study and the results they reach.
4. Scientific knowledge is created with creativity and imagination: Scientists use their creativity and imagination in every stage of their scientific work.
5. Science is influenced by the sociocultural environment: Political establishment, social values, economic conditions, and cultural structure influence how, what and to what degree scientists study a subject.
6. Scientific theories and laws: Theories are scientific explanations while laws are scientific descriptions of the natural phenomenon. They serve different purposes in science and there is no hierarchical relationship between them.
7. Scientific method: There is no one universal scientific method that all scientists follow. Many different fields of science use many different methods to produce scientific knowledge.

In this study, we focused on the first four themes since these are the most appropriate for the elementary school level (Lederman & Lederman, 2005). The study group consisted of elementary school STs and therefore we concentrated our efforts for teaching and learning of the most relevant NOS themes for the elementary level.

In the literature, there are three different approaches to teach this view of NOS: historical approach, implicit approach and explicit-reflective approach. In historical approach, NOS is taught through discussions about how scientific knowledge changed over time and lives of scientists and their work (Khishfe & Abd-El-Khalick, 2002). Implicit approach is based on the idea that students can learn about NOS while doing inquiry-based activities (Abd-El-Khalick & Lederman, 2000). In this approach, it is assumed that students can learn NOS as they work like scientists in the classroom. However research has shown that implicit approach is not very effective in teaching NOS (Abd-El-Khalick, 2002; Khishfe & Abd-El-Khalick, 2002; Lederman, 1992). According to explicit reflective approach, students learn NOS best if it is discussed with students during and after inquiry activities in the classroom rather than waiting for students to figure out what it is for themselves (Abd-El-Khalick & Lederman, 2000). In this approach, themes of NOS are discussed with students explicitly. Research shows that explicit reflective approaches are more effective in helping children learn about NOS compared to other approaches (Schwartz & Lederman, 2002; Schwartz et al, 2004).

One of the new approaches in teaching NOS involves using popular media news about science (Çakmakçı & Yalaki, 2012). Students understanding of NOS can be improved by asking them questions about scientific studies mentioned in printed or visual media such as: What is the scientific claim in this news? What evidence did scientists use to support their claims? What methods of science were mentioned in the news? How science is influenced by the social and cultural environment? Another new approach that is used recently to teach NOS involves using documentary films to help students understand NOS (Seçkin Kapucu & Çakmakçı, 2015). In this approach, systematically planned and used documentary movies are suggested to help students to learn about NOS. Generic activities that are not related to science subjects or science activities have also been used for teaching NOS (Lederman, 2007). However activities that are integrated into science subjects may provide better results, which is a claim that needs to be further investigated.

Although understanding of NOS is considered to be one of the basic elements of scientific literacy, research shows that students, STs, and teachers do not have an adequate understanding of NOS (Abd-El-Khalick & Lederman, 2000; Aslan, Yalçın &Taşar, 2009; Doğan &Abd-El-Khalick, 2008; Doğan et al., 2012; Khishfe & Abd-El-Khalick, 2002; Köseoğlu, Tümay & Üstün, 2010; Lederman et al., 2002; Lederman, 1992, 2007; Taşar, 2003). Lederman (2007) argued that the reason why students are not at a desired level in terms of NOS understanding is because of the misconceptions that their teachers have. Within the framework of postmodern arguments that criticized the positivist views of science, todays' understanding of NOS is shaped. However, a naive positivist understanding of science is still at the root of most teachers' misconceptions about NOS (Bell et al, 2003; Lederman, 1992; McComas, 1996). Studies showed that both teachers and STs require in-service and preservice training to improve their understanding of NOS (Lederman, 2007). To improve students', STs', and teachers' understanding of NOS, it should be taught effectively. Research shows that every approach used in teaching of NOS is effective in developing certain themes of NOS understanding and no singe approach is enough to develop all of the NOS themes alone (Lederman, 1992; Lederman et al., 2002; Khishfe & Abd-El-Khalick, 2002; Khishfe, 2008). Because of this, various approaches of teaching NOS were utilized together in this study to achieve a more effective NOS teaching and learning.

The role of classroom teachers on young children's learning of NOS is obvious. Accordingly, elementary level STs' views of NOS have a direct influence on young students understanding of NOS. If classroom teachers' NOS views can be enriched by contemporary ideas, they may use better strategies in teaching NOS to young students. One of the duties of classroom teachers is to help their students learn NOS appropriately and help them develop an adequate scientific literacy. However, literature review revealed that the number of studies that investigated elementary level STs' understanding of NOS is relatively limited in Turkey (Tatar, Karakuyu & Tüysüz 2011a, 2011b). Therefore, the purpose of this study was to improve STs' understanding of NOS and how to teach it. As indicated in many studies, different techniques should be applied for an extended period of time to change misconceptions about science (Tuan & Chin, 1999). For this purpose, a teaching plan, which included multiple approaches of teaching, was developed to improve STs' understanding of NOS. The teaching plan included historical approach activities, generic activities, explicit-reflective approach activities, and media news investigation activities which were applied three hours a week for nine weeks. These approaches to teach NOS were used in the literature by various researchers and they were reported to be effective in teaching certain aspects of NOS (Cakmakci &Yalaki, 2012; Khishfe & Abd-El-Khalick, 2002; Michel & Neumann, 2016; Tolvanen, Jansson, Vesterinen, & Aksela, 2014). Although there are more approaches to teaching NOS, the chosen methods were a good representation of what is studied in the literature. We investigated the effects of this teaching plan on STs' understanding of NOS.

The intensive intervention that includes a variety of approaches for teaching NOS to ST's is the main characteristic of this study. As Ochanji (2003) indicate, teacher education programs should offer more than a superficial knowledge and understanding of NOS for future teachers to teach it effectively in their classrooms. Teacher education programs should offer examples, cases, context, and pedagogy for teaching and learning of NOS. The contribution of this study is to provide an example of such an effective teacher education program as most studies in the literature offer a single approach to teach NOS.

Problem Situation

What is the effect of intensive, multiple approach teaching on STs' understanding of NOS?

Sub Problems

1. What is the STs' level of understanding of NOS before the intervention?
2. How did STs' understanding of NOS changed after the teaching intervention?

Method

We used the convergent parallel mixed method design to investigate classroom teacher candidates' ideas about NOS and how to teach it (Creswell & Plano-Clark, 2011; Mcmillan & Schumacher, 1997). In this design, qualitative and quantitative data were gathered at the same time. Qualitative and quantitative data were collected and analyzed independently, but results obtained from two types of data were mixed during the overall interpretation. Using a combination of qualitative and quantitative methods enriches research data and enhances validity and reliability of the conclusions derived from the study (Lincoln & Guba, 1985).

Study Group

The study group included 65 third year students attending the division of classroom education at a major university in Ankara, Turkey during the 2015 fall semester. The students in the study group were attending a science and technology methods course in which the study took place. The course provided an appropriate context for this study as its aim was to teach STs how to apply certain activities in the science classroom. The attendees of the course were a convenience sample for this study.

Data Collection Instruments

We used quantitative and qualitative data collection instruments together in this convergent parallel mixed method study.

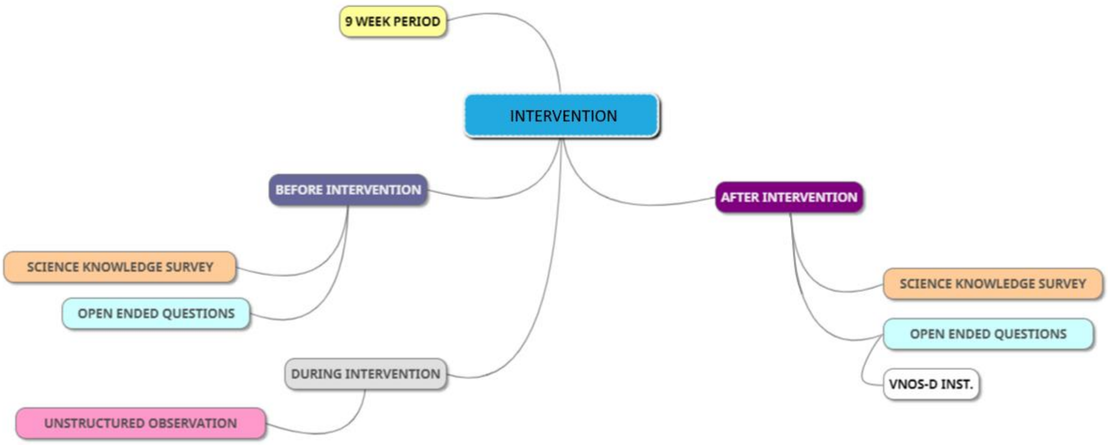

Figure 1. Mind map of data collection instruments before and after intervention

To determine classroom teachers' ideas about NOS and some basic scientific concepts, we used Science Knowledge Survey (SKS). This test was originally developed by Flammer (1993). It was translated and adapted into Turkish by Doğan, Çakıroğlu, Bilican and Çavuş (2012). SKS included 25 items, some of which contained postmodern while others contained positivist views of science. The questions included two answer choices: "I agree" and "I don't agree." This test was applied before and after the intervention.Before the intervention we asked open ended questions to students about NOS themes such as the tentative nature of science, scientific knowledge is based on empirical evidence, subjective nature of science, and the role of imagination and creativity in science. The open-ended questions were based on the "Views of Nature of Science-D (VNOS-D)" instrument developed by Lederman and Khishfe (2002) and they were further validated through expert opinions. The VNOS-D questionnaire was applied after the intervention to facilitate the data collection procedure through open-ended questions.

Table 1. Data sources for the sub research questions

Sub questions	Data source
1. Sub question	Qualitative data (open ended questions prepared based on VNOS-D) + Science Knowledge Survey (SKS)
2. Sub question	Qualitative data (VNOS-D + open ended questions) + Science Knowledge Survey (SKS)

Unstructured classroom observations were conducted during the nine-week intervention period to support the other data obtained in the study. One of the researchers acted as a participant observer. Field notes were taken during the observation sessions and they were rewritten in more detail immediately afterwards. The observer also included her reflections in the observation notes. Table 1 shows the data sources for the sub research questions.

Application Procedure

In this study, four different teaching approaches were used during the intervention to improve STs ideas about NOS and how to teach it. The intervention lasted nine weeks and during this time, STs completed various activities related to NOS. The purpose of the intervention was to help STs to use and learn various methods and activities to teach historical development of science, properties of scientific knowledge, and NOS. Table 2 shows the sequence of teaching applications during the nine weeks of application.

Table 2. Purpose and scope of the developed education program

Weeks	Application	Purpose and scope
1. Week	Science Knowledge Survey (Pre-test) Collecting written comments about scientific myths	The purpose was creating a medium for discussing the relationship among science, technology, and society so that we can determine students' prior knowledge about these concepts.
2. Week	Nature and history of science through the historical approach	The aim was helping STs to learn something about the history of science, development of scientific information, and properties of scientific knowledge. Students were asked to investigate various scientists' contribution to science (for example: İbn-i Sina, Graham Bell, Marie Cruie, Thomas Edison, Nicolas Tesla, Albert Einstein, Stephen Hawking, Cahit Arf, Oktay Sinanoğlu, Canan Dağdeviren, Aziz Sancar). STs' presentations were critiqued based on their NOS content.
3. Week	Nature and history of science through the historical approach	
4. Week	Student groups' presentations of scientists.	
5. Week	Properties and nature of science through generic activities Fossilized footprints Young and old women What is in the tube?	The purpose was helping STs learn about the following themes: scientific knowledge is open to change, scientific knowledge is based on evidence obtained through experiments and observations, observations and inferences are different from one another, scientific theories and laws are different types of knowledge, scientific knowledge can be subjective, imagination and creativity have an important role in science, scientific knowledge is influenced by social and cultural norms.
6. Week	Explicit – reflective method Adventure of atomic models activity* Which model? Atomic Models activity*	With the adventure of atomic models activity, we aimed STs to learn about the atomic models' historical development and NOS themes at the same time. Which model? Atomic Models activity was aimed to show STs that models are produced for a specific purpose, one model cannot explain every situation or all natural events and they may change based on new data and evidence.
7. Week	Explicit – reflective method Formation of Living Organisms activity* Nature of science through media news	With the "Formation of Living Organisms" activity we expected STs to learn about how the research about living things developed in time and by looking at cases in science, learn about how scientific knowledge can be distinguished from nonscientific knowledge. We helped STs to critique news and situations that they can see on media by using critical thinking skills. For this purpose we asked STs to evaluate a news article based on the criteria provided to them. This helped students to understand NOS and the structure of scientific knowledge.
8. Week	Explicit – reflective method Sky Adventure activity* Earth's Shape and Rotation activity* Nature of science through media news	The Sky Adventure activity was used to help STs to learn about sun, shapes, sizes, distances of the earth and the moon, and at the same time about NOS themes. Students compared sizes, shapes, and distances between the earth and the moon using the models that they developed. Earth's Shape and Rotation activity was used to help STs to evaluate evidences of earths shape and rotation obtained from photographs of stars taken from earth and also to help them understand that science is based on observations and evidence and observations and inferences are different from each other.
9. Week	Nature of science through media news Science Knowledge Survey (Post-test) VNOS-D (Post-test)	Students were asked to discuss their prior knowledge about NOS and their current understanding of NOS.

*These activities were obtained from the book titled "Teaching Nature of Science through Activities" which was prepared as part of the "Bidomeg" project (Yalaki, 2016)

Since STs are going to provide education in the elementary level, we focused on NOS themes that are appropriate for his level (Lederman & Lederman, 2005). The targeted themes at this level were: (1) tentative nature of scientific knowledge, (2) scientific knowledge is based on observations and experiments, (3) subjective nature of scientific knowledge, and (4) importance of imagination and creativity in science.

Table 3. Distribution of activities based on the targeted NOS themes

NOS Themes / **Activities**	Scientific knowledge is tentative	Based on experiment and observation	Subjective nature of science	Importance of creativity and imagination
Fossilized footprints	+	+	+	+
Young and old women	+		+	+
What is in the tube?		+	+	+
Adventure of Atomic Models activity	+	+		+
Which model? Atomic models activity	+	+		+
Formation of Living Organisms activity	+	+		
Sky Adventure activity	+	+	+	+
Earth's Shape and Rotation activity	+	+	+	

Data Analysis

The quantitative data obtained during the study was analyzed using the SPSS 21.0 (Scientific Package for Social Sciences) software program. The data obtained through the SKS instrument was marked as "1" if correct and "0" if otherwise. We used descriptive statistic and dependent samples t-test for data analysis. Data obtained from open-ended questions and open-ended questions were analyzed by content analysis and descriptive analysis techniques. For coding the data, a rubric developed by Lederman and Holiday (2011) and adapted and translated into Turkish by Yalaki and Çakmakçı (2011) was used (Appendix 1). Data obtained from the open-ended questions and the VNOS-D questionnaire was grouped into three categories based on this rubric. Students who had inadequate views of NOS were categorized as "naive," those who had acceptable but incomplete views of NOS were categorized as "transition," and those who had adequate views of NOS were categorized as "informed". The data obtained from classroom observations were analyzed descriptively. In the descriptive analyses, the data are summarized based on the predetermined themes (Yıldırm & Şimşek, 2015). Nature of science themes were considered for analyzing the observation notes in order to support the other findings in this study.

Results

This section presents qualitative and quantitative findings under separate titles. The qualitative findings obtained from the open-ended questions prior to intervention and open-ended questions with VNOS-D after the intervention are presented according to the targeted themes of NOS. The findings obtained from the SKS are presented under the title of the quantitative findings.

Qualitative Findings

The Tentative Nature of Scientific Knowledge

Prior to the intervention, 67% of the STs had an inadequate understanding on the tentative nature of scientific knowledge, whereas 33% of the participants had views in the *transition* category. Before the intervention, 67% of the STs thought that scientific knowledge is absolute and does not change; change in scientific knowledge is associated with technological advancement; and current scientific knowledge is valid everywhere. On the other hand, 33% of the participants stated that scientific knowledge is tentative, but could not explain and exemplify it. Thus, those individuals were included in the *transition* category. It was determined that the STs did not have an informed understanding on the tentative nature of scientific knowledge before the intervention. Some STs' views about the tentative nature of scientific knowledge before the intervention are presented below.

The views in the *naive* category:

- Scientific knowledge is proven to be right. It is absolute.
- Scientific knowledge is absolute and accepted by everybody. It is objective and testable.
- Scientists generate scientific knowledge, which does not change in the future.
- Scientific knowledge is required to be proven. It refers to universal phenomena accepted by everybody. It does not change from person to person.

The views in the *transition* category:

- Scientific knowledge can change in the future. Science is open to novelty and development.
- Science pursues certainty, but changes occur in science as well.
- Scientific knowledge changes and develops along with technological developments.

The views in the *informed* category:

- Scientific knowledge develops day by day. It is based on experiment, research and evidence. What differs scientific knowledge from other disciplines most importantly is its evidence-based nature. Science is falsifiable, or scientific knowledge is tentative.
- Scientific knowledge is based on empirical evidence. What makes it different from other disciplines is its cumulative progress. There is no science without evidence. Any new knowledge can change a previous one.

After the intervention, 6% of the STs had an inadequate understanding on the tentative nature of scientific knowledge; 65% of the participants held transitional views; and 29% of them had an informed understanding on science. The comparison of the qualitative data obtained before and after the intervention shows that the percentage of the individuals having an inadequate understanding largely decreased, while the percentages of those in the *transition* and *informed* categories substantially increased. After the intervention, the STs stated that scientific knowledge is subject to change based on new findings and results of scientific research and technological advancement. They also stated that scientific knowledge is durable but never certain and absolute and it is tentative through reconsideration of the current data and evidence. These findings indicate that STs' views about the tentative nature of scientific knowledge changed positively. Some STs' views about the tentative nature of scientific knowledge after the intervention are presented below.

The views in the *transition* category:

> As technology and opportunities develop, scientific knowledge may change. Scientists can find the deficiencies and mistakes in the work done. For example, it was accepted for centuries that the earth is flat, but then it was proved that it is actually round.

The views in the *informed* category:

> Scientists produce knowledge by reinterpreting the data they obtain as a result of experiment and systematic observation. Knowledge may change in the future with the development of knowledge and the re-interpretation of the current data with the emergence of new data.
>
> Scientific knowledge may change in the future because scientists can access new information by re-interpreting the previous scientific knowledge, or they can refute the old knowledge with the new information.

> I think that scientific knowledge may change because scientific knowledge is never absolute although it has a reliable and durable structure. It is tentative and open to change. It may be changed through tests and re-evaluations. It is open to criticism. For example, transition occurred from Newtonian physics to Einstein physics.
>
> Scientific knowledge may change in the future because there is no one-hundred-percent certainty in science. Knowledge changes as new evidence is obtained from on-going research, experiments, and observations. For example, it was thought that cancer could not be destroyed by a precise solution. Now this knowledge has changed with the knowledge provided Aziz Sancar.

Considering the findings obtained before and after the intervention, it can be said that the activities used in this study were effective in changing the views of the STs about the tentative nature of scientific knowledge. This finding is also supported by the classroom observations. In pre-class discussions, most of the STs claimed that scientific knowledge does not change. They gave evidence based on their prior learning, e.g., “law of gravity does not change”. After the intervention, there was a considerable increase in the number of students holding views regarding tentative nature of scientific knowledge.

Dependence of Scientific Knowledge on Experimental Evidence

Before the intervention, 65% of the STs had an inadequate perspective on the dependence of scientific knowledge on experimental evidence, whereas 35% of them had transitional views. These results indicate that before the intervention, 65% of the STs thought that science is a collection of proved knowledge, an objective endeavor and a search of proved facts. 35% of the participants, on the other hand, considered that science is based on experimental evidence, but could not explain and exemplify it. Thus, those individuals were included in the *transition* category. STs did not have a developed perspective on the dependence of science on experimental evidence. Some STs’ views about the dependence of scientific knowledge on experimental evidence before the intervention are presented below.

The views in the *naive* category:

> Scientific knowledge is an aggregate of knowledge that is objective, observable, measurable, identifiable, advancing, self-developing, and accepted valid by everyone.

The views in the *transition* category:

> Scientific knowledge is obtained based on experimental evidence. Observations and experiments are in the foreground. It is provable. It is concrete.
>
> Scientific knowledge is obtained through observations and experiments.
>
> Science depends on experiment. Thinking is not enough alone. Evidence is important in science.
>
> Scientific knowledge is concrete knowledge obtained through research and observation.
>
> Scientific knowledge is obtained using a scientific method. In other words, evidence is collected. It progresses cumulatively. It is objective. Scientific knowledge is based on evidence. What makes it different from other disciplines is its cumulative progress. There is no science without evidence. Any new knowledge can change a previous one.

The views in the *informed* category:

> Scientific knowledge is produced by experimentation and observation. Reasonable and logical solutions are developed.

> Scientific knowledge is based on experimentation and observation. It arises as a result of certain research. Science incorporates a process depending on experimentation. There is no one-hundred-percent truth.

After the intervention, 8% of the STs had an inadequate perspective on the dependence of scientific knowledge on experiment and observation; 61% of the participants had transitional views; and 31% of them had a developed perspective on science. Majority of the STs (61%) had transitional views with regard to the dependence of scientific knowledge on evidence. The individuals included in the *transition* category stated that science is based on experimental evidence, but they did not express that scientific knowledge is never proved absolutely. This is why they were included in this category. The individuals in the *informed* category stated that science depends not only on experimental evidence but involves reasoning and logical inference as well; it depends on direct or indirect observation of the world; and scientific knowledge can never be proved absolutely.

The comparison of the qualitative data obtained before and after the intervention shows that the percentage of the individuals in *naïve* category largely decreased, while the percentages of those in the *transition* and *informed* categories substantially increased. It was determined that the views about the dependence of scientific knowledge on experimental evidence changed positively. Some STs' views about the dependence of scientific knowledge on experimental evidence after the intervention are presented below.

The views in the *transition* category:

> Knowledge is produced using different scientific methods. Hypotheses are formulated and they are accepted or rejected by further observations and experiment results. New knowledge is obtained as a result of long-term studies, experiments, and observations.
>
> Scientific knowledge is produced through experiment, observation, inquiry and discussion. Knowledge is produced by inquiry. It is generated through integration of the old and the new knowledge. Scientists make observations and experiments, question new information using their prior knowledge, and thereby construct new knowledge or refute the existing one.

The views in the *informed* category:

> Knowledge is produced through research, observation, and experiment. Scientists reach new knowledge through experiment, observation, and inference.
>
> In natural sciences, knowledge is generated through imagination, research, inquiry, and discussion. Scientists attain knowledge by wondering it and using their imagination.

The findings obtained before and after the intervention demonstrate that the STs' view about the dependence of scientific knowledge on experimental evidence improved.

Subjectivity of Scientific Knowledge

Before the intervention, 74% of the STs had an inadequate perspective on the subjectivity of scientific knowledge, whereas 25% of the participants had transitional views and 1% had informed views. According to these results, before the intervention, 74% of the STs thought that scientists are objective, and they cannot be subjective. 25% of the participants, on the other hand, said that scientists could have different views and ideas, but could not explain or exemplify it at a satisfactory level. Thus, those individuals were included in the *transition* category. 1% of the STs thought that scientists' prior knowledge, experience, and education will affect their work, and their creativity and imagination may play a role in their inferences, thereby leading to different thoughts. In this way, they demonstrated a more developed perspective on science and they were included in the *informed* category. Some STs' views about the subjectivity of scientific knowledge before the intervention are presented below.

The views in the *naive* category:

> What makes scientific knowledge different from other disciplines is its objectivity, true objectivity. Scientific knowledge is certain. Individuals' views do not change.
>
> Scientific knowledge is objective. The most important feature making science different from other disciplines is its objectivity.
>
> Scientific knowledge is required to be proved. It refers to universal phenomena accepted by everybody. It does not change from person to person.
>
> Scientific knowledge is an aggregate of knowledge that is objective, observable, measurable, identifiable, advancing, self-developing, and accepted valid by everyone.

The views in the *informed* category:

> Scientific knowledge is subjective. This is because it is affected by the education and experience of the person engaged in it. This is why different views come out.

After the intervention, 13% of the STs had an inadequate perspective on the subjectivity of scientific knowledge, whereas 23% of the participants had transitional views and 64% of them had informed views. The comparison of the qualitative data obtained before and after the intervention shows that the percentages of the individuals in the *naive* and *transition* categories largely decreased, while the percentage of those in the *informed* category substantially increased. It was determined that after the intervention, majority of the STs (64%) thought that the theories scientists believe in as well as their values, beliefs, prior knowledge and experience, education, and expectations will affect their works; their creativity and imagination may play a role in their inferences; and all this can lead to different views. Thus, the individuals in this group were found to have a more postmodern perspective on science. It was found out that the views about the subjectivity of scientific knowledge improved. Some STs' views about the subjectivity of scientific knowledge after the intervention are presented below.

The views in the *naive* category:

> This is because the current situations and events date back to very old times. Science has an idea about the existence of dinosaurs because scientists can prove it. However, what they were has not been presented by science objectively and with common evidence yet. That is, the reason is lack of data.

The views in the *transition* category:

> This is because everybody is just expressing their own views.

The views in the *informed* category:

> Scientists make different inferences based on the same knowledge. Knowledge is affected by scientists' personal characteristics, creativity, and social, political, and cultural values surrounding them. Scientific knowledge is subjective.
>
> Scientific knowledge is subjective. Scientists put forward different ideas about a subject based on their imagination, belief, social and cultural background, experience, and education. Although they have the same data, they have different views because they are different from each other.

Comparison of findings obtained before and after the intervention reveals development of STs' views regarding subjectivity of nature of scientific knowledge. In addition, observation results support this finding. At the beginning of the intervention, STs viewed science as an objective endeavor. They supported their claim as, "If it is not totally objective, it is not science". After the student groups' presentations of scientists, they recognized science as a human activity and understood that science is not an endeavor which is fully objective.

Role of Imagination and Creativity in Science

Before the intervention, 97% of the STs had an inadequate perspective on the role of imagination and creativity in science, whereas 3% of them held transitional views. These results indicate that before the intervention, almost all of the STs (97%) thought that imagination and creativity have no influence on the generation of scientific knowledge. They thought that scientific method is definite and certain; and so there is no need for imagination and creativity. 3% of the STs, on the other hand, stated that imagination and creativity play a part in the production of scientific knowledge, but they did not explain and exemplify it. This is why they were included in the *transition* category. As in other NOS themes, most STs had an inadequate perspective on the role of imagination and creativity in science. None of the STs fell under the *informed* category in this theme. Some STs' views about the role of imagination and creativity in science before the intervention are presented below.

The views in the *naive* category:

> Scientific knowledge is obtained by using scientific methods. It is universal and absolute.
> Scientific knowledge is obtained using a scientific method.
>
> Scientific knowledge is obtained through certain methods. Data and evidences are collected. Then the obtained data are interpreted.
>
> Scientific knowledge is obtained through scientific methods. It is obtained through experiment and proving.

The views in the *transition* category:

> Scientific knowledge is obtained as a result of curiosity and research. In this process, scientists imagine. They design and conduct different experiments. They obtain the results by trial and error.
> Scientists discover scientific knowledge through experimental and logical ways. They decided by reasoning.

After the intervention, 5% of the STs had an inadequate perspective on the role of imagination and creativity in science, whereas 80% of the participants had views in the *transition* category and 15% of them were in the *informed* category.

The comparison of the qualitative data obtained before and after the intervention shows that the percentage of the individuals having an inadequate perspective largely decreased, while the percentages of those in the *transition* and *informed* categories substantially increased. After the intervention, majority of the STs stated that imagination and creativity are influential on obtaining scientific knowledge, but they did not explain or exemplify at a satisfactory level. Also, they said that imagination and creativity can be used in some stages of the production of scientific knowledge. 15% of the STs stated that scientists' imagination and creativity are influential on obtaining scientific knowledge and having different views on scientific knowledge; imagination and creativity are influential on every stage of the production of scientific knowledge; and there is no single scientific method for the production of scientific knowledge. As a result, it was found that the views about the role of imagination and creativity in obtaining scientific knowledge improved, but not at a sufficient level, given the small number of individuals in the *informed* category. Some STs' views about the role of imagination and creativity in the process of obtaining scientific knowledge after the intervention are presented below.

The views in the *transition* category:

> They are used in the stage of interpretation. For example, when modeling, scientists make what is invisible visible by using their imagination. Creativity and imagination are not used in experiment and observation. Scientists describe the idea or model they have created in the stage of reporting,

> during which they use their creativity. Creativity and imagination are used in the stage of planning, as well.
>
> Scientists use their imagination and creativity in the observation and interpretation stages of their research. This is because they are subjective stages. They depend on how a person looks. Therefore, imagination and creativity come into play in these stages.
>
> They use their imagination and creativity in the stage of interpretation. They make comments about the causes at the end of their observations. However, every scientist has a unique creativity and can explain the causes of their observations in a different way. For instance, different scientists provided different interpretations about the causes of the extinction of dinosaurs.
>
> Scientists use their imagination and creativity from the initial to the final stage of their research. As a matter of fact, the most important factors influential on search of knowledge are curiosity and imagination.

The views in the *informed* category:

> If scientists did not use their imagination, we would not have most of the inventions we use today. Imagination is like the seed of inventions.
>
> Scientists use their imagination and creativity in every stage of their research. They use them from the identification of research problems to the interpretation of the results obtained.
>
> Imagination is needed in every stage of research because they try to find something which has not existed until then. Finding the unknown requires creativity and imagination.

The findings obtained before and after the intervention demonstrate that the STs' views about the role of imagination and creativity in obtaining scientific knowledge improved. Data obtained from classroom observations support this finding. In the early weeks of intervention, STs emphasized that observation and experiment were sufficient to provide scientific knowledge. They underestimated the role of imagination and creativity as a role in the production of scientific knowledge. Towards the end of the intervention, especially after the atomic models activity, STs noticed that scientific knowledge involves scientist's creativity and imagination.

Table 4 presents the results before and after the intervention. Majority of the STs had an inadequate perspective on NOS before the intervention. However, the percentage of the individuals with an inadequate perspective largely decreased, and the percentages of those with views falling into the *transition* and *informed* categories substantially increased after the intervention. It was determined that the views of majority of the STs about these themes had changed and improved by the end of the intervention.

Table 4. Frequency of the individuals in categories before and after intervention for each NOS theme

The Themes of NOS		Naive	Transition	Informed
The tentative nature of scientific knowledge	Before	67%	33%	0%
	After	6%	65%	29%
The dependence of scientific knowledge on experimental evidence	Before	65%	35%	0%
	After	8%	61%	31%
The subjectivity of scientific knowledge	Before	76%	23%	1%
	After	13%	23%	64%
The role of imagination and creativity in science	Before	97%	3%	0%
	After	5%	80%	15%
General View	Before	76%	24%	0%
	After	8%	57%	35%

Quantitative Findings

Comparison of the Pre-Test and Post-Test Scores From the SKS

The SKS was administered to the STs as a pre-test and as a post-test. The data obtained from the SKS had a normal distribution and an analysis was done through dependent t-test to reveal whether there was a difference between the pre-test and post-test scores. The dependent t-test results concerning the mean pre-test and post-test scores are presented in Table 5.

Table 5. The dependent sample t-test results of the SKS

The Themes of NOS		Mean	n	Std. Deviation	p	df	t
The tentative nature of scientific knowledge	Pre-test	0.55	48	0.2360	0.00*	43	-3.362
	Post-test	0.66	48	0.2382			
The dependence of scientific knowledge on evidence	Pre-test	0.51	48	0.1529	0.028*	46	-5.002
	Post-test	0.63	48	0.1141			
The subjectivity of scientific knowledge	Pre-test	0.35	48	0.3444	0.04*	46	-5.291
	Post-test	0.64	48	0.3410			
The role of imagination and creativity in science	Pre-test	0.77	48	0.4247	0.038*	47	-1.952
	Post-test	0.89	48	0.4087			
General View	Pre-test	0.54	48	0.1638	0.007*	45	-6.731
	Post-test	0.71	48	0.1404			

*Mean differences are significant at the 0.05 level.

The STs had a mean score of 54 out of 100 in the SKS as a pre-test and a mean score of 71 out of 100 in the SKS as a post-test, which refers to a rise of 40% in the mean score of the STs through the intervention. The p-value calculated at the end of the analyses, with a confidence interval of 95% ($p<0.05$), indicates that there is a statistically significant difference between the pre-test and post-test scores achieved by the STs in the SKS [$t(45)=-6,731$; $p<0.05$]. According to the Table 5, there are statistically significant differences between the STs' mean pre-test and post-test scores in each theme of NOS.

These results show that the learning approaches and activities used during the intervention were effective in improving the STs' views about the targeted NOS themes. These results are in agreement with the qualitative data provided above. The various data sources used in this study, which included open-ended questions, observation notes and the SKS instrument provided evidence that were in mutual agreement. This triangulation of evidence improves the validity of the findings.

Discussion and Conclusion

This study attempted to improve the STs' views about NOS through teaching NOS based on a multi approach extensive intervention. Before the intervention, the STs held beliefs that can be categorized as myths about science, such as science is only based on data obtained through experiments and observations; imagination and creativity are not effective in the production of scientific knowledge; scientific knowledge is absolute, objective, and unchangeable. All these perceptions are a result of a naïve positivist science view, since these individuals have gone through an educational process dominated by such views.

The qualitative and quantitative data obtained before the intervention support each other. Before the intervention, the STs were found to have inadequate perspectives on NOS and to hold some misconceptions. Prior to the intervention, majority of the STs were determined to have an inadequate perspective on the themes of NOS. This result is in agreement with findings from other studies in the literature (Abd-El-Khalich & Akerson, 2004; Abd-El-Khalich & Boujaoude, 1997; Dagher & BouJaoude, 1997; Dagher et al., 2004; Doğan et al., 2008; Köseoglu, Tümay & Üstün, 2010; Lederman, 1992; Macaroğlu et al., 1998; McComas, 2000; Norris & Phillips, 1994; Saraç, 2012; Shiang-Yao & Lederman, 2002, 2007; Tatar et al., 2011a; Taşar, 2003). One of the reasons why STs consistently have inadequate understanding of NOS may be the existence of common misconceptions of science in textbooks and other resources in science education (McComas, 2000). The misconceptions of STs about NOS are formed during their elementary and secondary education throughout the years and the misrepresentation of NOS during this education plays an important role in the formation of their NOS views (İrez, 2009).

At the end of the intervention, the STs' views about NOS improved toward a contemporary view of science in the light of postmodern discussions. It was determined that the practices involved during the intervention in teaching certain NOS themes improved the STs' views about NOS. Research in this area advised that inadequate views of NOS cannot be changed to the "informed level" in a short period of time; since it is not easy to change STs' views which they internalized during their prior education over the years (Lederman, 2007; McComas, 2008). The nine-week-long applications in this study had a significant influence on the STs' views about NOS. During this period, STs had a chance to discuss various aspects of NOS and evaluate their own views as well as their peers' views. In the end, their views about the targeted four themes of NOS improved significantly.

Doğan, Çakıroğlu, Çavuş, Bilican & Arslan (2011) obtained a similar result on an in-service education program that helped science teachers develop their views of NOS over a long intervention. Especially interventions that involve explicit-reflective approaches are effective in improving students', STs', and teachers' NOS views (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007; Çavuş, 2010; Köseoğlu, Tümay & Budak, 2008; Schwartz, Lederman & Crawford, 2004). Abd-El-Khalick & Lederman (2000) suggested that interventions that involve historical approach with explicit-reflective approaches may be more effective in teaching NOS. Using different approaches together over sufficient time periods seems to be a good way for improving STs' NOS views (Tuan & Chin, 1999).

As a result, in this study, both the quantitative and the qualitative findings indicated the positive influence of the practices involving a variety of activities on the improvement of the STs' views about NOS. It can be said that change in the perspectives of NOS requires sufficient time, and use of different activities.

Recommendations

The present study involved the development and application of four different teaching approaches for teaching NOS. With four different approaches adopted, an attempt was made to appeal to all of the participants. For further study, STs may be followed in their classroom practices to assess how they utilize their knowledge of NOS in teaching.

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Appendix. Rubric for scoring VNOS-D+ questionnaire (Adapted from Lederman & Holliday, 2011)

Tenets	Naive	Transitional	Informed
Tentative	• Perceive science as technology. Change in science equals technological developments. • Proven knowledge does not change. • Scientific knowledge is universal. • Theories can change but not laws.	• Scientific knowledge can change (technological improvement aids change in science and scientific knowledge expands cumulatively). • Scientific knowledge may be changed when experimental techniques improve, or new evidence is produced. • Change as a result of new investigations and findings.	• Scientific knowledge is durable but never absolute or certain. This knowledge, including theories and laws, is tentative and subject to change due to new evidence. • Change can be evolutionary and revolutionary. • Change may also occur as a result of re-conceptualization of current data.
Empirically Based	• Perceive science as technology. • Science is pursuit of truth. • Science is collection of proven knowledge. • Science is objective.	• Based on empirical evidence (no further elaboration) • Based on experiments and/or direct observations.	• Scientific knowledge is, at least partially, based on and/or derived from observations of the natural world. • Observations may be direct or indirect. • Science does not rely solely on empirical evidence. • Empirical evidence support rather than prove scientific knowledge.
Subjective (Theory Laden)	• Lack of enough evidence cause different opinions. If there is enough evidence, there will be a consensus among scientists. • Limitation of human ability and technology cause different opinions. • Science is objective. • Science is universal. Scientific truth cannot change from person to person.	• Science is subjective. • Scientists may have different ideas.	• Scientific knowledge is subjective. Scientists' theoretical commitments, beliefs, previous knowledge, training, experiences, and expectations actually influence their work. Scientists' observations (and investigations) are always motivated and guided by, and acquire meaning in reference to questions or problems. These questions or problems, in turn, are derived from within certain theoretical perspectives (theory-laden). • Creativity and imagination play a role in inferences. • Scientists have different backgrounds and values which may lead to different interpretations of data and different conclusions. Because of this, one set of observations may lead to different and equally valid inferences.
Role of Imagination and Creativity	• Imagination and creativity has no role in scientific activity. • Scientists do not use imagination or creativity because imagination and/or creativity are in conflict with objectivity. • Methods of science are certain and scientists do not need to imagine. • Imagination and creativity are used while designing and innovating new technology.	• Scientific knowledge involves human imagination and creativity. The student does not elaborate her answer. • Scientists use their imagination or creativity in some phases of their work, notably in designing experiments.	• Scientists use their imagination or creativity throughout their scientific investigations. Science involves the *invention* of explanations and this requires a great deal of creativity by scientists. • Imagination and creativity play a role in *all stages* of scientific research. • There is no single scientific method.

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Student Understanding of a Simple Heating Curve: Scientific Interpretations and Consistency of Responses

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Abstract

This work seeks to elucidate undergraduate science students' basic knowledge of concepts related to the energy changes for a simple heating curve and their ability to integrate related concepts. The participants were drawn from first and second semester General Chemistry classes, as well as junior/senior level Physical Chemistry classes at a four-year public university in the United States. The research instrument for this study was developed and tested over an 18-month period from preliminary data from students at the same university. The data were analyzed for students' basic knowledge and the ability to make connections between related concepts. A definite lack of demonstrated skill in integrating multiple concepts was revealed at all student levels with respondents often giving inconsistent answers to related questions. It is suggested that these critical thinking skills can be cultivated in students through various active learning pedagogies based on explicit multi-concept problem solving exercises, rather than the usual simple ones that test concepts individually.

Introduction

The study of energy changes during chemical and physical processes is a concept that pervades all levels of chemistry instruction. The ideas are imbedded in the United States (U.S.) *Next Generation Science Standards* (NGSS, 2016) for middle through high school. Beginning in middle school and continuing at subsequent grades, the standards discuss the role that energy transfer plays in various processes and also proposes introducing some ideas from Kinetic Molecular Theory (KMT) as one of the Disciplinary Core Ideas (PS3.A): “Temperature is a measure of the average kinetic energy of particles.” The relationship of a particle's average kinetic energy (KE) to its temperature as stated in KMT is of fundamental importance in understanding the physical world at the particulate level. KMT was cited as one of the six "Great Ideas" of chemistry that should be taught in General Chemistry (Gillespie, 1997). However, students sometimes have difficulty integrating the ideas of molecular motion and KMT as was noted by Osborne and Cosgrove (1983) many years ago when they wrote, "Further, more ideas to do with particles moving and colliding appeared to be understood by older pupils, but sustained probing of these ideas did not produce sound scientific explanations in terms of intermolecular forces or of loss of kinetic energy" (p. 830).

One application of the concept of KMT is to phase transitions of simple substances. As part of learning about this concept, a simple “Temperature vs. Energy Added” heating curve for a substance is typically presented (Figure 1) and discussed in physical science and chemistry textbooks from middle school through college. The associated discussion often centers around the fact that the temperature during phase transitions is constant. The simple shape of this plot, along with the associated phases, are easily memorized by students at the pre-college level. On the other hand, the more difficult ideas such as the relationship of the positively sloped regions to the heat capacity and the lengths of the horizontal regions to the enthalpies of fusion and vaporization are introduced later in a student's physical science training. A critical examination of college students' knowledge of these horizontal regions and their relationship to energy changes provides the context for the current report.

In general, the idea of energy changes during physical processes presents many problems to beginning science students. Some of these are simply related to the concept of *heat*. Bar and Travis (1991) studied children in grades 1-9 and their progression in understanding of boiling and evaporation. One finding for younger children was that when describing the composition of bubbles, 40% of 13-14 year olds indicated that they contain *heat*. Further work by Chang (1999) investigated the conceptual knowledge of evaporation, condensation, and boiling among teachers in Taiwan. Examples of difficulties with understanding the role of *heat* and temperature were seen even in these individuals with significant chemistry training. Perhaps most relevant to the current work is the investigation by Viennot (1997) who examined yet another area of difficulty that is related to energy exchange during phase transitions. He noted that some learning difficulties may be related to the fact that the transfer of energy does not have to lead to an increase in temperature for a phase change and pointed out that one alternative belief is that the maximum temperature for a substance is the boiling point. Lastly, in the work of Hwang and Hwang (1990), as summarized by Chang (1999), it was reported that a number of students at grade levels from middle school to university have difficulty understanding the balance of energy when a liquid is boiling and believe that the temperature would keep rising upon heating. A previous investigation of phase transitions by Jasien (2013) also noted confusion related to the relationship of temperature and energy transfer during phase transitions among college students.

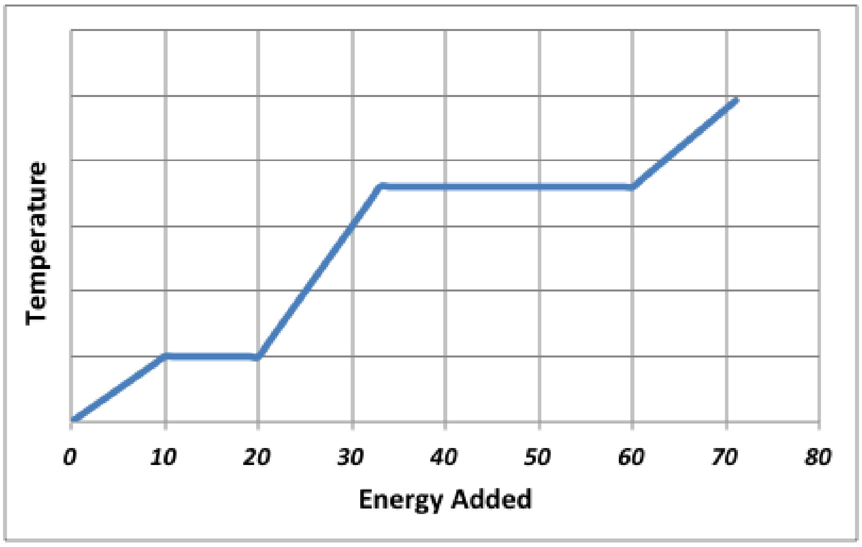

Figure 1. A typical "Temperature vs. Energy Added" plot

College-level chemistry textbooks have widely varying coverage of heating curves and the analysis of them in terms of KE and PE changes. In addition, these books usually only briefly mention the related concepts of KMT that explain phase transitions. For example, one widely used U.S. chemistry textbook by Mcmurry et al. (2012) states, "Once the temperature of the water reaches 100°C, addition of further heat again goes into overcoming intermolecular forces rather than into increasing the temperature as indicated by the second plateau at 100°C on the heating curve" (p. 361).

Another commonly used textbook by Zumdahl & Zumdahl (2014) describes changes in potential energy (PE) at the melting point of solid water and mentions intermolecular forces, but not KE as follows, "At this temperature, called the *melting point*, all the added energy is used to disrupt the ice structure by breaking the hydrogen bonds, thus increasing the potential energy of the water molecules" (p. 402).

Spencer et al. (2006) gives a much more complete description by explaining the associated energy changes during the phase transition as: "At the boiling point of the liquid, the energy input from heating overcomes the intermolecular forces that attract the molecules to one another. Since the energy is used to overcome the intermolecular forces, there is no increase in the kinetic energy of the molecules and hence no change in the temperature of the system" (p. 321).

The relationships between KMT and the corresponding energy changes are fundamental to an understanding of phase transitions, yet how well do students really understand these ideas? Given the various concepts involved in understanding phase transitions, this topic is ripe for an investigation that examines college students' abilities to analyze a heating curve, evaluate the associated energy changes, and relate these to KMT. The goal of the current investigation is to address the following research question: "Are there significant differences in the abilities of college chemistry students at different educational levels to use KMT to describe the energy changes in a phase transition?" This ability to integrate or "draw connections among ideas" is one of the higher-order cognitive skills as outlined in Bloom's Taxonomy (Bloom et al., 1956). It is an important part of critical thinking. Furthermore, the ability to "Analyze and Interpret Data" is an important goal of science education and is pervasive in science standards (NGSS, 2016).

Method

Participants

The data reported in this work was collected from students at a mid-sized (~12,000+ student) public university in the U.S. The students surveyed came from a ethnically diverse group from a university that is classified by the federal government as an Hispanic Serving Institution. Although no specific gender or ethnicity information was collected during the administration of the assessment, it would be expected that the distribution of the backgrounds of the respondents reflects the diversity of the university, which means that greater than 50% of the students in all groups were female. The protocol for the data collection was approved by the University Institutional Review Board for Research on Human Subjects. Data came from various groups over the period from Fall 2014 to Spring 2016. A total of 181 2nd-semester General Chemistry (GC2) students from five sections, 76 Physical Chemistry (PHC) students from two sections of a course covering thermodynamics and chemical kinetics, and 72 1st-semester General Chemistry (GC1) students from one section were assessed. The GC2 sections were taught by two experienced instructors in the Department, while one of the two PHC sections and the GC1 section were taught by the author. In all cases, the assessment was administered a few weeks after the appropriate material was discussed in class and the students had already been tested through a course exam.

Data Collection and Analysis

The assessment instrument used in this investigation was developed over an 18-month period that involved collecting preliminary data from 2nd-semester General Chemistry and upper-division Physical Chemistry students. In the early development stages, questions on the topics of phase transitions and energy changes were asked in open-ended response format. Analysis of the answers to the questions allowed for the categorization of common responses, which were used to develop a multiple-choice based assessment instrument. This test-version of the assessment consisted of some basic questions on a "Temperature vs. Energy Added" graph (Figure 1), followed by specific sets of paired questions about the associated energy changes and the reasons for them. The questions were reviewed by another experienced faculty member in the department for clarity, to assure that students would understand them and provide responses that would answer the proposed research question.

A test-version of the assessment was administered to several classes of GC2 and PHC students. Analysis of these results led to minor modifications in the wording of some questions/answers to remove ambiguities and eliminate seldom chosen responses. The result was a final assessment consisting of: (i) four recall-type questions on KMT, KE, and the interpretation of a heating curve (Box 1), and (ii) three paired synthesis questions related to changes in the total energy (E), KE, and PE during a phase transition (Box 2). Because the development of responses was based on student essays, it is believed that questions and answers, as posed, provide sufficient insight into the thought processes of students to address the primary research question.

Box 1: The four "recall-type" questions used in this work.

1. *According to Kinetic Molecular Theory, the average kinetic energy of a collection of particles is directly related to the particles'*
   a) temperature   b) mass   c) volume   d) potential energy   e) All of the above.

2. *Kinetic energy is best described as:*
   a) stored energy due to the position or condition of an object
   b) energy due to an object's motion
   c) the energy available to do work on another object
   d) a measure of heat energy
   e) All of the above.

3. *The phase(s) of the substance most likely to exist in the region between 20 and 33 units of energy being added is/are:*
   a) solid   b) liquid   c) gas   d) solid and liquid   e) liquid and gas

4. *The phase(s) of the substance most likely to exist in the region between 33 and 60 units of energy being added is/are:*
   a) solid   b) liquid   c) gas   d) solid and liquid   e) liquid and gas

Separate statistical analyses of the responses of the five sections of GC2 and the two sections of PHC students were done in two ways to check for inter-section differences for each of the two groups. First, a point system for the correct answers and associated reasons was used to calculate an overall score for each student. The overall mean scores were compared using either an ANOVA (GC2 – 5 sections) or independent samples t-test (PHC – 2 sections). These results indicated no significant difference between sections for the GC2 groups [$F(4,176) = .85$, $p = .50$] or for the PHC groups [$F(1,74) = .075$, $p = .78$]. Additionally, the distribution of responses (i.e. A, B, C, D, E) for each question was examined for differences using a simple chi-square test. Only one question of the ten for one section of the GC2 group showed a statistically significant difference ($p < .05$) in the distribution of the responses. Based on these results, the five sections of GC2 students were grouped together ($N = 181$). For the two sections of the PHC students, none of the ten questions showed a significant difference in the distribution of responses, i.e. all p-values > .05, and both sections were grouped ($N = 76$).

Box 2: The six "analysis-type" questions used in this work.

5. *What happens to the total energy of the substance in the region between 33 and 60 units?*
   a) It increases. *b) It decreases.*
   c) It remains constant. *d) It could increase or decrease depending on the substance.*

6. *The best reason for the answer to question 5 is:*
   a) There is no change in the temperature of the substance.
   b) Energy is being transferred into the substance.
   c) The Law of Conservation of Energy holds.
   d) The particles are moving faster.
   e) There is no physical or chemical change.

7. *What happens to the kinetic energy of the substance in the region between 33 and 60 units?*
   a) It increases. *b) It decreases.*
   c) It remains constant. *d) It could increase or decrease depending on the substance.*

8. *The best reason for the answer to question 7 is:*
   a) There is no change in the temperature of the substance.
   b) Energy is being transferred into the substance.
   c) The Law of Conservation of Energy holds.
   d) The particles are moving faster.
   e) There is no physical or chemical change.

9. *What happens to the potential energy of the substance in the region between 33 and 60 units?*
   a) It increases. *b) It decreases.*
   c) It remains constant. *d) It could increase or decrease depending on the substance.*

10. *The best reason for the answer to question 9 is:*
   a) There is no change in the temperature of the substance.
   b) Energy is being transferred into the substance.
   c) There is no physical or chemical change.
   d) The change in potential energy is opposite that of the kinetic energy.
   e) Chemical bonds are being broken.

All subsequent comparisons of the responses of the three groups (GC1, GC2, and PHC) for individual question or correlated responses used a simple chi-square analysis to identify significant differences. To simplify the analysis, student responses were assigned to be either correct or incorrect. In all of these analyses, only the corresponding p-values are reported with a criterion of $p < .05$ being used to determine statistical significance. When performing a chi-square analysis for one degree of freedom, i.e. a 2 x 2 table of data, the analysis utilized the Yates correction for continuity and these p-values are labeled p'.

Results and Discussion

The presentation and discussion of the data from this study is divided into three parts. The first relates to questions assessing lower-order cognitive skills associated with the recall questions (Q1-Q4), the second examines the abilities of students to analyze energy changes during a phase transition (Q5-Q10), while the third describes the ability of students to choose answers that are self-consistent. These latter two give information on students' abilities to "apply" and "analyze" as categorized in Bloom's Taxonomy.

Recall Questions

Given in Table 1 are the results for Q1-Q4, which examined knowledge that can best be categorized as simple recall. The percentage of correct responses in column Q1(a) of Table 1 includes only those students who correctly answered (a). The column labeled Q1(a & e) gives the percentage of students choosing answer (a) (*correct*) plus those answering (e) (*partially correct*).

As can be seen from Table 1, the percentage of students correctly answering each of the four questions is conspicuously lower than might be expected. This is consistent with what other researchers have concluded about students' alternative conceptions of basic topics (Barke et al., 2009; Bodner, 1991; Kind, 2004; Mulford et al., 2002). For two of the four questions there is a statistically significant difference among the groups examined, with the GC2 students scoring lower in the majority of categories.

Table 1. Percentage correct by group: Q1-Q4 along with chi-square p-value

Group	Q1(a)	Q1(a&e)	Q2	Q3	Q4	Q3 & Q4
GC1	43.1	59.8	63.9	59.7	43.1	38.9
GC2	30.4	70.2	72.4	46.4	38.7	33.7
PHC	40.8	73.7	81.6	61.8	51.3	50.0
p	.007	.15	.054	.033	.17	.05

The pattern of correct responses is not generally consistent with what one might expect, as it does not mirror the educational level of the students. The fact that the GC1 students overall perform better than the GC2 students in some categories may be attributed to the fact that many of the GC2 students did not take the 1st-semester course in the preceding semester and therefore the information may not be as fresh in their memories, when compared to the GC1 students. On the other hand, the 2nd-semester course at the university specifically addresses the concept of enthalpy changes in phase transitions at a much higher-level than is done in the 1st-semester course, so this material has been recently "covered". For the PHC students, the relationship between temperature and the translational KE, $E_{tran} = \frac{3}{2}RT$, had been recently discussed in the context of the molar heat capacity for a perfect monatomic gas. An interesting result shown in Table 1 is that although there is a statistically significant difference between groups in correctly identifying the pure liquid region of the phase diagram (Q3), this is not true for the liquid-vapor phase change region (Q4).

With respect to the question on KMT (Q1), there was confusion among students about what KMT posits. This led to a large percentage of students in the GC2 and PHC groups selecting the response (e), even though it included the answers: *volume* and *potential energy*. One might speculate that the reason for this is that students recalled that the formula for KE is ½ mv^2 and therefore the only "reasonable" response that included both *temperature* and *mass* was (e). When including answers (a) and (e) any significant differences between the groups on Q1 vanish.

Energy Change Questions

Table 2 gives the percentage of correct responses for questions dealing with the changes in E (Q5), KE (Q7), and PE (Q9) during the liquid to vapor phase change. The results for the "reasons" for the respective changes (Q6, Q8, Q10) are also tabulated, independent of whether students had correctly answered the question on the direction of the energy change. Perhaps more important in revealing how well students integrate concepts, Table 2 presents the percentage of students who correctly answered both questions in a paired set. This is given in the columns labeled X|Y, which signifies that X was correct, given that Y was also correct. The ability to correctly answer each of the paired energy questions requires slightly higher cognitive skills than the "recall" questions (Q1-Q4). The data in Table 2 do not show statistically significant differences between groups, except for Q10.

An interesting feature of these data is that only about one in three of the GC1 and GC2 students and one in two PHC students can correctly reason that the energy of the substance is increasing (Q5). This occurs despite the fact that the x-axis in the plot (Figure 1) is clearly labeled "Energy Added." Answering this question correctly requires the student to interpret the meaning of the label on the x-axis and relate it to their answer for the change in E. The lack of significant differences in the responses is quite disconcerting given that the more academically advanced PHC students might be expected to perform better than students in the GC1 or GC2 groups.

Table 2. Percentage correct by group: Analysis Questions (Q5-Q10) along with chi-squre p-value

Group	Q5	Q6	Q6|Q5	Q7	Q8	Q8|Q7	Q9	Q10	Q10|Q9
GC1	34.7	30.6	25.0	69.4	45.8	44.4	47.2	33.3	23.6
GC2	38.1	33.1	29.3	55.2	34.3	29.8	38.1	22.1	16.0
PHC	51.3	40.8	39.5	53.9	39.5	39.5	40.8	36.8	23.7
p	.08	.37	.13	.08	.22	.06	.41	.03	.22

The closeness of the values in columns Q6 and Q6|Q5, as well as in Q7 and Q8|Q7 for all the groups reflects the fact that although a number of students may have serendipitously correctly answered the questions about how E or KE change, students getting the reason correct in most cases got the direction correct. This is less true for the question about the PE, because the correct reason is not as straightforward as that for the E and KE questions. For the reason why PE changes (Q10), answers (a), (c), and (d) should be quickly ruled out as incorrect, however answer (e) might be deemed acceptable by students. The reason is that students often equate "intermolecular forces" with "chemical bonds" (Miller, 2016). It is also been observed that because of their lack of experience with other liquids, students often only think of water when they think of phase transitions (Jasien, 2013). Since the predominant intermolecular force holding water molecules together in the liquid is hydrogen bonding, choosing: "*(e) Chemical bonds are being broken*." as a reason for the change in PE could make logical sense to students. It may even be the case that some of these students' previous chemistry instructors or their reference material may have used the term "intermolecular bonds" to describe "intermolecular forces" (Purdue, 2016; Wikibooks, 2016; MITOPENCOURSEWARE, 2016). The purpose here is not to debate the correctness of this usage, but to simply point out that this terminology can very well lead to the choice of answer (e) as the reason for the PE change. This may account for the fact that only 3% of GC1 students chose (e) as the reason for the PE increase, while 16% of GC2 and 23% of PHC students did so. The GC1 students all came from the author's section where it was strongly emphasized that "intermolecular forces" are distinct from "chemical bonds". Nevertheless, including the students who would be credited with answering both Q9 and Q10 correctly with either (b) or (e) for the reason, does not lead to significant differences in the groups for Q10|Q9 category.

A range of 54-69% of the students correctly reasoned that KE was constant in the constant T region, with 30-44% giving both the correct change in KE and the reason for it. This may imply that these students made the correct conceptual connection, but could also simply be an artifact of students seeing no change in T and associating it with no energy change. In fact, Table 3 gives some information on students answering *incorrectly* that E and PE are constant in the phase change region. In all three groups this is on the order of 50% for E and 20% for PE. Of those answering in this way, anywhere from about one-third to one-half gave the reason as: *There is no change in the temperature of the substance*. However, this was less common for the PE than for the total E. For all data analyzed, there were no significant differences among the groups.

Table 3. Percentage by group indicating constant E and PE during the phase change

Group	E constant	NTC|E constant*	PE constant	NTC|PE constant*
GC1	59.7	55.8	23.6	29.4
GC2	57.5	52.9	23.2	42.9
PHC	47.4	38.9	19.7	33.3
p	.24	.42	.80	.69

* Percentage of students in the previous column indicating a reason of "No temperature change" (NTC).

It appears as if at least some of those students answering that the KE was constant along with the correct reason may have simply associated the constant T with no energy change. In order to get a rough estimate of how many students may have reasoned this way, the number of students either answering that E is constant because T is constant <u>or</u> PE is constant because T is constant can be removed from those in the Q8|Q7 groups. This reduces the percentage of students in this category from 44.4% to 33.3% (GC1), 29.8% to 19.9% (GC2), and 39.5% to 30.3% (PHC), a decrease of about 10% for each group. These data along with those in Table 3 may indicate that a substantial number of students make the erroneous connection that if T is constant, so must be E or PE, as had been reported (Viennot, 1997).

Consistency of Responses

Although the results in Tables 2 and 3 present interesting snapshots of the abilities of students to analyze the energy changes and reasons for them, another interesting result involves the ability of students to make connections between concepts as they synthesize their knowledge of KMT, energy changes, and phase changes. Given in Table 4 is a summary of some student responses to the questions on KMT (Q1) and the KE changes (Q7,Q8) for the liquid-vapor phase transition region of the diagram. The column headings use the notation X|Y as introduced in the previous section. The Q1(a&e) column from Table 1 is reproduced here for ease of comparison. The column labeled Q7|Q1(a&e) indicates a huge falloff in the percentage of students that correctly say that KE depends on T and can then use this idea to conclude that the KE is constant in the phase change region. These decreases amount to 11% (GC1), 30% (GC2), and 34% (PHC). There is a similar huge drop off in students who say that KE depends on T and give a correct reason for Q8 that: "There is no change in the temperature of the substance." This latter comparison is not as clear-cut as the former, since these percentages include students who could given any of the four answers for the change in KE in the phase change region. A more telling statistic is given in the Q8|(Q1a&e&Q7) column. This gives the percentage of students who correctly associated (i) constant KE with constant T from KMT, (ii) constant T from the plot in the phase change region, and (iii) the reason for the constant KE. This amounts to from 23% to 35% of the students. In none of the three cases just discussed, is there a significant difference among the three groups. Needless to say, this is somewhat disappointing, especially for the PHC group which has a significant amount of chemistry (and physics) background.

Table 4. Percentage of correct responses by group for "synthesis" questions

GRP	Q1(a&e)	Q7|Q1(a&e)	Q8|Q1(a&e)	Q8|(Q1a&e&Q7)	Q8|(Q1a&e&Q7)*
GC1	59.8	48.6	36.1	34.7	58.1
GC2	70.2	39.8	24.9	22.7	32.3
PHC	73.7	39.5	30.3	30.3	41.1
p	.15	.40	.19	.11	.01

* Includes only the student subset correctly identifying the relationship of average KE to T.

It could be argued that this is an unfair comparison since it includes all students, independent of whether they stated that the average KE of particles depends on temperature. Given in the last column of Table 4 are the percentages of students making the connections between KMT, the KE change, and the reason for it in the phase change region. Here there is a significant difference between the groups, with the GC1 group now answering the three questions correctly at a rate 17% higher than the PHC students and 26% higher than the GC2 students. However, no significant difference between the GC2 and PHC groups ($p' = .35$) was seen.

Despite students' *conceptions* that KE depends on T, many disregarded this *knowledge* when answering the question related to the "Temperature vs. Energy Added" graph. Two possible reasons for this disconnect are: (1) students were unable to actually process what the graph meant, and/or (2) they were unable to analyze the questions and integrate the ideas needed to make the connection between the questions. This is Bloom's Taxonomy "Analyze," which includes the ability to "draw connections between ideas." Given the relative performance of the groups, it may be hypothesized that the GC1 group's success rate may be more related to the recentness of the material than their ability to analyze the situation more completely.

One last measure of students' abilities to integrate knowledge will now be examined. Here, the reason for a particular answer will not be considered; only whether a consistent set of answers is given for the changes in E, KE, and PE. There are a number of possibilities for consistent combinations other than the correct one. For instance a student could answer that the total energy increases and that the KE increases and PE decreases. Although not correct, the answers are consistent, as long as $|\Delta KE| > |\Delta PE|$. The data in Table 5 examines these answers, but only for the subset of students who correctly answered that the energy was increasing in the phase change region. This provides further evidence that students answering these types of multiple-choice questions may not relate their answers from one question to another. This may be the legacy of our students being "raised" on assessments based on multiple-choice questions that examine one concept at a time.

One interesting outcome of montoring the incorrect responses is the common belief that the KE and PE must always change in opposite directions. Examining all student responses, independent of how they said the PE would change, 31.9% of GC1, 40.9% of GC2, and 26.3% of PHC students thought that KE and PE must change in opposite directions, i.e. answer (d) in Q10. This student misconception was verified as being quite common by an experienced university physics instructor (personal communication with Dr. C. DeLeone, September 2016).

Table 5: Consistency of energy changes for students stating the total energy increases*

KE	PE	GC1 (*N* = 25)	GC2 (*N* = 69)	PHC (*N* = 39)
constant^	increase^	56	29	44
increase	increase	0	3	8
increase	constant	4	10	13
increase	decrease	24	22	10
decrease	increase	0	1	0
inconsistent		16	35	26

* Percentage of students for the given N. ^ Correct answer.

Implications for Teaching

Although the sample size used in this study is relatively small and the findings may not be generalizable, this work reveals several student misconceptions and inconsistencies in university-level chemistry students. The problem of conceptual inconsistencies is not new, but the current work elucidates some new instances where students fail to integrate related ideas and develop a consistent picture of a concept. A large number of students also appeared to completely neglect a previous response when deciding on the answer to a related question. Some of this may be associated with the way students are tested. Exam questions often focus on simple problems that examine one concept at a time. This may be due to difficulties in creating or grading multiple-concept questions which, more often than not, involve essay-type assessments with a commensurate increase in grading load. On the other hand, some instructors may not ask these concept-integration questions since students may do poorly on them, which can be demoralizing for students. Unfortunately, a Catch-22 situation arises where we don't teach students to integrate concepts since it is difficult to assess them, so students do not learn this skill. The ability to connect ideas is an essential skill and additional emphasis is being placed on this at many levels, particularly in the early years of formal science education (Chiu & Linn, 2011; Davis & Linn, 2000; Linn et al., 2006; Tinker & Pallant, 2008).

Over the years, various pedagogical methods to encourage students to think critically have been developed. Many have shown promise for helping students think critically and integrate concepts, at least in the hands of instructors well-trained and enthusiastic about the specific innovation. One method that aims to help students draw connections is *concept mapping* (Nakhleh & Saglam, 2005). A complete study investigated the effect of this technique on general chemistry students and concluded that: "When used appropriately, they challenged students to think at a deeper level" (Francisco et al., 2002). Perhaps one reason for the lack of widespread use of *concept mapping* is in the phrase: "When used appropriately". This implies that there may be a substantial barrier for instructors and students to efficiently use this technique, although the effort may be worth it.

The problem of helping students make connections and integrate concepts through writing has been addressed via the Science Writing Heuristic (SWH) described by Greenbowe and Hand (2005). This has shown promise in helping students develop connections during experimentation and improve their critical thinking abilities in the lab (Gupta et al. 2014), but also may be part of the solution for teaching critical thinking in the classroom setting as well.

Yuretich (2004) has described how active learning techniques in large lecture classes can be used to teach critical thinking skills. He reported on his efforts to convert multiple-choice questions into a better tool to teach and assess the critical thinking abilities of students in his large oceanography classes for non-science majors. Some of their class activities involve a "think-pair-share" format, as well as multiple-choice questions that lead to students analyzing, synthesizing, and evaluating the topics and thereby use higher-order cognitive skills. This type of repeated questioning has been seen to be particularly effective for students who are "low-skilled comprehenders". Pyburn et al. (2014) compared the use of multiple-choice based activities with "elaborative interrogation" on the development of chemistry skills in general chemistry and concluded that for all levels of chemistry: "… testing can be used to enhance (not just assess) student learning…" (p. 2055). This idea of repeated retrieval of information is consistent with some modern theories of "learning" (Brown et al., 2014).

One advantage of using a "think-pair-share" format with multiple-choice conceptual questions that test critical thinking is that this method can be implemented in a low stress classroom-learning situation where the students are not necessarily graded. This less threatening atmosphere may facilitate them taking the chance to express their ideas in discussions with other students and the instructor. This is in fact, the pedagogical method of choice used by the author in a "flipped" version (Bergman & Sams, 2014) of 1st-semester General Chemistry. The "think-pair-share" questions that have been developed progress from those requiring lower-order, to those necessitating higher-order cognitive skills. This may account for some of the ability of the GC1 students to outperform the GC2 and PHC students on some questions. However, this is purely speculative and this hypothesis needs to be tested by a future investigation with a control group, since it may turn out that any higher achievement on certain questions may simply be due to the temporal proximity of the course material.

Conclusion

Assessment of students' knowledge of KMT and its relationship to energy changes during phase transitions in a simple heating curve has revealed a number of student misconceptions and inconsistencies. Despite the fact that the "recall" questions posed should have been easily answered by students, there still remain many of them who struggle to demonstrate even the most basic knowledge. More importantly, this study underscored the definite lack of demonstrated skill in integrating multiple concepts. In some cases, students completely disregarded previous answers when answering subsequent questions, resulting in conflicting responses. Overall, the current results provide further evidence of the need for instructors to build critical thinking skills in students. Experienced instructors "know" that students often learn facts in isolation, i.e. Bloom's "Remembering". In these cases, students fail to achieve integration of related ideas, i.e. Bloom's "Applying" and "Analyzing". This situation can leave extensive gaps in a student's knowledge of any topic. It is suggested that although there are definite challenges with doing so, more multi-concept problems should be presented to students early in their university education to encourage the development of their critical thinking skills. There have been a number of demonstrated pedagogical methods for doing this, which should be more commonly utilized. For instance the use of the "think pair-share" format in conjunction with questions that incrementally ramp up the number of concepts needed to answer correctly is one easily implemented method for helping cultivate these skills in students (although there are many others). Having said this, instructors need to be sure to also include these types of questions on graded assessments, otherwise students will not see any value in learning to "Apply" and "Analyze", since their grade will not be affected by not doing so.

Limitations of the Study

The current work represents a snapshot of student understanding of KMT and energy changes for a simple heating curve. Although the data was not collected in direct student interviews, the answer choices were based on the most common responses in essay format and therefore are a fairly accurate reflection of student thinking. Since the reported data was collected from students at a single university, the results may not be transferrable to every university. Furthermore, the General Chemistry curriculum as taught at the university, may not exactly match the topical coverage of all first-year chemistry courses. In addition, due to the diverse student population of the university, the results may not be transferrable to students of more highly selective colleges and universities. However, the correlations elucidated here may very well be transferrable to other public universities with ethnically diverse students. Lastly, the relatively good performance of the GC1 students may be due to the temporal proximity of the tested material or unconscious bias during instruction that might lead to better performance by this group.

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The Relationships between Parental Involvement, Students' Basic Psychological Needs and Students' Engagement in Science: A Path Analysis

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Abstract

This study aimed to investigate relationships between Turkish middle school students' perceptions of parental involvement, students' basic psychological needs, and their engagement in science. Parental involvement was addressed with four dimensions: parents' educational aspiration, parental communication, parents' participation, and parental autonomy support. Students' basic psychological needs incorporated autonomy, competence, and relatedness. Additionally, students' engagement consisted of behavioral, cognitive, emotional, and agentic engagement. The sample of the study included 926 sixth, seventh, and eight grade students educated in one of the largest cities located in eastern part of Turkey. A path analysis using LISREL 8.8 programme was conducted to examine the hypothesized relations among variables of the study. Analysis results showed that parent educational aspiration, parental communication, parent participation, and parent autonomy support were statistically significantly and positively related to basic psychological needs. Besides, students whose basic psychological needs were met demonstrated more behavioral, cognitive, emotional, and agentic engagement in science.

Introduction

Waterman (2005) defines motivation as a factor that brings out human behavior. Motivation is an element enabling individuals to take action for executing certain behaviors (Adler, Milne, & Stablen, 2001). Studies that have been carried out on the effects of student motivation in all branches in general and science learning in particular demonstrate that motivation is an undeniable factor for the improvement of students' science process skills, critical thinking skills, and academic achievement (e.g., Lee & Brophy, 1996; Yılmaz & Huyugüzel Çavaş, 2007). The insufficiency of motivation level may hinder the execution of the behavior (Brophy, 1998).

One of the theories focusing on the issue of motivation is self-determination theory. According to the self-determination theory, basic psychological needs of an individual are universal and they are common needs for all individuals (Deci & Ryan, 2000). The basic psychological needs are inborn and an individual is in an effort to satisfy these needs in every stage of life (Kasser & Ryan, 1999). There are three basic psychological needs as sources of internal motivation for individuals: autonomy, competence, and relatedness. Autonomy is a person's ability to make decisions on his/her own, to initiate his/her own behavior, to prefer and sustain it (Deci & Ryan, 1985). Autonomous students feel that they are free to decide how to study and free to express their opinions, people around them consider their feelings, and they are not pressured (Baard, Deci, & Ryan, 2004). Competence is the feeling of being efficient in coping with the problems encountered within a particular environment (Deci & Ryan, 1985). In other words, competence refers to the students' feeling of capable and accomplishing tasks, and being able to gain new skills (Baard et al., 2004). Relatedness refers to the ability to establish supportive relations with the environment (Deci & Ryan, 1985). Students high in relatedness like people they interact with, have lots of social contacts, and feel that people are friendly towards them (Baard et al., 2004).

One of the factors which influence students' motivation is parental involvement in school lives. Parents play an important role in motivating their children and children's use of what they learn actively in their social environments (Danielson, 2002). A supportive home atmosphere has a positive impact on students' learning outcomes (Trivette & Anderson, 1995). Gonzalez-DeHass, Willems, and Holbein (2005) emphasize that parental involvement is of great importance in students' academic motivation and that various dimensions of parental involvement must be studied in relation to their effects on students' motivation. In this respect, Fan and Williams (2010) studied the impact of parental involvement on 10^{th} grade students' motivation. The researchers focused on certain dimensions of parental involvement such as parental participation in students' out-of-school activities, parental advice, parent-school communication, parental involvement in school activities, and parents' educational aspiration. They found that parents' educational aspiration and school-initiated contact with parents significantly and positively predicted engagement and students' self-efficacy and intrinsic motivation both in mathematics and English. Parental advising was significantly and positively related to higher self-efficacy and intrinsic motivation in English but unrelated to these motivational outcomes in mathematics, which indicates that the studied relations may differ from subject to subject. The present study is interested in how parental involvement is related to students' basic psychological needs in science. In the current study, parental involvement was addressed with four dimensions: parents' educational aspiration, parental communication, parents' participation, and parental autonomy support. Parents' educational aspiration is about students' perceptions that how far their parents want them to go in school (from middle school to graduate school). Parental communication refers to students' discussion of the things they learn in class and school activities with their parents. Parents' participation addresses parents' attendance to school meetings and events, visiting student's class, and speaking with the teachers (Fan, 2001). Parental autonomy support, on the other hand, refers to students' perception that their parents give them advice about how they should behave; talk with them about when they have done something wrong rather than punish them, and think it is okay to make mistakes (Robbins, 1994). Some studies report that parental involvement and students' psychological needs (i.e., autonomy, competency, and relatedness) are in a positive relationship (Grolnick, 2015; Grolnick, Ryan, & Deci, 1991; Marbell & Grolnick, 2013).

Previous study findings point out that when students' level of motivation is high, they are more likely to engage in classes (e.g., Reeve & Lee, 2014; Uçar & Sungur, 2017). Students' engagement in classes is the learning effort of students through instructional activities offered to them, in other words, the students' reaction to what is offered and absorption of it (Fredricks, Blumenfeld, & Paris 2004). Students' engagement is a multidimensional concept (Fredricks et al., 2004; Sinatra, Heddy, & Lombardi, 2015). Engagement consists of dimensions of (i) behavioral, (ii) cognitive, (iii) emotional, and (iv) agentic engagement (Reeve, 2012; Reeve & Tseng, 2011). Behavioral engagement can be defined as active participation in activities, showing effort and concentration. Cognitive engagement is students' trying to comprehend the information in order to learn it (Newmann, Wehlage, & Lamborn, 1992). Emotional engagement consists of students' emotional reactions such as sadness, cheerfulness or happiness that they feel during learning activities (Skinner & Belmont, 1993). Agentic engagement is a dimension of engagement suggested recently by Reeve and Tseng (2011), indicating students' active and constructive contribution to instruction such as by asking questions and expressing their opinions. Student engagement is important due to its positive relationship with positive student outputs such as academic achievement (Fredricks et al., 2004).

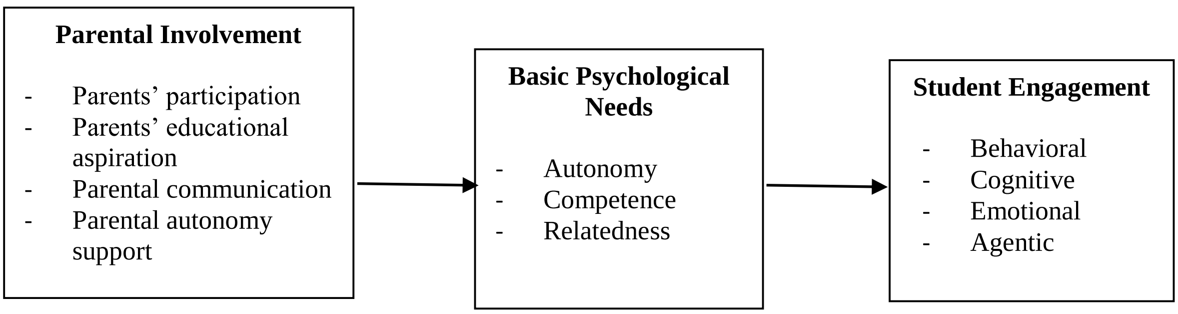

Figure 1. The hypothesized model showing the relations between parental factors, students' motivation and students' engagement

Connell (1990) developed a model and analyzed the relations among social environment, basic psychological needs, and behavior. According to the model, the social environment involving parents, classroom and school influences students' basic psychological needs. Basic psychological needs in turn play an important role in students' engagement. Regarding student engagement and motivation, domain specificity is important since they differ in different domains (Sinatra et al., 2015). Under the light of the relevant literature and inspired from the model developed by Connell, this study aims to investigate the relationships between the level of involvement by middle school students' parents into school life, students' motivation and engagement in science. The model to be tested is presented in Figure 1. Parental participation, parents' educational aspiration, parental communication, and parental autonomy support are the family factors to be discussed in this study. Students' motivation in science classes will be dealt with in relation to basic psychological needs. Components of basic psychological needs are autonomy, competence and relatedness. Students' engagement in science is addressed with behavioral, cognitive, emotional, and agentic engagement aspects.

As mentioned, self-determination theory emphasizes the importance of meeting students' basic psychological needs (Deci & Ryan, 2000) and literature points out the role of parents in students' motivation (e.g., Danielson, 2002). Gonzalez-DeHass et al. (2005) identify the gap in the literature and mention the need for studies examining the relations between student motivation and parental involvement by incorporating various aspects of parental involvement. Similarly, Fan and William (2010) suggest that there is need to investigate different aspects of parental involvement since different aspects may affect student motivation distinctively. Therefore, this study aims to contribute to the literature by addressing various aspects of parental involvement (i.e., parental participation, parents' educational aspiration, parental communication, and parental autonomy support). Furthermore, factors associated with student engagement deserves investigation because student engagement contributes to meaningful learning and academic achievement (Fredricks et al., 2004; Raftery, Grolnick, & Flamm, 2012). Hence, from the self-determination theory perspective and based on Connell's (1990) model, this study desires to examine the relationships between parental involvement, student motivation, and student engagement in science.

Method

This study is a correlational study examining the relationships between parental involvement in school life, students' basic psychological needs and engagement in science. By the use of this method, it is aimed to reveal the relations among the variables of interest and determine the levels of relations.

Sample

Participants of the study involves 6th, 7th and 8th grade students studying at nine public schools located in three central districts of the city of Erzurum. Erzurum is one of the largest cities in eastern part of Turkey. The schools in which the study would be carried out were selected through convenience sampling. These schools were easily accessible for the authors of the study. A pilot study was conducted to perform validity and reliability analyses for the scales that were translated into Turkish (to be mentioned in data collection tools section). The pilot study involved 200 middle school students studying within the provincial borders of Erzurum. The pilot study consisted of 125 (62.5%) female students, 74 (37.0%) male students, and one student who did not specify his/her gender. The pilot study involved 71 (35.5%) 6th grade students, 65 (32.5%) 7th grade students and 63 (31.5%) 8th grade students. In the main study, there were 926 participants; 415 (44.88%) of whom were female students and 448 (48.4%) of whom were male students. The study involved 324 (35%) 6th grade students, 374 (40.4%) 7th grade students and 183 (19.8%) 8th grade students. The mean age of the participants was 13.04 (*SD*= .91). The students' end-of-year average for science class was 3.47 (*SD*= 1.27) over 5 in the previous term. Most of the participants had non-working mothers (79.4%) whereas they had working fathers (79.4%). Likewise, most of the participants had three and more siblings (74.7%).

Data Collection Tools

The data were collected through, Demographic Information Questionnaire, Student Engagement Scale, Parental Involvement Scale, and Basic Psychological Needs Scale.

Demographic Information Survey

Respondents were asked about their gender, date of birth, grades, number of siblings, end-of-year score for science class in the previous term, and whether their parents work, with the purposes of obtaining background information about the students and their families.

Student Engagement Scale

The scale was developed by Reeve and Tseng (2011) and adapted to Turkish by Uçar and Sungur (2017). It is a 4-point Likert scale (1= Strongly Disagree, 4= Strongly Agree) with 22 items. The scale includes sub-dimensions of behavioral, cognitive, emotional and agentic engagement. Behavioral engagement was measured with 5 items (exemplary item: 'I listen carefully in science class'), emotional engagement includes 4 items (exemplary item: ‘When we work on something in science class, I feel interested’), cognitive engagement involves 8 items (exemplary item: ‘When I study science, I try to connect what I am learning with my own experiences’), and agentic engagement was measured with 5 items (exemplary item: ‘During science class, I express my preferences and opinions’). The results of the confirmatory factor analysis conducted by Uçar and Sungur (2017) provide evidence about the validity of the Turkish version of the scale. Cronbach alpha reliability coefficients varied between .78 and .94 for the sub-dimensions. The reliability levels obtained in this study were similarly high. Cronbach Alpha coefficient for agentic engagement is .90, behavioral engagement is .94, emotional engagement is .90 and cognitive engagement is .94.

Parental Involvement Scale

In this study, parental involvement is addressed with four dimensions, which are parents’ educational aspiration, parental communication, parental participation, and parental autonomy support. Parents’ educational aspiration, parental communication, and parental participation sub-scales were taken from the scale used by Fan (2001). Parental autonomy support sub-scale was adapted from Perceptions of Parent Scales (POPS), which was first used in a PhD dissertation by Robbins (1994), and for which the reliability and validity proof was provided once again by Niemiec et al. (2006). All dimensions used to evaluate the parental involvement were translated and adapted into Turkish in this study. The scale consists of 18 items.

The items in the scale were first translated from English into Turkish, and another researcher did the back-translation from Turkish into English. The translated items were compared with the original items and necessary corrections were made. The items that were translated into Turkish were examined by a linguist and necessary revisions were made. In the pilot study, participants completed Turkish form of the parental involvement scale. In order to examine construct validity of the scale, confirmatory factor analysis was conducted on the data by using LISREL 8.8 programme (Jöreskog & Sörbom, 2007). It is suggested that a number of goodness of fit indices should be used while analysis results are evaluated. When the root mean squared error of approximation (RMSEA) is below 0.1, it refers to good model fit (Steiger, 1990). It is recommended that the standardized root mean squared residual (S-RMR) should be below 0.05 for goodness of fit (Kelloway, 1998). That the comparative fit index (CFI), non-normed fit index (NNFI) and incremental fit index (IFI) are over 0.9 reveals the conformity between the proposed model and data set (Bentler, 1990; Kelloway, 1998). Fit indices obtained from the pilot study (RMSEA= 0.071, S-RMR= 0.068, CFI= 0.911, NNFI= 0.893, IFI= 0.913) show that the proposed factor structure fits the data set but is not at the desired level.

After the pilot study, the items were reviewed through the opinions of an expert and 5 middle school students and some modifications were made after which the main study was carried out. The goodness of fit indices (RMSEA= 0.084, S-RMR= 0.040, CFI= 0.984, NNFI= 0.981, IFI= 0.984) obtained from the confirmatory factor analysis that was conducted on the main study data show that the proposed factor structure has a good model fit with the data set. Parents’ educational aspiration consists of two items including five options about the educational level to which parents wish their children to reach (1= middle school, 2= high school, 3= associate degree, 4= undergraduate degree, 5= graduate degree). Other items are composed of 5 point Likert type (1= never, 2= rarely, 3= sometimes, 4= usually, 5= always). Parental communication consists of 5 items (exemplary item: ‘I discuss school activities with parents’), parental participation consists of 4 items (exemplary item: ‘My parents attend school meetings’), and parental autonomy support consists of 7 items (exemplary item: ‘My parents think it's OK if I make mistakes’). Cronbach’s Alpha coefficient for the sub-dimensions of the scale is .95 for the parents’ educational aspiration, .92 for parental communication, .88 for parental involvement and .89 for parental autonomy support.

Basic Psychological Needs Scale

The items used by Baard et al. (2004) to measure individuals’ basic psychological needs were adapted into Turkish by Durmaz (2012). The scale consists of three psychological needs, which are sense of relatedness, competence, and autonomy. Sense of relatedness has 6 items (exemplary item: ‘I really like the people I interact with in science class’), competence includes 8 items (exemplary item: ‘I have been able to learn interesting new skills recently in science class’), and autonomy consists of 7 items (exemplary item: ‘I generally feel free to express my ideas and opinions in science class’). In Durmaz’s (2012) study, Cronbach’s Alpha values for the sub-dimensions of basic psychological needs scale were estimated .72 for the need for autonomy, .65 for the need for competency and .87 for the need for autonomy. Reliability coefficients obtained in the present study were high: Cronbach's Alpha value was .91 for autonomy, .90 for competency and .88 for the dimension of autonomy.

Procedures

Firstly, permission was taken from Erzurum Provincial National Education Directorate under Ministry of Education for administration of surveys to the students. The survey was in paper form. The first author of the study collected the data in class and no particular class was selected. Directions written on the surveys were also explained by the data collector and it was explained that the data were going to be used only for scientific research purposes. The participants were not asked any information that would reveal their identity. The participants completed surveys within one class period that is 40 minutes. All the data were collected in one and a half month.

Results

Through preliminary analyses, the distribution of the variables, the existence of outliers, and the correlation among the variables were examined. Skewness and Kurtosis values signify the normal distribution of the variables. Multivariate outliers were identified by Mahalanobis distance and 4 participants were excluded from the study. Pearson correlations between autonomy, relatedness, and competence showed high positive relations between the variables. The correlation between autonomy and competency was r= .89; the correlation between autonomy and relatedness was r= .91; and the correlation between competency and relatedness was r= .90. Deci and Ryan, developers of the scale, were contacted and asked whether these structures could be dealt with together under these circumstances. Indeed, a number of studies dealt with autonomy, competence and relatedness collectively (e.g., Reeve & Tseng, 2011; Van den Broeck, Vansteenkiste, De Witte, & Lens, 2008). Deci and Ryan responded that after the dimensions were formed, the mean score can be taken to generate the 'basic psychological needs' variable. Therefore, the basic psychological needs variable was formed by taking the mean value for the autonomy, competence, and relatedness.

Descriptive Statistics

Initially, the level of students' perceptions of their parents' school involvement (parents' educational aspiration, parental communication, parental participation, and parental autonomy support) were examined. It was observed that most students believe that their parents want them to take graduate degree. Furthermore, parental involvement is at medium level in dimensions such as parental communication (M= 3.56), parental participation (M= 3.35), and parental autonomy support (M = 3.51). This outcome signifies that parents sometimes speak to their children about the activities they do in class, that they sometimes attend to their school activities and that they sometimes support their autonomous actions. The mean values for basic psychological needs dimension of relatedness (M= 3.54), competence (M = 3.46) and autonomy (M = 3.46) are close to each other. These findings indicate that students are at an average level with respect to feeling free about how to study science, feeling themselves competent in science class, and being in good terms with the people they communicate while studying science.

The mean scores for behavioral engagement (M = 3.05), cognitive engagement (M = 3.05), emotional engagement (M = 2.91), and agentic engagement (M = 2.84) are also close to each other. These scores show that students tend to make a difference in the flow of science lesson actively such as by telling his/her preferences about learning activities and informing their teachers of their interests (agentic engagement). Students generally tend to concentrate during science class and study more (behavioral engagement), enjoy acquiring new information (emotional engagement) as well as try to associate new information with their already acquired knowledge (cognitive engagement). In a study conducted by Uçar and Sungur (2017) in Turkey, the level of 7th grade students' engagement in science class was measured by using the same scale and the mean scores of the dimensions of engagement ranged from 2.74 to 3.19 which are similar to those found in this study.

Inferential Statistics

The model involving the relationships among students' perception about parental involvement in their school lives, students' basic psychological needs in science class and their engagement in science class were tested through path analysis by the use of LISREL 8.8 programme (Jöreskog & Sörbom, 2007). Goodness of fit indices obtained as a result of analysis (RMSEA = 0.092, S-RMR = 0.032, CFI = 0.993, NNFI = 0.985, IFI = 0.993, GFI = 0.968) show that the proposed model fits well to the data set. The standardized path coefficients are presented in Table 1 and the figure representing the model is given in Figure 2.

Table 1. Standardized coefficients

Direct Effect	Standardized Coefficients	*SE* of the estimates	*t*	R^2
Basic psychological needs				0.82
Parents' educational aspiration	0.12	0.01	6.36*	
Parental communication	0.36	0.03	11.34*	
Parents' participation	0.14	0.02	5.18*	
Parental autonomy support	0.37	0.03	13.24*	
Agentic engagement				0.72
Basic psychological needs	0.85	0.01	48.51*	
Emotional engagement				0.70
Basic psychological needs	0.84	0.01	46.67*	
Cognitive engagement				0.71
Basic psychological needs	0.84	0.01	47.46*	
Behavioral engagement				0.74
Basic psychological needs	0.86	0.01	50.91*	

Note: * $p < .05$

According to the analysis results, students' perception about parental involvement explain 82% of the variance in basic psychological needs which is a considerable amount of variance (See Table 1). According to the parameter estimates, high levels of parental autonomy support (γ= .37), parent communication (γ= .36), parent participation (γ= .14), and parents' educational aspiration (γ= .12) are statistically significantly and positively linked to students' basic psychological needs. Furthermore, basic psychological needs variable is statistically significantly related to each dimension of engagement: Basic psychological needs variable positively predicts agentic engagement (γ = .85), emotional engagement (γ = .84), cognitive engagement (γ = .84), and behavioral engagement (γ = .86). The explained variance in the dimensions of engagement varies between 70% and 74%.

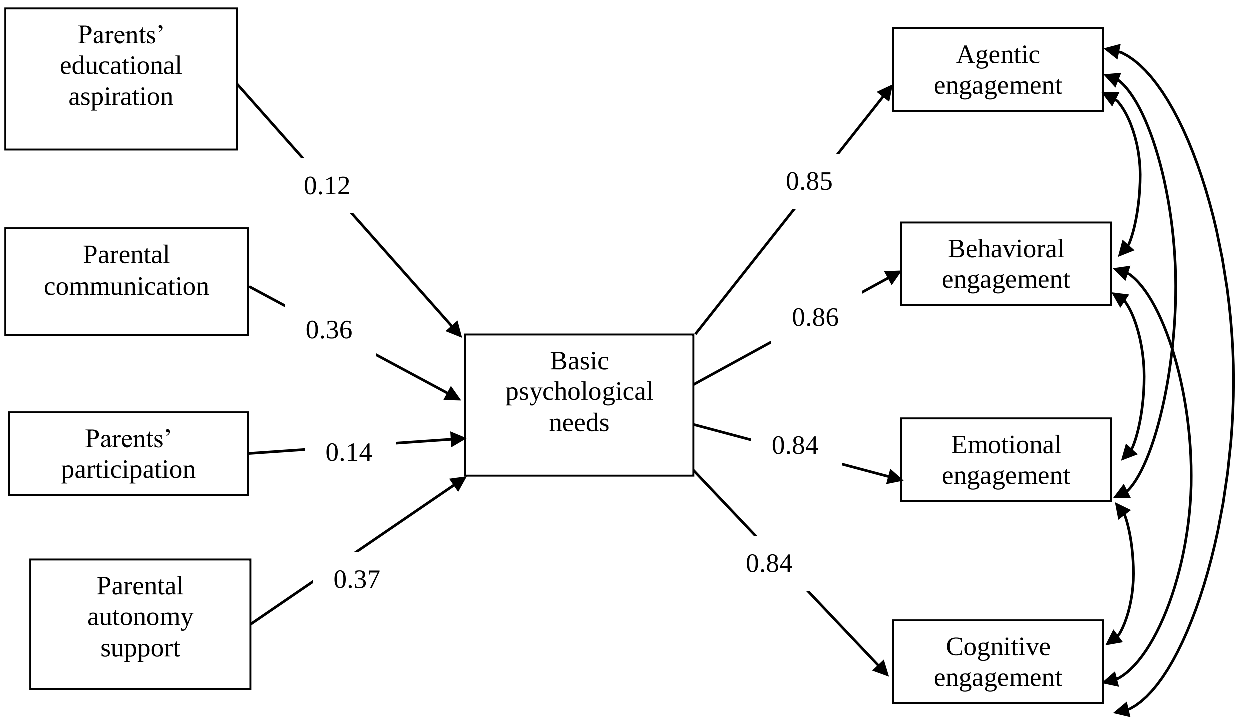

Figure 2. The model showing the relations between parental involvement, basic psychological needs, and engagement variables

Note: $p < .05$ for all standardized coefficients

Discussion and Conclusion

This study examined the relationships among parent involvement of middle school students, students' motivation, and engagement in science through testing a model. Parental factors addressed in the study comprise of parental participation, parents' educational aspiration, parental communication, and parental autonomy support whereas students' motivation in science class is examined in consideration with basic psychological needs of autonomy, competence, and relatedness. Students' engagement in science class was addressed with behavioral, cognitive, emotional, and agentic engagement.

The Predictive Effect of Parental Involvement on Basic Psychological Needs

On analyzing the relationships among students' perception about their parental involvement and their basic psychological needs in science, parents' high educational aspiration, parental communication with their children, parental participation, and parental autonomy support statistically significantly and positively predict students' basic psychological needs. The examination of standardized coefficients revealed that parental communication and parental autonomy support predict basic psychological needs better than the other parental involvement variables in the model. These findings can be expected because as parents' want their children study at higher levels of schools, students may feel more competent; as parents communicate with their children about academic and social school activities and participate in school meetings, students may feel more related to the school; and as parents give more responsibility to their children for their behaviors and allow children make decisions, students may feel more autonomous. Parental communication and autonomy support especially seem to be useful in fulfilling students' basic psychological needs.

The studies investigating the relationships between parental involvement and students' motivation have produced similar results to our study and suggested that there is a positive relationship between parental involvement and students' motivation. For example, Fan and Williams (2010) studied the relationship between parental involvement and students' motivation among 10th grade students. The variables examined about students' motivation are engagement, intrinsic motivation in English and mathematics classes and self-efficacy. Parental involvement consists of many variables such as parental communication, parents' educational aspiration, and parental advice for students about school. Multiple regression analyses results show that parents' educational aspiration for their children and parents' communication about the positive circumstances at school positively predict students' motivation. On the other hand, parental communication about children's poor performance at school is in negative relationship with all motivational dimensions. Parental advice for their children about school (issues about classes they choose at school and studying for the university entrance exam) has a positive relationship with their self-efficacy and intrinsic motivation in English class. In another study, Fan, Williams and Wolters (2012) explored the relationship between parental involvement and students' motivation, and asserted that parents who have positive communication with school increase their children's motivation. The parent communication mentioned in the present study also involves issues such as communicating with the children about social activities at school, in-class activities, and plans for high-school life, and is in line with the results obtained by Fan and his colleagues.

Grolnick (2015) investigated the relationship between mothers' involvement and some student outcomes. 178 students studying at 4th, 5th and 6th grade and their mothers participated in the study. The path analysis showed that mothers' involvement predicts students' level of competency statistically significantly and positively. In another study which sampled 6th grade students, parental autonomy support was found to be positively associated with students' autonomy (Marbell & Grolnick, 2013). In another study, Grolnick, Ryan, and Deci (1991) explored the effect of family environment on students' academic success and motivation in a sample of 3rd grade to 6th grade students. The results obtained from the study showed that parental autonomy support is positively linked to students' sense of competency and autonomy. Previous research also examined the situation in college students. Ratelle, Larose, Guay, and Senécal (2005) found that college students who get parental autonomy support are more autonomous and that parental involvement is statistically significantly related to students' autonomy and sense of relatedness. To sum up, studies exist in the literature supporting the positive relationship between parental involvement and students' basic psychological needs which is also found in the present study. When parents' educational aspiration is for a higher education and when they speak to their children about academic and social activities at school and plans for high-school life, attend parent meetings at school and speak to teachers, support their children's autonomy, students may feel more competent, autonomous, and related.

The Relationship between Students' Basic Psychological Needs and Students' Engagement

Besides investigating the relationship between parental involvement and basic psychological needs, this study examined how basic psychological needs are linked to student engagement. Analysis results show that students' basic psychological needs predict agentic, emotional, cognitive, and behavioral engagement statistically significantly and positively. This finding is important because as students' basic psychological needs are fulfilled, they are more likely to engage in science. In other words, students who feel more autonomous, competent, and related in science class contribute to the course of class by asking questions and telling the teacher about likes and dislikes about the lesson, concentrate more in class, show more interest in class, like to learn new things in class, and associate new information with their experiences. Therefore, meeting students' basic psychological needs appear to be a way to promote students' science engagement. Supporting students' autonomy helps students ask questions freely, become interested in activities and share their opinions readily (Reeve, 2012; Reeve & Lee, 2014). Pintrich and Schunk (2002) asserted in their study that individuals with a high level of competency, another dimension of basic psychological needs, show more effort in their work or otherwise they become sick and tired of their jobs. Furrer and Skinner (2003) found that the more the children's sense of relatedness, the higher is the probability that children adopt and embrace their environment, as a result of which children's engagement will increase significantly. The study also mentions that the sense of relatedness minimizes students' feelings of being under pressure, anxious, sick, and tired about learning and having negative attitudes towards their educational life. Based on the findings of the previous studies and results obtained from the present study, meeting students' basic psychological needs seem to be important for students' engagement.

In conclusion, this study revealed that parental involvement positively predicts students' basic psychological needs which in turn predicts student engagement in science positively. Hence, it seems that students who feel competent, related, and autonomous are more likely to engage in class. These students tend to contribute to the instruction by asking more questions and specifying their personal preferences, concentrate on the learning material during class, enjoy learning new things, and associate newly learnt material with their experiences. Accordingly, meeting students' basic psychological needs seems to promote students' science engagement and parental involvement has potential to fulfill these needs. Therefore, based on the findings of the present study we suggest that parents' possession of high educational aspiration for their children and cause their children to perceive about their expectation is important. This may help to increase students' competency beliefs. Furthermore, parents' communication with their children about academic and social activities at school and plans for high-school life appears to support students' basic psychological needs. We also suggest that parents attend school activities, visit their children's classes, and speak to teachers. Besides, as long as parents speak to their children about how to fulfil responsibilities, tolerate and speak to them about what is right and what is wrong when they make mistakes, it may support their need for autonomy. Having an efficient educational period depends on whether the child's basic psychological needs are met well and the family should have the equipment that can meet these needs (Sönmez, 1990; Yörükoğlu, 1983). Parents' desire for the education of the child's puts some responsibilities to the parents and it affects parents' participation in out-of-school activities, involvement in the child's homework, and communication with the child (Hill & Tyson, 2009). Parents should not put in constant rules and keep a repressive attitude in their communication with their children. Parents who accept their child as an individual and take the child's views and suggestions into account create a democratic home environment (Barbato, Graham, & Perse, 2003). Individuals who receive support from their parents for meeting the need for autonomy establish positive relationships with their parents and their surroundings and they in turn can easily solve the problems they encounter (McElhaney & Allen, 2001). Additionally, parents' autonomy support contributes to the children's interest in the lesson and academic achievement (Chirkov & Ryan, 2001).

In the future studies, activities can be arranged to increase parental involvement for the sake of meeting students' basic psychological needs. Various activities can be organized to make parents aware of this issue. For instance, seminars can be given to parents, so that they can be provided with continuous interaction by introducing exemplary roles and models for promoting students' motivation. The efficiency of these social activities can be studied through experimental design. Moreover, besides the role of parental involvement, researchers who will conduct research in this area may consider the influence of teacher practices and school environment on students' motivation and engagement. When the child's basic psychological needs are considered and addressed in the school context, the child may not feel pressured in the learning process and may reduce his or her anxiety and negative feelings towards the lesson (Anderman, 1999; Eccles & Midgley, 1989). Additionally, in the future studies, qualitative data may be collected through classroom observations to measure student engagement and parent interviews can conducted to get in depth information about parental involvement.

The present study has some limitations that should be mentioned. The variables of the study were measured through students' self-reports and thus measures of student engagement, motivation, and parental involvement depend on students' perceptions. As the study has a correlational design, it is not possible to constitute a cause-and-effect relation between variables of the study. Additionally, given that students' motivation and engagement are subject-specific (Sinatra et al., 2015), the relations must be examined with other subjects, as well.

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Turkish Science Teacher Candidates Understandings of Equitable Assessment and Their Plans about It

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Abstract

This study aims to investigate how Turkish science teacher candidates understand equitable assessment and in what ways they plan to provide equitable assessment practices. 156 science teacher candidates from a teacher education program in a large university in Eastern part of Turkey participated in the current study. A questionnaire and semi-structured interviews served as data sources. All collected data were qualitatively analyzed to illustrate science teacher candidates' understandings of equitable assessment and their plans to achieve equitable assessment in their lessons. Results of the study showed that science teacher candidates mostly equated equitable assessment with fairness including fairness in grading. But most of the teacher candidates did not consider that providing equal opportunities for students to display their levels of understanding about the related concepts was not an important characteristic of equitable assessment. The results also showed that participants focused on differences in learning styles and language as reasons why to provide equitable assessment and accordingly stated some ways to achieve equality in assessment processes for these groups. While preparing teachers, teacher education programs need to emphasize more understanding of diversity and provide the knowledge and attitudes necessary for effective teaching.

Introduction

Today teachers need more to serve for all students than before because contemporary schools are different places than those schools where people attended a few decades ago. Recently almost all nations have experienced the influx of refugees, immigrants and migrants, which have changed the demographical structures of many schools and classrooms. In return, this presents challenges for teachers to understand the increased diversity in ethnics, linguistics, culture, religion and intellect which should be taken into consideration to provide effective instruction for all students. Researchers have illustrated that teaching science in equitable and contemporary ways is a complex and also difficult endeavor for teachers and even more difficult for prospective and beginner science teachers (Lawton, Philpott, & Furey, 2011; Mentz & Barrett, 2011). Therefore, as Linda Darling-Hammond has described, "teachers need a much deeper knowledge base about teaching for diverse learners than ever before and more highly developed diagnostic abilities to guide their decisions" (Darling-Hammond, 2006, p. 300).

Turkey is a multicultural country and students bring diverse cultural backgrounds into their classrooms. Turkey has seven different regions where diverse people having different cultures, native languages, religions etc. live together. These differences form a diverse student population for educational system of Turkey. Furthermore, by the influx of refugees, immigrants and migrants, the diversity of students has also been increasing at schools in Turkey as well. Particularly, the refugees and immigrants from different countries such as Syria, Iraq, Iran and Afghanistan require Turkish educational system to serve all students regardless of their cultural, linguistically, religious and ethnical backgrounds. According to the office of the United Nations High Commissioner for Refugees (UNHCR), more than 3.7 million refugees, out of whom 3.3 million are Syrian, live in Turkey according to numbers at the end of the 2017 and more than 50% of them are at school age. Thus, it is critical for Turkey to develop inclusive programs and also prepare teachers to meet the needs of these diverse groups of learners.

Teachers constitute a vital part of educational systems and are responsible for transferring planned educational programs into real classroom practices (Smith & Southerland, 2007). Thus, teachers' competences are important to meet the needs of diverse students too. Taking diversity of students into account during planning and practicing the instruction is also highlighted by Ministry of National Education (MoNE) of Turkey and it is determined as a prerequisite for teachers according to “The General Qualifications of Teaching Profession” standards published by MoNE (MoNE, 2017). According to these standards, teachers are expected first to “Prepare a flexible instructional plan by considering individual differences and sociocultural characteristics of students.” and second to “Design a learning environment by considering individual differences and needs of learners.” (MoNE, 2017, p. 14) Thus, as it is required by MoNE (2017), it is important to prepare both in-service and teacher candidates for an effective teaching and assessing a diverse group of learners in Turkey.

Equitable instruction in science is crucial since learning science is dependent on cognitive and physical differences as well as other differences such as ethnicity, language and culture. Furthermore, these differences also influence how students engage in scientific practices, learn science and show their conceptual understandings (Fusco & Barton, 2001; Lyon, 2013; Siegel, 2007). One of the dilemmas which science teachers face in delivering equitable instruction is to uncover, assess and support diverse students’ learning of science (Fusco & Barton, 2001; Lyon, 2017; Siegel, 2014). In order to assess and support diverse students’ science learning, science teachers need to understand and use equitable assessment (EA) practices, and so, they can provide equal opportunities for all students in scientific practices. EA includes assessment practices in which students are given equal opportunities to show what they know and what they need to do to master their own learning (Hazel, Logan & Gallagher, 1997; Siegel, 2014; Suskie, 2000). It requires teachers to use most appropriate assessment forms in accordance with their students’ characteristics such as their language and intellectual abilities, genders and cultures. In other words, each student should be considered as a special case and accordingly, her/his science learning should be supported through developing, applying and interpreting the assessment.

Formative assessment which is known as assessment for learning is important for science teachers to uncover, monitor and foster all students’ science learning. Using EA practices in formative assessment process to collect data on students’ learning and using these data to provide feedback and revising the lessons accordingly were proved to affect learning successes of all students in science (Fusco & Barton, 2001; Siegel, 2007; Siegel, 2014; Suskie, 2000). Beside of helping students to learn, EA behaves as a tool to reveal any inequalities which may occur during instruction in classrooms (Lyon, 2013); also, using EA is essential for minority students since they cannot otherwise be given any learning opportunity. Furthermore, teachers’ beliefs about learning and learners influence their assessment decisions as well (Siegel, 2014).

Science teacher candidates in Turkey should be prepared to assess and support diverse student learning of science since they may teach such a diverse group of students in their professional lives. In order to make science teachers in EA practices to assess and help all students’ learning, it is important for science teacher educators to provide that science teacher candidates (a) have a detailed knowledge and understanding of EA and (b) value and desire to engage EA practices to facilitate learning regardless of students’ individual differences. In literature there is no study about science teachers’ understandings or practices of EA in Turkey. Therefore, this study aims to investigate how Turkish science teacher candidates understand EA and in what ways they plan to provide EA practices for their students.

Conceptual Framework

The current study is constructed upon three key assumptions. First, learning is a socially-constructed and culturally-mediated activity and together with cognitive or physical differences, learning also depends upon other factors such as age, gender, language, social class, ethnicity and disability (Lawton et al., 2011; Mentz & Barrett, 2011). For that reason, since the demographical structures of many schools and classrooms are changed under influence of globalization, we should handle the problems of fairness and equality from a larger point of view.

Second, teachers’ knowledge and beliefs are essential in effective learning, teaching and assessment practices (Scott & Weber, 2014; Tierney, Simon & Charland, 2011). Especially, teachers’ knowledge and beliefs about diverse learners are crucial for accomplishing equality during instruction and assessment (Siegel, 2014). In order for science teachers to equitably assess and support student learning, they should know not only about EA but also about the differences among learners as well (Lee, 2001). Teachers’ beliefs about diversity influence their practices (Siegel, 2014) and teachers who think that providing language, culture and learning opportunities during teaching process is not their responsibility do not tend to use EA to achieve equality (Lee, Luykx, Buxton & Shaver, 2007). Furthermore, teachers’ beliefs about learning and learners also influence their assessment decisions (Siegel, 2014).

Third, teachers' knowledge, skills and their usage of EA strategies are important. Teachers should have knowledge and skills to design/choose and implement EA to facilitate diverse students' learning. Designing and using EA requires teachers to have the target science concepts and be aware of the learner differences such as culture and language and be open to them (Darling-Hammond, 2006). Teachers should also know how to modify an assessment for minority students and what kind of accommodations they should do and how they will equitably assess and support their students' learning through these accommodations (Abedi, Hofstetter & Lord, 2004). However, this is more difficult for teacher candidates because of their lack of classroom experiences (Siegel, 2014). For teachers, providing accommodations for some students endanger fairness because these accommodations make assessment task easier for them. EA is not just about fairness, however, it is about providing equal opportunities for all learners to participate in learning process and show that they are learning. Therefore, EA strategies should not just ensure fairness but they must be challenging and supportive to learning as well (Siegel, 2007; Siegel, 2014).

According to the three key assumptions underlying the current study, this study aims to investigate Turkish science teacher candidates' understandings of EA through the following research questions;

1. How do science teacher candidates understand EA?
    a. How do participants view EA?
    b. Why is EA important for the participants?
    c. What factors influence EA according to the participants think?
2. How do science teacher candidates plan to achieve EA?

Methods

This study is qualitative in nature and uses case study design to investigate how science teacher candidates understand EA and plan to provide EA opportunities for students. Case studies have a clear advantage over other research designs because "the strategy employed is to investigate 'how' or 'why' questions asked about a contemporary set of events over which the researcher has no control" (Yin, 2009, p. 9). The study also contains multiple data sources, which researchers have identified as the unique power of the case study research design (Yin, 2009). While many studies focus on how science teachers provide EA opportunities to their language and cultural minority students (e.g., Lyon, 2013; Lyon, 2017; Siegel, 2014), this study aims to use a general perspective of equality to understand how science teacher candidates understand EA and plan to provide EA practices.

Participants

One hundred fifty six science teacher candidates studying in a teacher education program of a public university in the Eastern part of Turkey participated in the first phase of the current study. These participants were at their third and fourth year in their four-year teacher-training program. We wanted our participants to have some essential knowledge about educational assessment in order to provide rich data sources for the study. For that reason, we chose junior and senior teacher candidates since 'Educational Measurement and Assessment' course in the program was provided during the first semester of third year. Therefore, the participating teacher candidates completed their 'Educational Measurement and Assessment' course before attending to the current study. 88 junior and 68 senior teacher candidates, 80 of whom were male and 76 were female, were the participants of the study. Twelve participants, six from juniors and six from seniors, were selected for the second phase of the study to conduct interviews. Codes such as P-1 (participant-1) and P-2 were used to illustrate participants' opinions according to their responses for interview questions.

Data Sources

The current study was a part of a larger study that aimed to investigate science teacher candidates' assessment literacy. For the current study, there were two main data sources. The first, a questionnaire with ten items related to EA was used to collect data on participants' understandings of EA. The questionnaire had a six-point Likert type scale to let participants show their opinion on a completely disagree (1) to completely agree (6) line. As the questionnaire did not use any negative items, the higher average from the questionnaire meant the participants gave a higher importance to EA. All of the 156 participants completed the questionnaire. The items used in the questionnaire are given within the tables in the result section to show participants' opinions for the importance of EA.

After all the 156 participants completed the questionnaire, 12 participants, six from juniors and six from seniors, were selected according to Teacher Conceptions of Assessment Scale survey that they completed for a larger study (Brown, 2008). The survey was developed by Brown (2008) and was used to explore teacher candidates' conceptions of classroom assessment for the larger study. Based on the participants' survey results, four high, four medium and four low scored teacher candidates were selected for interviews to increase representation ability of the group. During the interview process, we used semi-structured interview questions to understand how teacher candidates understood EA deeply and in what ways they planned to provide EA practices for their students. Each of these interviews took approximately 20 minutes. As it is shown at Appendix 1, the interview questions aimed to investigate teacher candidates' ideas and understanding of EA and their plans for EA through focusing on individual differences of learners.

Data Analysis

Data from the questionnaire were analyzed to have a general picture of all participating teacher candidates about their understandings of EA. To achieve this, we used descriptive tables in the result section to show the averages and percentages for each item according to the participants' responses to six-point likert scale within the questionnaire. Data from the twelve participants' interviews were analyzed to investigate participants' understandings of EA and the ways they planned to provide EA. We used inductive coding rather than deductive coding to develop themes that explained participants' understandings of EA (Hatch, 2002). First, open coding was used by recording data on a spreadsheet during the analysis for each participant's interview to develop categories. Second, categories were analyzed to group similar categories under a more general category for each participant. Then, the categories were compared and contrasted to see common themes that explained the patterns of participants' thinking of EA. Later, we categorized the themes according to research questions to design the findings. For instance, we coded the first interview participant's definition of EA as using assessment to provide fair grades since the participant stated, 'For me, EA is to provide ways for a student to show what exactly s/he knows to provide fair grades.' Then, we combined the participant's other statements that focused on fair grading such as 'I think teachers need to observe their students well to provide fair grades.' to develop a general category that we named as fairness in grading. Then, by comparing and contrasting similar codes that focused on fair grading from other interview participants, we used fairness in grading as a common theme that represented the participants' views of EA.

To increase the reliability of interpretation of data, we used 'investigator triangulation' (Patton, 2015) in which more than one researcher interpreted a subset of the data to accomplish agreement of themes' development. We also used notes to show number of participants who supported the same category. Participants' responses to interview questions can be found in result section.

Results

We frame the findings of the study in accordance with the themes about teacher candidates' understandings of EA. The findings are presented according to related research questions. For each theme, we first used tables to represent the results of the related items from the questionnaire and then, we provided data from participants' interviews to support each of the themes.

Views and Importance of Equitable Assessment (RQ 1a, b)

In order to understand teacher candidates' ideas about why an assessment had to be equitable, three items were used in questionnaire (see Table 1) to illustrate participants' views of EA. The first item was related to the role of assessment in supporting all students to engage them in learning. The item aimed to uncover to what extend the participants agreed on the importance of providing equal assessment to support all students' participations in learning process. As it can be seen from Table 1, the results show that about 80% of participating teacher candidates (based on the combination scores of 4, 5, and 6) think assessments should be equitable since assessment is a way to engage all students in learning. The second item in the questionnaire was about the influence of assessment on students' motivation, self-efficacy and decisions about what to learn. This item revealed what participants thought about the importance of EA regarding its influences on students. According to the results most of the participants (84%) believed that assessment should have been equitable since it influenced students' motivation, self-efficacy and decisions about what to learn. Use of assessment to inform all students about important learning goals was the third item in the questionnaire. The implication of the item was that all students needed to be informed about learning goals through assessment; therefore, assessment should have been equitable for all students. Similarly, most of the participants (74.9%) approved this idea as a reason for EA.

Table 1. Participants' thinking about importance of EA

Views of EA (N: 156)	(1) Completely Disagree		(2)		(3)		(4)		(5)		(6) Completely Agree		Average ($\overline{X}$)
Questionnaire İtems	N	%	N	%	N	%	N	%	N	%	N	%	
Classroom assessment should be equitable because:													
Assessing students' scientific thinking and reasoning allow all students to engage in an effective science learning environment.	9	5.8	7	4.5	15	9.6	35	22.4	50	32.1	40	25.6	4.46
Classroom assessment influences all students' motivation, self-efficacy and decisions about what are important to learn.	8	5.1	5	3.2	12	7.7	34	21.8	51	32.7	46	29.5	4.61
Classroom assessment should inform all students about important learning goals.	11	7.1	9	5.8	19	12.2	32	20.5	34	21.8	51	32.7	4.41

Contrary to the results of the questionnaire, the results of interviews showed that the participants either did not have any idea about EA or they associated EA with fair assessments and fair grading practices rather than providing equal opportunities to engage all students in learning process to show their learning. For instance, some of the participants reported for EA that 'I do not have any idea' (P-2) or 'I have never thought about this before' (P-9). Many of the participants (P-1, 4, 7, 8, 10 and 11) also reported a vague understanding of EA or they often linked EA with fairness. Even if the participants were aware of the differences among learners and highlighted the importance of considering these differences during assessment processes, they tended to relate them with fair grading. For example, one of the participants highlighted the role of EA in providing fairness in grading as she reported;

> For me, EA should provide ways for a student to show what exactly s/he knows to have fair grades. However, we know each student has different abilities and speed of learning, and so teachers should observe their students very well to decide what types of assessments are appropriate for their students to show their real learning. I think, in this way, grades are being fairer.' (P-1)

One of other participants also underlined using appropriate assessment to provide fair grades as an aim of EA since, as he indicates, 'Making a fish to walk on a land and making it to swim in water are not same and not fair. So, students also should be provided proper forms of assessments to show their knowledge and abilities.' (P-3) Some of the participants (P-5, 7, 11) also linked EA with content validity by explaining the importance of asking questions from different cognitive levels and in all covered units. For instance, one of the participants emphasized, '…to be fair, teachers should ask questions from all covered units rather than some of them. Plus, an EA includes questions from all levels of difficulty because asking all easy or hard questions do not show students' real success.' (P-5) A few of the participants (P-7, 8, 9, 12) interpreted EA according to student-teacher relationships. For these participants', EA is related with teachers' fairness in grading students' works as one of them states, 'Teachers need to behave fair to all of their students. A teacher may like or dislike one of his students and this should not be a bias to give her/him an unfair grade.' (P-7) Similarly, one of the participants indicated, 'Teachers should disregard their personal opinions about a student and provide fair grades based on what s/he provided on her/his exam paper.' (P-9)

In summary, the results of the questionnaire showed that the participants mostly supported the idea that assessment should be equal for all students to show their own learning and it should equitably let students to access science content. The results of their interviews, on the contrary, displayed that participants generally understood EA as to provide fairness on letting students to show their real learning and in grading.

Factors Influencing EA (RQ 1c)

One of the enquiries in this study was to reveal the factors that the teachers believed which influenced students to demonstrate their learning during assessment process. For this purpose, we provided two different items in the questionnaire (see Table 2). First item was about the assumption that it was important to consider how it supported an individual student or groups of students since the assessment might provide inequalities for some students as a result of its nature during development of an assessment task.

According to the results, most of the participants (83.3%) favored the idea that the usage of an assessment with individual or groups of students influenced equality. The second item within the questionnaire was about the influences of students' languages, cultures, learning styles and other differences on their understandings and demonstrations of their learning on assessment tasks. The responses of the participants illustrated that more than three fourths of the participants (81.3%) supported the idea that students' individual differences influenced their engagement in assessment processes to show their own learning.

On the other hand, according to the results of participants' interviews, participants just focused on the differences on students' learning styles and languages. During the interviews no participant mentioned about nature of assessment tasks and differences in students' culture, age, gender, ethnicity, ability, socio-economic situations and disabilities as sources for inequitable assessment practices. Most of the participants reported that language differences affected students' performances on assessments. For example, P-6 stated, 'Being assessed in a language other than native language reduces students' understanding and getting low grades on assessment makes them lose their self-confidence.' Likewise, according to P-3 '…being assessed in another language requires students to spend more time to understand and respond to assessments and this generates disadvantages for them.' Besides, participants generally mentioned differences of learning styles as a source of inequality during the process of assessment. For that reason, all of them supported the usage of various assessment methods to make all students show their learning. For example P-3 stated that;

> I think we need to use different methods to assess our students since students are not robots and they have differences. Thus, I plan to use different assessment items in an exam such as multiple-choice, fill-in-the blank, true-false and open ended questions.

Table 2. Participants' ideas about factors influencing equality

Views of EA (N: 156)	**(1) Completely Disagree**		**(2)**		**(3)**		**(4)**		**(5)**		**(6) Completely Agree**		**Average ($\overline{X}$)**
Questionnaire Items	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	
In order to equitably assess student learning:													
While developing assessments, how and in what ways they support individual or groups of students should be considered.	4	2.6	6	3.8	16	10.3	25	16.0	29	18.6	76	48.7	4.90
In assessing student learning, students' cultural (regional) differences, language abilities, learning styles and other differences must be taken into consideration.	11	7.1	7	4.5	11	7.1	26	16.7	29	18.6	72	46.2	4.73

Participants' Plans to Accomplish EA (RQ 2)

In order to investigate the ways the participants thought to be successful in EA, we provided five items in our questionnaire (see Table 3). The first item focused on the similarities of assessments used during instruction and assessment processes because students feel comfortable in showing their learning on assessments especially with familiar ones. The results showed that more than 80% of the participants (82.7%) agreed on providing familiar assessments to accomplish equality. Informing students about the criteria to evaluate their assessment results formed the second item in the questionnaire. The results of the questionnaire also showed that 80.8 % participants approved informing students about the standards that they would be assessed to achieve EA. The third item emphasized the capability of an assessment to reveal students' learning in different forms including written, verbal, auditory and reading skills as indicators for EA. Based on the results, more than four fifths of the participants (86.6%) supported the idea of revealing student learning at different forms to attain EA. Utilizing different assessment methods formed our fourth item in the section. The results showed that most participants (87.8%) stuck with the idea of providing a variety of assessments to achieve EA and more than half of them (59.6%) completely supported it. The last item was related to the ways of providing EA such as usage of accommodations including visuals and basic sentences for language minorities (LM). When we look at the Table 3, it is seen that majority of the participants (85.9%) share the idea of using accommodations to provide EA.

Table 3. Participants' ways to accomplish EA

Views of EA (N: 156)	**(1) Completely Disagree**		**(2)**		**(3)**		**(4)**		**(5)**		**(6) Completely Agree**		**Average ($\overline{X}$)**
Questionnaire İtems	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	
In order classroom assessment to be equitable:													
Assessment strategies used to assess student learning should be similar to those that used during classroom instruction.	5	3.2	8	5.1	14	9.0	33	21.2	43	27.6	53	34.0	4.66
Students should be informed about the criteria that they will be assessed before the assessment process start.	6	3.8	8	5.1	16	10.3	40	25.6	32	20.5	54	34.6	4.57
Assessment process should reveal both students' written and verbal as well as auditory and reading skills.	6	3.8	3	1.9	12	7.7	24	15.4	36	23.1	75	48.1	4.95
While teachers assessing student learning, they should use a variety of assessment methods.	7	4.5	4	2.6	8	5.1	16	10.3	28	17.9	93	59.6	5.13
While students are assessed, teachers should provide accommodations such as pictures, graphs, basic words and dictionaries for the students, whose language proficiency are not so good.	6	3.8	5	3.2	11	7.1	15	9.6	29	18.6	90	57.7	5.08

Participants' interviews mostly supported the results of the questionnaire in terms of their thinking to achieve EA. Also, as it could be seen at Table 4, interview participants offered additional ways such as making students to work with their friends and parents (25%); improving students' language skills (58.3%); providing assessments in students' native language (33.3%); and providing deserved grades (33.3%). However, while participants provided the ways to achieve EA, they generally centered only upon LMs and students' learning styles to provide equality and did not think about other underrepresented groups (e.g., culture, socio-economic situation). For example, some participants (P-1 and P-3) believed that as students learned differently, they showed their learning in different ways. Therefore, 'Teachers should observe their students very well in order to decide what types of assessment their students need to show their own learning.' (P-1) All of the interview participants reported that teachers should have used multiple assessments in order to fairly assess what their students really understood to give fair grades. For example, P-4 stated;

> Using multiple assessments help me to see the levels of my students' understanding, at which content they are good and at which content they are not good. Thus, I use different assessments such as multiple-choice and open-ended questions, projects and performance-based assessments.

Similarly, one of the participants indicated '... in order to assess real learning, I would not just use a multiple-choice test to assess, I would use different types of questions including open-ended and fill in the blanks.' (P-1) However, some participants (P-7, P-10 and P-11) indicated that using one assessment task to assess all students' learning seemed fair since it was hard to use different assessment for each student because of limited time. For instance, P-11 explained, 'Usage of one assessment to assess all students' learning is fair since all students take same exam and provide their response based on their knowledge.' Besides, another participant, P-7, indicated;
In general, I think usage of one assessment to assess students' learning is fair even if students have differences. You cannot provide different assessment for each individual student and you should choose one of the most proper strategies to use and in my opinion, this is fair.

Table 4. Ways interviewed participants think to achieve EA

Ways to achieve EA	**Percent of responses (%)**
Using various assessment strategies (including hands-on activities, lab experiments, projects, observation, visuals and oral exams)	100
Improving LMs' language abilities	58.3
Using basic words and daily life language for LM	50
Providing assessments in LMs' native languages	33.3
Learning LMs' native language	33.3
Giving grades based on what students' deserved	33.3
Letting LMs to use dictionary during assessments	25
Providing extra time for LMs to complete assessments	25
Motivating LMs to work with friends and parents	25

In addition, the participants mostly considered LMs as underrepresented groups and they claimed improving language ability of LMs was a way to achieve EA. For example, one of the participants stressed that LMs should have improved their language abilities since 'they do not just compete with their friends in classroom, they also compete with other students nationally as well.' (P-3) Likewise, P-6 reported that 'Even if improving language skills of LMs is in the responsibility of language teachers, I would teach LMs meaning of essential terms to be successful in my lesson.' One of the common themes emerged from the results was the usage of visuals and hands-on activities to assess LMs' learning (67%). P-1 stated, 'Most probably if we used hands-on assessments, LMs can understand since they are visual.' One of the participants also indicated, 'Using more visuals and lab activities can be useful for LMs since our field (science) is appropriate for this. Besides, language is not a limitation for LMs in this way.' (P-5) Another way to achieve EA for the participants was to use short and familiar words and sentences during instruction and assessment. In order to decrease the influence of language on LMs' learning P-4 indicated that 'I avoid using complex sentences and terms during my instruction and assessment and try to use daily life Turkish rather than rarely used words.' One of the other participants also stated, 'It will be difficult for LMs to understand long paragraphs and complex sentences so I can shorten and simplify them and avoid using terms.' (P-8) Other participants offered scaffolding of language as a way and stated, 'If you used a high level Turkish, it will be hard for LMs to understand so we need to express our ideas at a simple level by using clear sentences, avoiding to combine ideas and providing subtitles.' (P-3) On the contrary, some participants (P-6, 7, 11) did not agree to make changes on assessments for minorities because using adjustments on assessment for minorities decreases cognitive level of assessment and makes assessment easy for other students. P-7 indicated, 'For minorities, I do not think to modify assessment task to assess them because it causes undesired situations within classroom as you need to apply the modified task to all students.' Following of the comments of P-7, we asked him to explain the undesired situations he indicated. Then, he stated, 'For instance, you simplify language of a task and this task may help LMs but for native Turkish students, this task does not reveal higher level learning since it seems easy for them.' Similarly, P-6 stated, 'Giving extra time for LMs does not seem reasonable to me since it endangers fairness.'

Discussion and Conclusion

There are serious discrepancies and gaps in terms of educational opportunities and outcomes in schools of many countries and some of them have much more inequalities than others (Carnoy & Rothstein, 2013). These include students' academic achievement, skills and other aspects of learning which should be improved through schooling (Duncan & Murnane, 2014). These gaps in learning of diverse learners are critical problems in many countries while the scope and forms of the problem vary from country to country. Thus, it is important to find ways to close these gaps and one of these ways is to provide equitable instruction with EA practices. Successful practices of equitable instruction and EA mainly depend on how teachers understand and apply these practices since teachers are responsible for the transition of an instructional practice into classrooms (Smith & Southerland, 2007). That is to say, preparing science teachers to apply equitable instruction and assessment practices is critical for promoting science learning of all students regardless of their backgrounds such as ethnicity and culture. Nowadays, this is more critical for Turkish science teachers because the diversity of students in Turkey has been growing rapidly. Thus, Turkish teachers including science teachers need to be ready to provide EA practices to support all their students' learning if they want to fulfill their responsibility towards their students. Furthermore, in order to effectively teach and assess science for diverse groups of students, we, as teacher educators, must provide teacher candidates with the knowledge and beliefs about diverse learners, with knowledge and beliefs about EA, and with skills and confidence in providing and modifying assessments for diverse learners.

This study investigated Turkish science teacher candidates' understanding of EA and their plans for EA and tried to find out whether they were ready to fulfill the responsibility. The results of the participants' surveys showed that the science teacher candidates mostly supported the idea of providing equal opportunities to make all students participate in learning process and to show their own learning while their interview results showed that some of the participants did not have any idea of EA and others associated EA with fairness including fairness in grading and fairness in student-teacher relationship. The results of their survey also showed that the participants considered the individual differences including age, culture, ethnicity, gender, ability, learning styles, language, socio-economic situations and disabilities as reasons to provide EA while their interview results pointed out that participants mostly focused on learning styles and language differences as sources for providing EA. Moreover, participants provided different ways such as providing diverse assessments and accommodations for LMs to achieve EA. We believe that the differences between participants` survey and interview results arise from the unfamiliarity of EA for them and as a result they supported the ideas provided within the survey while they could not provide a rich explanation for EA during their interviews.

Teachers' understandings and their perceptions are influential factors for their various instructional practices, about how they plan to incorporate the diverse backgrounds of students in their lessons, about how to elicit and improve their learning and about which ways should be used to meet the needs of their diverse students (Blachard & Muller, 2015; Siegel, 2014). The reasons of teachers' negative perceptions regarding students with diverse backgrounds can be that they do not see meeting the students' needs as their responsibilities (Cheathan, Jimenez-Silva, Wodrich, & Kasai, 2013). Because of the negative perceptions, teachers may not also make any effort to understand their students' backgrounds or find ways to meet their needs. This, in turn, affects their decisions about their instruction and students' learning (Cheathan et al., 2013; Wong, Indiatsi, & Wong, 2015). Thus, it is important for teachers to know their students' backgrounds and take these backgrounds into consideration during their instructional decisions to meet students' needs to enhance their learning. The results of participants' surveys showed that they recognized the individual differences such as age, culture, ethnicity, gender, ability, learning styles, language, socio-economic situations and disabilities for reasons to provide EA. However, their interview results showed that they only identified learning styles and language differences as the main reasons to provide EA and accordingly, they provided detailed information about how to address differences in learning styles and language during assessment process to achieve equality. Similarly, the results of Siegel's (2014) and Lyon's (2013) studies showed that science teacher candidates' focused on learning styles and language as individual differences in their studies when they explained benefits of EA. Yet, it is important for teachers to consider a larger views of student diversity because students convey diverse cultures (including language, gender, ethnicity, socioeconomic status), epistemologies (including learning styles and views) and experiences to classrooms that affect how they interpret and learn science content and how they show their understandings of science concepts (Solano-Flores, & Nelson-Barber, 2001). Thus, teachers need to know and understand the individual differences broadly and consider them to provide equal contexts for their students to reach a high quality learning of science and engage in it. In this way, teachers can handle students' individual differences by (a) providing instruction and assessment within culturally, epistemologically, and cognitively meaningful contexts, (b) letting students work on appropriate tasks to reach rigorous science content and (c) using culturally and cognitively sensitive assessments to learn about students' weaknesses and strengths to modify instruction and help all students' learning (Abedi, Hofstetter, & Lord, 2004; Lyon, 2013; Siegel, 2014).

Teachers' understandings and beliefs of EA are important because they shape teachers' instructional and assessment practices to meet the needs of diverse learners (Abell & Siegel, 2011; Siegel, 2014; Siegel et al., 2014). EA is not just a way to measure students' learning fairly, but more importantly, it is a way to reduce biases to support all students' learning (Siegel, 2014). According to the results of the study, while the survey results showed the science teacher candidates agreed on the importance of equally engaging all students in learning and the importance of assessment processes to show their own learning, the interviews showed that teacher candidates mostly perceived EA as a way to provide fair grades rather than providing ways to make students equally access and participate in learning processes to enhance their learning. This is aligned with what Siegel (2014) has found in her study that science teacher candidates mostly equate EA with fairness if method courses do not focus on EA purposefully. Providing fairness in grading is critical, however, it is more important for teachers to comprehend EA as a way to make all students equally participate in a learning context to learn and display their own learning (Abell & Siegel, 2011; Siegel, 2014). Thus first, a more sophisticated understanding of EA requires teachers to view diversity as an opportunity to understand each student's culture and identity which underpin each action of the student; second, it requires teachers to think about ways to provide greater access to rigorous science content and display opportunities for all students to show their conceptual learning (Kusimo et al., 2000; Abell & Siegel, 2011; Lyon, 2013).

Providing ways to make all students learning visible is an important aspect of EA and this requires teachers to consider individual differences of their students while planning teaching and assessing them (Lyon, 2017; Siegel, 2014). As teachers beliefs and views influence their practices, their views about diversity and individual differences also shape how they plan to provide EA opportunities for their students (Carter, 2008; Siegel, 2014). The results of the study showed that the teachers generally considered learning styles and language proficiencies as individual differences to address and provide EA practices. Thus, they planned to use different strategies and accommodations to achieve EA by addressing differences in learning styles and language abilities of students; but they did not consider other differences such as gender and culture in their plans to achieve EA. Similar to findings of other studies (Abedi et al., 2004; Cranford, 2018; Lyon, 2013; Siegel, 2014), usage of multiple assessments to assess student learning was found as one of the important ways to address differences in learning styles by participants. Besides, different ways such as usage of daily life and basic sentences, providing extra time, and providing assessment in students' native languages were found to achieve EA for language minority students by the participants. While the obtained ways in planning to provide EA are useful, we, as teacher educators, should prepare teachers to consider diversity from a larger point of view to provide EA to assess and support all students' learning. In addition, teacher candidates need to be engaged in EA practices to see which ways are more effective to address a specific minority group (Cranford, 2018).

Implication

Providing equitable science assessment is a tough issue because there are challenges to consider and address a diverse group of students to find out what they know and what can be done to support their science learning. Although there are more to be done to prepare teachers sufficiently to assess equitably, the findings of the study have some suggestions as the followings to prepare teachers to achieve EA. Teacher education programs should provide ways for teacher candidates to recognize diversity from a larger point of view and teacher candidates should be aware of the diversity of students whom they are being prepared to teach. Furthermore, the knowledge and attitudes necessary for effectively teaching and assessing diverse learners must be provided for teacher candidates to make them ready for providing EA. In order to practice EA, teacher candidates should be provided with tools and guidance to overcome the difficulties that they may face within the real teaching practices.

On the other hand, two different concerns emerged according to the results of the study to take into consideration while preparing teachers to assess equitably. The first one is about the belief that using same assessment for all students' learning is fair and that it is difficult to use different assessments for each student because of limited time. The second concern was about that while the participants think making adjustment on assessment for minorities is useful, it decreases the cognitive level of assessment and makes it easy for other students. It can be concluded that both concerns can shape the teacher candidates' decisions to provide EA. Similar concerns were found by Lyon (2013) in his study that the teacher candidates were worried about reducing or scaffolding language demand of an assessment which was shaped by teachers' beliefs about language minorities. Thus, as educators, we need to provide ways and try to convince teacher candidates about; (a) various formative assessments can be easily used in a short time to elicit and assess students' learning without increasing their workload and (b) assessments can be scaffolded for minority students without reducing content demands of the assessment tasks.

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Appendix. Interview Questions

1. Can you define equitable assessment?
2. What does it mean for you to assess students equitably?
3. As a teacher candidate, do you think to use more than one way to assess your students' learning? Why? How does it help?
4. How do you assess a student's learning, having low Turkish language ability, of a topic you taught?
5. Do you think a student with native Turkish language and a student with non-native Turkish language should be assessed in the same way? Why?
6. If you are being assessed in English instead of Turkish language in your science lessons, will it affect your achievement in these lessons? Why?
7. What other differences do you think influence students to show their real learning?
8. In what ways do you plan to equitably assess your students' science learning?

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Students' Generated Animation: An Innovative Approach to Inculcate Collaborative Problem Solving (CPS) Skills in Learning Physics

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Abstract

Inculcating collaborative problem solving (*hereinafter* CPS) skills to help develop students' knowledge, especially for problem solving (PS) involved in the subject of physics is of utmost importance in the 21st century. It was on such grounds that in the present study, physics PS learning was innovated by engaging students' generated animation within the recent CPS learning framework process. Next, the effectiveness of the steps in this innovative approach, which was developed as Lensmation CPS Module, in inculcating CPS skills was determined. Seventy respondents were involved in this quasi-experimental study, in which one treatment group was exposed to the module whereas the control group practised the conventional PS learning. In the course of completing their PS tasks, the students who were involved in this study had their CPS skills assessed using the CPS Proficiency Rubrics. MANOVA analysis revealed significant effects on CPS skills between the two groups. It is concluded that the innovative PS learning approach which tapped into students' ICT literacy in physics CPS learning was effective in inculcating CPS skills among the students.

Introduction

CPS skills have over the years been considered as critical and necessary across various educational contexts and workforce. More importantly, a growing interest has been observed in CPS skills in the 21st century. A closer look at inculcating CPS skills reveals that it facilitates both the division of labour and the integration of information from various sources of knowledge, perspectives and experiences. Additionally, CPS skills may equally enhance the creativity and quality of solutions created by means of effective teamwork. At present, the learning framework process is based on the one propagated by the *Organisation for Economic Co-operation and Development* (OECD) (OECD, 2013). Such a paradigm transition from PS to CPS is a result of scholars' disposition towards exploring collaboration owing to its distinct advantages over individual PS. In addition, related previous studies have revealed that the PS skills paradigm may limit the capacities of individuals who work alone to resolve problems. It was also found that in individual PS, the method of solution was not immediately obvious to the individual engaged in the PS task (OECD, 2010).

It was owing to such drawback that the OECD has alternatively considered CPS (OECD, 2013). In this regard, the defined CPS as the capacity of an individual to effectively engage in a process, in which two or more agents (i.e. human beings or computer-simulated participants) attempt to solve a problem by both shared understanding and efforts required to find a solution. More specifically, such a process may involve pooling their knowledge, skills and efforts to reach such a solution. As presented in Table 1, there are three major CPS competencies which are crossed with the four-major individual PS processes from the PISA 2012 PS framework (OECD, 2010) to form a matrix of specific skills for CPS framework (OECD, 2013). The specific skills have associated actions, processes, and strategies that define what it means for the student to be competent.

In line with such a definition, the infusion of CPS skills among communities may help overcome the present PS work challenges. It is worth highlighting that the transition from manufacturing to a service economy which is more information and knowledge-based has culminated in wider availability of networked computers. In such a scenario, individuals are expected to work with diverse teams using collaborative technology. Considering the level of transformation as discussed in the foregoing paragraphs, there is a growing need for CPS skills in civic contexts such as social networking, volunteering, participation in communal activities, transactions, administration and public services. In this regard, students upon leaving schools and stepping into the workforce and public life may have to equip themselves with CPS skills as well as the ability to engage in such a collaboration using appropriate technology. In line with such a view, the present study focuses on inculcating students' CPS skills in PS learning. In addition, it is believed that the inculcation of CPS skills not only develop individual PS skills among students, but also enhance their social interaction, teamwork and ICT literacy in the course of the PS learning process (OECD, 2013).

Table 1. Matrix of CPS framework (OECD, 2013)

		CPS Competencies		
		(1) Establishing and maintaining shared understanding	(2) Taking appropriate action to solve the problem	(3) Establishing and maintaining team organisation
Problem Solving (PS) Skills	(A) Exploring and Understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction to solve the problem, along with goals	(A3) Understanding roles to solve problem
	(B) Representing and Formulating	(B1) Discovering perspectives and abilities of team members	(B2) Identifying and describing tasks to be completed	(B3) Describe roles and team organisation (communication protocol/rules of engagement)
	(C) Planning and Executing	(C1) Communicating with team members about the actions to be/being performed	(C2) Enacting plans	(C3) Following rules of engagement, (e.g., prompting other team members to perform their tasks)
	(D) Monitoring and Reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback and adapting the team organisation and roles

Note: The 12 skill cells have been labelled with a letter-number combination referring to the rows and columns for ease of cross- referencing later in the document (OECD, 2013).

Physics PS Learning in Malaysian Secondary Schools

It is noteworthy that the application of CPS skills in PS learning has been dominated by Western countries for over a decade. Such a development does not mean that it is acceptable for a developing country like Malaysia to lag behind in inculcating its potential workforce with the CPS skills. Thus, in order to address the challenges within the global economy, Malaysia may have to aim to produce students who are capable of solving problems, particularly the ones which are related to fundamental physics. Physics PS skills are strongly required as one of the most important components to help construct students' knowledge, which in turn may help contribute to the nation's development in the area of science and technology.

Notwithstanding, a comprehensive review of the related literature reveals that the development of physics-based PS skills in Malaysia lags both in paradigms and ICT applications in comparison with its Western and other Asian counterparts, including Singapore, Korea, and Japan. A closer look at the Malaysian context revealed that in the past decade, the learning approach of PS skills for physics subject has been practiced among individuals (Zulkepli Mohamad, 2010) and groups (cooperative)(Muzaitulakmam Abdul Mutalib, 2014; Zurida, Mohd Ali, & Ahmad Nurulazam, 2005). It can therefore be argued that individual and group (i.e. cooperative) PS methods may have failed to inculcate students' PS skills owing to the possibility that there is a mismatch between the pedagogical theories and the actual realities in classrooms (Halim, Halim, Meerah, & Osman, 2010). In reference to Neo (2005), the researcher reported that all the activities and processes relevant to PS within the Malaysian context were still directed by the teachers. Consequently, the teaching and learning (T&L) models on PS skills have mostly been dominated by the teachers and hence the development of students' PS skills has been limited during their learning process.

Furthermore, DeWitt, Alias, & Siraj (2013) argued that despite the learning method being employed revolving around social interactions, it was conducted at low cognitive levels. Futhermore, other factors such as unstructured learning methods, passive interaction, lack of collaboration, minimal inquiry, and limited time allocated for discussion may have further deteriorated the quality of solution. In addition, the teachers have been directed to carry out intensive exercises in their respective classes, which is the least effective method. It is considered so because physics intensive exercises may only help familiarise students with answers to questions of conventional format. In such a case, in the event of having to face questions which may challenge their PS skills, the majority of students may fail to resolve the problems (Sulaiman, Abdullah, & Ali, 2007). Thus, in solving the problem the students' PS strategies may remain novice (Zamri, 2016). In addition, the conventional intensive exercise method may also force the students to memorise the contexts, which eventually result in a rather boring learning environment, culminating in the lack of interest, non-interactivity (Ishak, Bakar, Lani, Salam, & Shahbodin, 2011), and inability to synthesize or think in a scientific manner (DeWitt, Alias, & Siraj 2013) among the students.

Over the years, the documents that were developed to carry out the qualitative analysis among physics students at the Malaysian Certificate of Examination (MCE) level frequently reported the inability of students in solving problems accurately (Lembaga Peperiksaan Malaysia, 2013). Moreover, as highlighted in the PISA report in the year of 2012 (Zamri, 2016), the PS skills among the students of Malaysia dropped below the average score that was set by the OECD. Such developments both at the local and international levels clearly indicate that the teaching methodology of the physics PS skills has been inadequate. It can also be argued that such a methodology may have failed to improve and develop the students' PS skills and the CPS skills. In order to address such a critical problem, the integration of ICT into the Malaysian education system, as targeted by the Malaysia Education Blueprint, is an imminent requirement (Ministry of Education Malaysia, 2013).

Despite the clear indication of the potential benefits of integrating ICT applications or even tapping into students' ICT literacy for the physics PS skills development, the integration of ICT however has not drawn widespread attention among scholars. Nonetheless, it is encouraging to note that there is at least one study by researchers Noor Izyan and Abdullah (2012) which involved at the implementation of ICT in the PS skills development of physics subject. It is worth highlighting that the ICT integration conducted by the reseachers Noor Izyan and Abdullah (2012) only focused on the usage of Microsoft PowerPoint for content presentation by the teachers. In this regard, the educational report by the organisation UNESCO (2013) revealed that ICT implementation in the Malaysian education system is too limited and did not explore anything more than the usage of word-processing applications as a teaching platform. In reality, students may be encouraged to apply their ICT knowledge to solve problems more actively (Jones, 2005).

Students' Generated Animation and CPS in Learning of Physics

A comprehensive review of reports of both local and international studies clearly indicates that the development of PS skills' learning in physics education in the context of Malaysia is lagging behind the current requirement of PS skills which have globally evolved from the individual PS to group (cooperative) PS, and more recently into the collaborative PS. In line with such a development globally, in the present study, an improvement to the existing PS learning method is proposed to inculcate CPS skills through the integration of current CPS learning framework process (OECD, 2013) and tapping into students' ICT literacy. Apart from that, the proposed method has also cultivated the sampled students' potential in both the construction and the exploration of computer based-evidences. It was discovered from the needs analysis that students would choose the animation platform as a medium to help apply their ICT literacy in the most difficult physics PS subtopic that is Lens. As indicated by the review of literature, slowmation is the simplest technique and a new form of stop motion animation which may allow the students to easily synthesize the complex processes that underpin the animation production based on minimal picture frame (G. F. Hoban, 2007).

Thus, the steps of integrating CPS and students' generated slowmation have been developed in the form of the Lensmation CPS Module. Figure 1 illustrates the Lensmation CPS framework, which is an innovative PS learning method that contains twelve processes of CPS (OECD, 2013) and five steps of students' generated slowmation that was adapted from the 5R Model (G. Hoban & Nielsen, 2010).

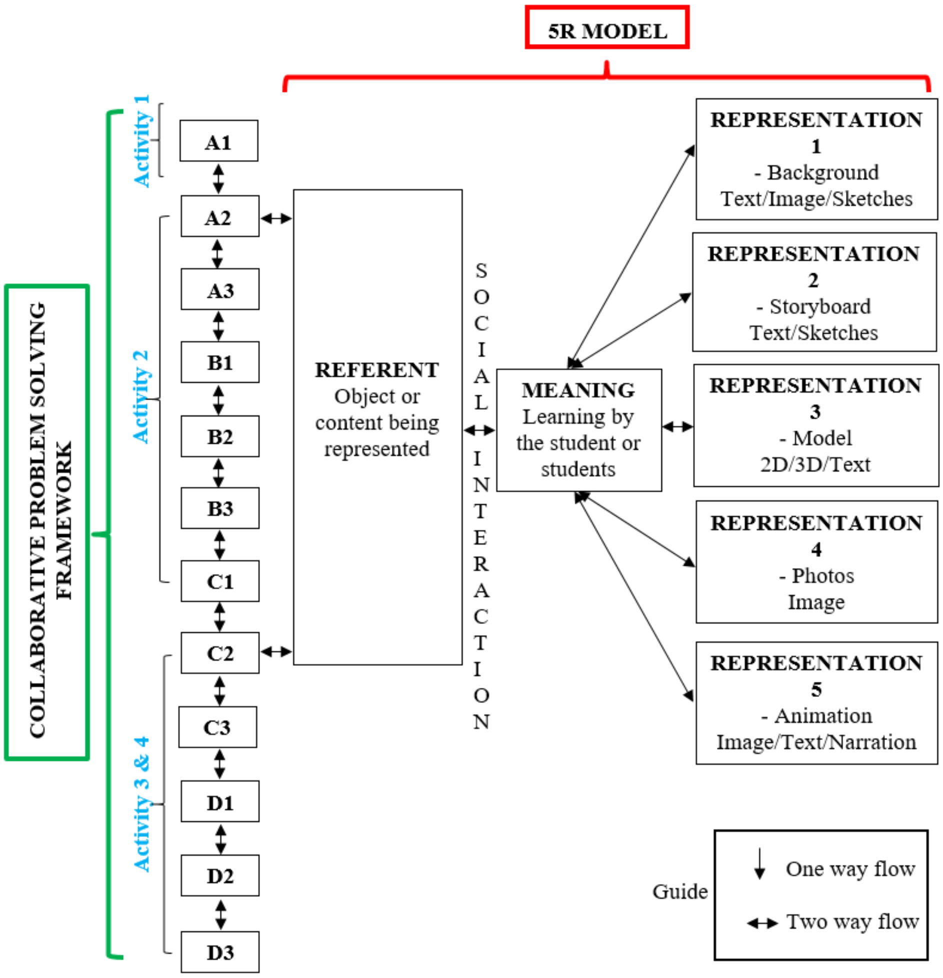


Figure 1. Learning steps in Lensmation CPS framework

Note: The letter-number combination refers to the CPS framework in Table 1.

It is widely believed that the proposed innovate approach may create a platform to help increase the students' ability in solving physics related problems and inculcating their CPS skills, particularly through structured teamwork interaction and ICT application.

Research Aim

The aim of the present study was to assess the effectiveness of the Lensmation CPS Module in inculcating CPS skills for PS learning of the Lens subtopics in the context of Malaysia. Researchers have recommended the implementation of this module in physics PS learning at the secondary school levels. It is believed that the implemention of this module may help expose students to the current PS learning approach learning and inculcate CPS skills among the students.

Method

Research Design

The present study employed a quasi-experimental approach with a non-equivalent control group research design. The study was conducted in two schools in Malaysia. Each school consisted of a control group which used the conventional approach module and a treatment group which used the Lensmation CPS Module.

Respondents

A total of 70 respondents (i.e. Form Four equivalent to 16 years old) participated in the study, of which the control group consisted of 29 students and the treatment group consisted of 41 students respectively. It should be noted that the respondents were drawn from schools which were randomly selected based on zones, the competency level of the students (i.e. based on their Mid-Year Physics Form Four Examination results), school bands and the number of student population in each school.

Instrument and Procedures

The CPS skills were measured using the Rubric of CPS Proficiency adapted from the organisation OECD (2013). The rubric contained 12 domains with a score of 0 to 2 and its description is presented in Table 2. The scores are given in line with the indicator of CPS skills acquired by the students when they underwent PS learning such as actions or communications.

Table 2. Description of CPS skills scores

CPS Skills Score	Description
0 (Below CPS skills standard)	The student: • responds to or generates information that has little relevance to the task. • contributes when explicitly or repeatedly prompted, student's actions contribute minimally to achieve team goals (example: they may pursue random or irrelevant actions). • operates individually, often not in concert with the appropriate role for the task. • actions or communications seldom help the team to resolve potential obstacles.
1 (At CPS skills standard)	The student: • responds to most requests for information and prompts for action • generally, selects actions that contribute to achieve team goals. • participates in assigned roles and contributes to the overall strategies for solving the problem • good team member but is not always proactive and on occasion initiates actions. • good team member but does not always proactively take the initiative to overcome difficult barriers in collaboration.
2 (Above CPS skills standard)	The student: • responds to requests for information and prompts for action and selects actions that contribute to achieving team goals. • proactively takes the initiative in requesting information from others, initiates unprompted actions and effectively responds to conflicts, changes in the problem situation and new obstacles to goals. • acts as a responsible team member when the situation requires and proactively takes the initiative to solve difficult barriers in collaboration.

The rubric was translated into Malay language through 'back translation' process (Brislin, 1970), by two credible language experts. Prior to administering the rubric in this study, three research assistants (i.e. experienced physics teachers) who acted as observers were given briefings and detailed description about the interpretation of each score based on students' actions and communication.

Data Analysis

The quantitative data obtained from the CPS skills instrument were analysed by means of descriptive and inferential statistics. All data were compiled and summarized in table form for analysis report. Descriptive analysis was carried out to get the mean scores estimation and standard deviation of the CPS skills score. On the other hand, MANOVA analysis was employed to measure the effects of the Lensmation CPS Module in cultivating CPS skills. The analysis involved two study groups (i.e. control and treatment) and twelve constructs of CPS skills as presented in Table 3 below.

Table 3. Constructs of CPS skills scores

CPS Skills Code	CPS Skills
A1	Discovering the perspectives and abilities of team members
A2	Discovering the type of collaborative interactions to solve the problem
A3	Understanding roles to solve problems
B1	Building a shared representation and negotiating the meaning of problems
B2	Identifying and describing tasks to be completed
B3	Describe roles and team organizations
C1	Communicating with team members about the actions to be or being performed
C2	Enacting plans
C3	Following rules of engagement
D1	Monitoring and repairing the shared understanding
D2	Monitoring results of actions and evaluating success in solving the problems
D3	Monitoring, providing feedback and adapting the team organization and roles

Results

MANOVA analysis was employed to analyse the data to determine the effects of the Lensmation CPS Module on inculcating CPS skills. Results are shown in Table 4. The findings revealed that there was a significant group effect on CPS skills [F (12,55) = 31.655, p < 0.05] with an effect size of 0.874.

Table 4. Multivariate test

Effect	*Pillai's Trace Value*	F	df	p	*Partial Eta Squared*
Group	0.874	31.655	1	0.000	0.874

Significance level = 0.05

Further analyses were made to obtain a more detailed picture of the CPS skills construct. Results of the analysis shown in Table 5 indicated that there was a significant effect between groups on A1 construct [F (1,66)] = 6.382, p < 0.05] with an effect size of 0.088, A2 construct [F (1,66)] = 17.730, p < 0.05] with an effect size of 0.212, A3 construct [F (1,66)] = 45.919, p < 0.05] with an effect size of 0.410, B1 construct [F (1,66)] = 60.382, p < 0.05] with an effect size of 0.478, B2 construct [F (1,66)] = 132.175, p < 0.05] with an effect size of 0.667, B3 construct [F (1,66)] = 188.729, p < 0.05] with an effect size of 0.741, C1 construct [F (1,66)] = 76.088, p < 0.05] with an effect size of 0.535, C2 construct [F (1,66)] = 88.738, p < 0.05] with an effect size of 0.573, C3 construct [F (1,66)] = 100.631, p < 0.05] with an effect size 0.604, D1 construct [F (1,66)] = 12.538, p < 0.05] with an effect size of 0.160, D2 construct [F (1,66)] = 113.095, p < 0.05] with an effect size of 0.631 and D3 construct [F (1,66)] = 118.755, p < 0.05] with an effect size of 0.643.

Table 5. Test of between-subjects effect

Effects	Dependent Variable	Squared Total	df	Mean Squared	F	p	*Partial Eta Squared*
Group	A1	1.036	1	1.036	6.382	0.014	0.088
	A2	2.671	1	2.671	17.730	0.000	0.212
	A3	15.593	1	15.593	45.919	0.000	0.410
	B1	9.894	1	9.894	60.382	0.000	0.478
	B2	14.752	1	14.752	132.175	0.000	0.667
	B3	16.774	1	16.774	188.729	0.000	0.741
	C1	8.174	1	8.174	76.088	0.000	0.535
	C2	26.522	1	26.522	88.738	0.000	0.573
	C3	24.392	1	24.392	100.631	0.000	0.604
	D1	3.260	1	3.260	12.538	0.001	0.160
	D2	19.298	1	19.298	113.095	0.000	0.631
	D3	27.743	1	27.743	118.755	0.000	0.643

Significance level = 0.05

Due to the effect between groups on the constructs' mean scores, the comparison for mean scores was also carried out. Table 6 indicates an expected mean margin for CPS skills constructs by group.

Table 6. Mean margin for CPS skills' constructs by group

Constructs	Group	Mean	Standard Deviation	Confidence Interval 95%	
				Lower	Upper
A1	Control	1.617	0.075	1.467	1.766
	Treatment	1.866	0.064	1.737	1.995
A2	Control	1.517	0.072	1.373	1.661
	Treatment	1.918	0.062	1.793	2.042
A3	Control	0.969	0.108	0.753	1.185
	Treatment	1.938	0.093	1.751	2.124
B1	Control	0.979	0.075	0.828	1.129
	Treatment	1.750	0.065	1.621	1.879
B2	Control	0.964	0.062	0.840	1.088
	Treatment	1.906	0.053	1.799	2.013
B3	Control	0.964	0.055	0.854	1.075
	Treatment	1.969	0.048	1.873	2.064
C1	Control	1.174	0.061	1.052	1.295
	Treatment	1.875	0.052	1.770	1.980
C2	Control	0.686	0.102	0.483	0.889
	Treatment	1.949	0.088	1.774	2.123
C3	Control	0.550	0.091	0.367	0.733
	Treatment	1.761	0.079	1.604	1.919
D1	Control	1.381	0.095	1.192	1.570
	Treatment	1.824	0.082	1.661	1.987
D2	Control	0.798	0.077	0.644	0.951
	Treatment	1.875	0.066	1.743	2.007
D3	Control	0.586	0.090	0.406	0.765
	Treatment	1.878	0.077	1.723	2.032

Based on Table 6, it can be concluded that the treatment group exceeded the control group for the twelve constructs of CPS skills. It is clear that A1 construct for the treatment group (mean = 1.866, SD = 0.064) is higher than A1 construct for the control group (mean = 1.617, SD = 0.075), A2 construct for treatment group (mean = 1.918, SD = 0.062) is higher than A2 construct for the control group (mean = 1.517, SD = 0.072), A3 construct for the treatment group (mean = 1.938, SD = 0.093) is higher than A3 construct for the control group (mean = 0.969, SD = 0.108), B1 construct for the treatment group (mean = 1.750, SD = 0.065) is higher than B1 construct for control group (mean = 0.979, SD = 0.075), B2 construct for treatment group (mean = 1.906, SD = 0.053) is higher than B2 construct for the control group (mean = 0.964, SD = 0.062), B3 construct for the treatment group (mean = 1.969, SD = 0.048) is higher than B3 contruct for the control group (mean = 0.964, SD = 0.055), C1 construct for the treatment group (mean = 1.875, SD = 0.052) is higher than C1 construct for the control group (mean = 1.174, SD = 0.061), C2 construct for the treatment group (mean = 1.949, SD = 0.088) is higher than C2 construct for the control group (mean = 0.686, SD = 0.102), C3 construct for the treatment group (mean = 1.761, SD = 0.079) is higher than C3 construct for the control group (mean = 0.550, SD = 0.091), D1 construct for the treatment group (mean = 1.824, SD = 0.082) is higher than D1 construct for the control group (mean = 1.381, SD = 0.095), D2 construct for the treatment group (mean = 1.875, SD = 0.066) is higher than D2 construct for the control group (mean = 0.798, SD = 0.077) and D3 construct for the treatment group (mean = 1.878, SD = 0.077) is higher than D2 construct for the control group (mean = 0.586, SD = 0.090). Figure 2 compares the mean score estimation of CPS skills' constructs according to group.

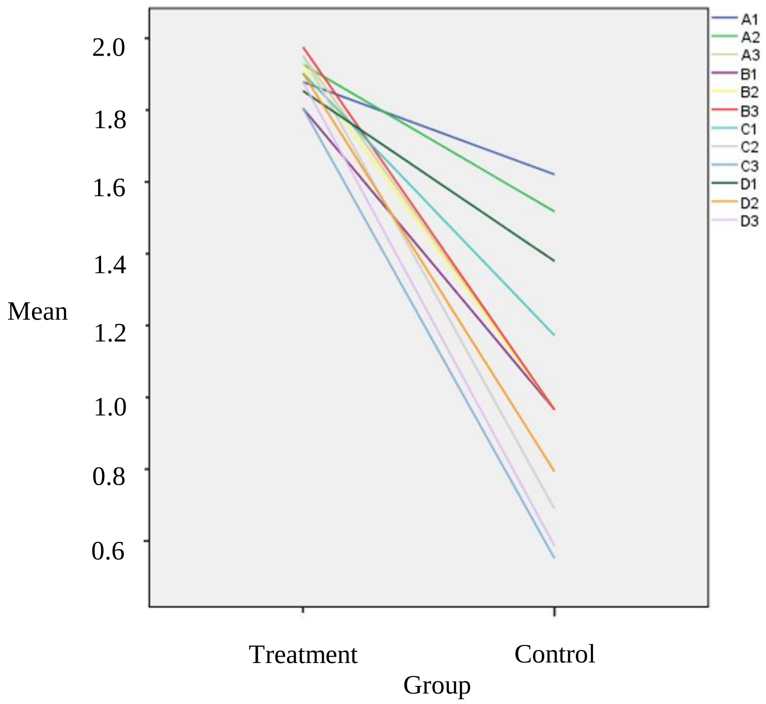


Figure 2. Comparisons of CPS skills constructs' mean score according to group

Based on the data analysis, it was found that the Lensmation CPS Module brought about positive effect on the overall CPS skills and its constructs. Therefore, it can be argued that the Lensmation CPS Module has inculcated CPS skills among the students in PS learning better than the conventional methods.

Discussion and Implication

Research Method

As regards the Malaysia Education Blueprint (2013-2025), Ministry of Education (MOE) has always strive to raise and improve the existing curriculum by engaging in innovation in the teaching and learning of science, especially in physics education. The innovation of PS learning method is expected to have an impact on the inculcation of CPS skills among students, which may contribute to the country's economic transformation in the 21st century. In reference to OECD (2013), the researchers deemed that CPS skills may be inculcated by means of integrating the current PS learning process, which is comprised of CPS theory and ICT applications.

It has to be noted that the success of inculcating the CPS skills among the students through the use of Lensmation CPS Module in the present study is attributable to several reasons. Firstly, it is due to the change of the PS learning method and the approach used by the students in the treatment group. In addition, the innovative approach has created an active learning environment because of the activities which guided the students to solve problems in a collaborative manner, through which, the students generated slowmation in structured steps.

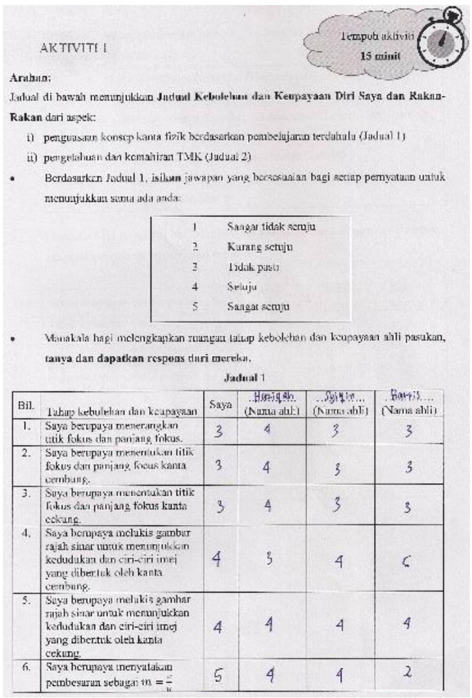
The backbone of the Lensmation CPS Module is the innovative learning model that integrated the 5R model (G. Hoban & Nielsen, 2010) which explained the systematic procedure of construction via slowmation with CPS framework (OECD, 2013). With regards to the innovative learning model, the students learnt strategically in a structured manner by means of using the module. In addition, the process involved in this innovative learning has improved the CPS competency and core skills (i.e. PS and collaborative skills). It is worth highlighting that other factors such as students' background (i.e. prior knowledge and characteristics) and context (i.e. characteristics of tasks, problem scenario, medium, and team composition) were also taken into consideration in the Lensmation CPS Module. Report in OECD (2013) has confirmed that consideration of those factors may inculcate students' CPS skills.

Thus, students from the treatment group were exposed to the Lensmation CPS Module activities which contained learning processes such as CPS, team communication, collaboration, teamwork and slowmation-generated animation. In order to guide the students in the process of acquiring and inculcating CPS skills, over twelve learning objectives with four student-centred activities were employed. Table 7 demonstrates the content of Activity 1.

Table 7. Content of Activity 1

Activity No.	Time	Content of Activity	Students Outcomes	CPS Skills
Activity 1	15 minutes	1. Students fill in the Table of Ability and Capability of Myself and Friends by sharing the information and views about themselves with the others. 2. The student asks the team members' abilities, perspectives and other related information.	- Table of Ability and Capability of Myself and Friends	Discovering perspective and abilities of team members (A1)

It is noteworthy that this activity (i.e. filling in the Table of Ability and Capability of Myself and Friends) of the Lensmation CPS Module may enhance A1 sub-skill score among students. The students need to fill in information such as the level of mastery of the concept of physics' Lens subtopic and their level of knowledge and ICT skills based on the discussion the students had with their respective team members. Figure 3 and Figure 4 show the photo and worksheet related to the discussion in Activity 1.


AKTIVITI 1

Tempoh aktiviti
15 minit

Arahan:

Jadual di bawah menunjukkan **Jadual Kebolehan dan Keupayaan Diri Saya dan Rakan-Rakan** dari aspek:

i) penguasaan konsep kanta fizik berdasarkan pembelajaran terdahulu (Jadual 1)

ii) pengetahuan dan kemahiran TMK (Jadual 2)

- Berdasarkan Jadual 1, isikan jawapan yang bersesuaian bagi setiap pernyataan untuk menunjukkan sama ada anda:

1	Sangat tidak setuju
2	Kurang setuju
3	Tidak pasti
4	Setuju
5	Sangat setuju

- Manakala bagi melengkapkan ruangan tahap kebolehan dan keupayaan ahli pasukan, **tanya dan dapatkan respons dari mereka.**

Jadual 1

Bil.	Tahap kebolehan dan keupayaan	Saya	[illegible] (Nama ahli)	[illegible] (Nama ahli)	[illegible] (Nama ahli)
1.	Saya berupaya menerangkan titik fokus dan panjang fokus.	3	4	3	3
2.	Saya berupaya menentukan titik fokus dan panjang focus kanta cembung.	3	4	3	3
3.	Saya berupaya menentukan titik fokus dan panjang fokus kanta cekung.	3	4	3	3
4.	Saya berupaya melukis gambar rajah sinar untuk menunjukkan kedudukan dan ciri-ciri imej yang dibentuk oleh kanta cembung.	4	5	4	5
5.	Saya berupaya melukis gambar rajah sinar untuk menunjukkan kedudukan dan ciri-ciri imej yang dibentuk oleh kanta cekung.	4	4	4	4
6.	Saya berupaya menyatakan pembesaran sebagai $m = \frac{v}{u}$	5	4	4	2

Figure 3. Students discussing in their team to fill in the worksheets of Activity 1

Figure 4. Table of Ability and Capability of Myself and Friends completed by the students

Throughout the PS learning method, the treatment group showed higher CPS skills in discovering the perspectives and abilities of their team members (i.e. A1) in comparison to the control group. This is because most of the students in the treatment group demonstrated their abilities as presented in Table 8 below.

Table 8. List of A1 sub-skill shown by the students

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
A1	Discovering perspective and abilities of team members	The student: (a) shares information and perspectives about one's self and others when asked but does not (b) inquire about the abilities, perspectives, and other information about other team members when completing Table of Ability and Capability of Myself and Friends.	The student: (a) shares information and perspectives about one's self and others when asked and (b) inquires about the abilities, perspectives, and other information about other team members when completing Table of Ability and Capability of Myself and Friends.

In Activity 2, it was found that the Lensmation CPS Module enhanced the A2, A3, B1, B2, B3 and C1 sub-skills score. Throughout this activity, the students were encouraged to ask, respond and understand the role of each team member. These actions were triggered when they completed the Work Planning Flow worksheet, which is comprised of:

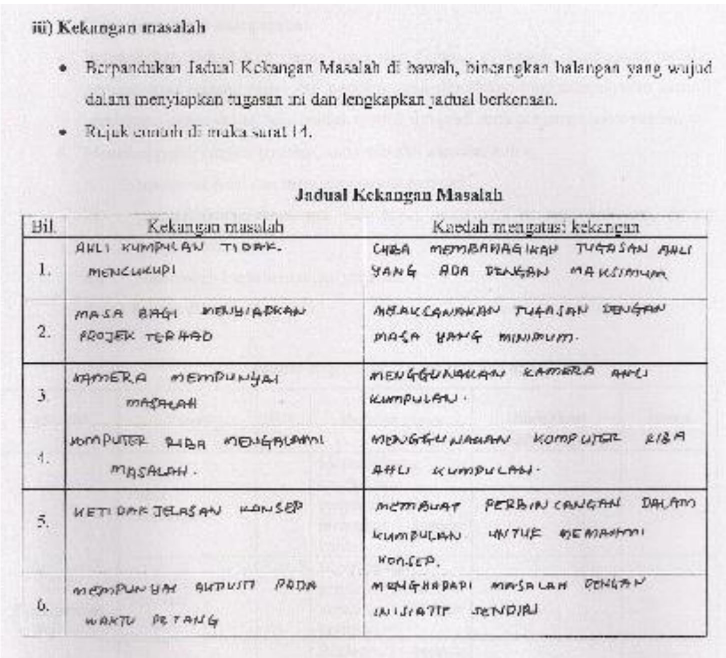
i) Interaction type: students discussed the methods of interaction that they applied during the activity.
ii) Goal of the problem: students and their team members summarized the information and PS in the form of texts, notes and images as Representation 1.
iii) Problem constraints: students discussed the obstacles that exist in the completed task by filling in the Table of Problem Constraints.
iv) The needs of the task and role: students discussed and completed the Table of Task Requirement and Role.

Table 9 presents the content of Activity 2.

Table 9. Content of Activity 2

Activity No.	Time	Content of Activity	Students outcomes	CPS skills
Activity 2	55 minutes	1. While completing the Work Planning Flow worksheet, aspects such as interaction type, goal of the problem, problem constraints and needs and roles of team members were discussed. 2. Texts, notes and images for Representation 1 (R1) were recorded as artifacts and research results to the PS task given.	- Work Planning Flow worksheet. - Representation 1 (R1).	- Discovering the type of interaction to solve the problem, along with goals (A2). - Understanding roles to solve problem (A3). - Building a shared representation and negotiating the meaning of the problem (B1). - Identifying and describing tasks to be completed (B2). - Describing the roles and team organisation (team protocol) (B3). - Communicating with team members about the actions to be and being performed (C1).

Figure 5 and Figure 6 illustrates the examples of the completed worksheets and Representation 1 constructed by the students during Activity 2.


iii) Kekangan masalah

- Berpandukan Jadual Kekangan Masalah di bawah, bincangkan halangan yang wujud dalam menyiapkan tugasan ini dan lengkapkan jadual berkenaan.
- Rujuk contoh di muka surat 14.

Jadual Kekangan Masalah

Bil.	Kekangan masalah	Kaedah mengatasi kekangan
1.	AHLI KUMPULAN TIDAK MENCUKUPI	CUBA MEMBAHAGIKAN TUGASAN AHLI YANG ADA DENGAN MAKSIMUM
2.	MASA BAGI MENYIAPKAN PROJEK TERHAD	MELAKSANAKAN TUGASAN DENGAN MASA YANG MINIMUM.
3.	KAMERA MEMPUNYAI MASALAH	MENGGUNAKAN KAMERA AHLI KUMPULAN.
4.	KOMPUTER RIBA MENGALAMI MASALAH.	MENGGUNAKAN KOMPUTER RIBA AHLI KUMPULAN.
5.	KETIDAK JELASAN KONSEP	MEMBUAT PERBINCANGAN DALAM KUMPULAN UNTUK MEMAHAMI KONSEP.
6.	MEMPUNYAI AKTIVITI PADA WAKTU PETANG	MENGHADAPI MASALAH DENGAN INISIATIF SENDIRI

Figure 5. Completed worksheets constructed by the students during Activity 2

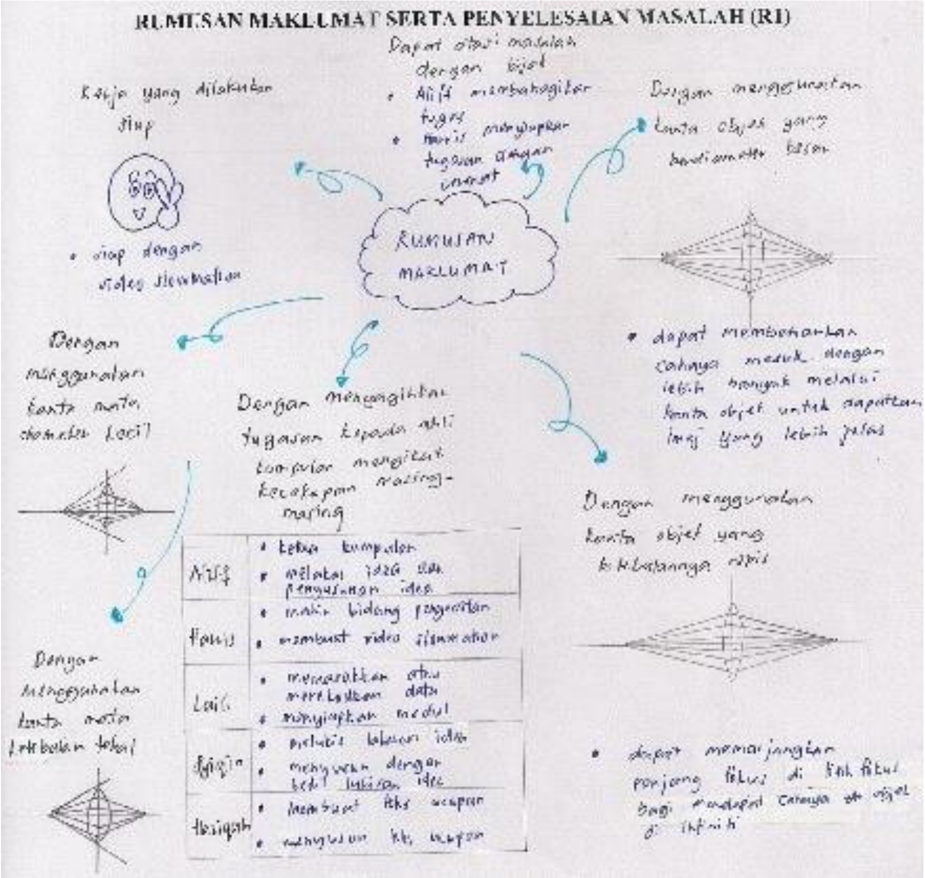


Figure 6. Representation 1 constructed by the students during Activity 2

In comparison, the treatment group showed higher CPS skills in A2, A3, B1, B2, B3 and C1 than the control group during PS learning. This is due to the fact that most of the students in the treatment group demostrated their abilities as shown in Table 10 below:

Table 10. List of A2 to C1 sub-skills shown by the students

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
A2	Discovering the type of interaction to solve the problem, along with goals	The student responds to requests but does not inquire about the actions, tasks, and plans to be completed by members of the team to solve the problem.	The student responds to requests and inquires about the actions, tasks, and plans to be completed by members of the team to solve the problem.
A3	Understanding roles to solve problem	The student acknowledges but does not inquire about roles take by other team members. The student's actions and communications reflect awareness that student is part of a team attempting to solve the problem.	The student both acknowledges and inquires about roles take by other team members. The student's actions and communications take the initiative in understanding the different team roles that need to be taken to solve the problem.
B1	Building a shared representation and negotiating the	The student responds to but does not initiate requests for clarification of the problem	The student both responds and initiates requests for clarification of the

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
	meaning of the problem	goals, problem constraints, task requirements, and roles taken by different team members.	problem goals, problem constraints, task requirements, and roles taken by different team members.
B2	Identifying and describing tasks to be completed	The student: (a) acknowledges or confirms the tasks to be completed when prompted but does not (b) take the initiative to identify, propose, describe, or change the tasks.	The student both: (a) acknowledges or confirms the tasks to be completed when prompted and (b) takes the initiative to identify, propose, describe, or change the tasks. The student takes the initiative to propose modifications to plans and tasks when there are changes in the problem or when there are major obstacles in the solution.
B3	Describing the roles and team organisation (team protocol)	The student: (a) acknowledges or confirms the roles of the student and other team members when prompted but does not (b) take the initiative to identify, propose, describe, or change the roles of the student and other team members.	The student both: (a) acknowledges or confirms the roles of the student and other team members when prompted and (b) takes the initiative to identify, propose, describe, or change the roles of the student and other team members. The student takes the initiative to propose reassignments in roles when there are changes in the problem or when a team member is not contributing as planned.
C1	Communicating with team members about the actions to be and being performed	The student: (a) communicates with team members (when asked) about the completion and results of tasks assigned to the student but does not take the initiative to (b) proactively communicate with other team members about the completion and results of tasks assigned to the student and (c) ask other team members about the completion and results of their tasks.	The student: (a) communicates with team members (when asked) about the completion and results of tasks assigned to the student and also takes the initiative to (b) proactively communicate with other team members about the completion and results of tasks assigned to the student and (c) ask other team members about the completion and results of their tasks.

Based on Activity 3 and 4, the researcher deemed that the Lensmation CPS Module may increase C2, C3, D1, D2 and D3 sub-skills score. In both activities, the students were facilitated by the teacher to:

i) Take action to:

- create Flow Chart of Idea Sketch
- produce storyboard as Representation 2 (R2)
- build model and texts as Representation 3 (R3)
- run photography of model and texts as Representation 4 (R4)
- generate slowmation by using Microsoft Movie Maker and Microsoft Movie Player as Representation 5 (R5)

All the above-mentioned actions were in accordance with the task distributions as planned in Activity 2 which are listed below.

ii) Solve problems through re-planning of PS strategies or team organisation or role.

iii) Encourage team members to complete the PS tasks through their assigned roles.

iv) Take initiatives or actions to resolve the gaps or errors.

Table 11 shows the content of Activity 3 and 4.

Table 11. Content of Activity 3 and 4

Activity No.	Time	Content of Activity	Students outcomes	CPS skills
Activity 3	45 minutes	1. Based on Representation 1 in Activity 2, the Flow Chart of Idea Sketch is completed. Then, the team produced a storyboard (i.e., Representation 2). 2.Students builtmodel and texts (i.e., Representation 3) parallel to the storyboard.	- Flow Chart of Idea Sketch. - Representation 2 (R2). - Representation 3 (R3).	- Enacting plans (C2). - Following rules of engagement (e.g. Taking actions to fulfil team goals and prompting other team members to perform their tasks) (C3). - Monitoring and repairing the shared understanding (D1). - Monitoring and describing the results of the actions, evaluating success in solving the problem (D2). - Monitoring, providing feedback and adapting the team organisation and roles (D3).
Activity 4	45 minutes	1. Students run photography of text and model guided by the storyboard. 2. Finally, they generated slowmation (i.e., evidence) to present their solutions of PS task (i.e., Representation 5).	- Representation 4 (R4). - Representation 5 (R5).	

Figure 7, Figure 8, Figure 9 and Figure 10 demonstrate examples of completed worksheets and Representation 2, 3, 4, and 5 constructed by the students during Activity 3 and 4.

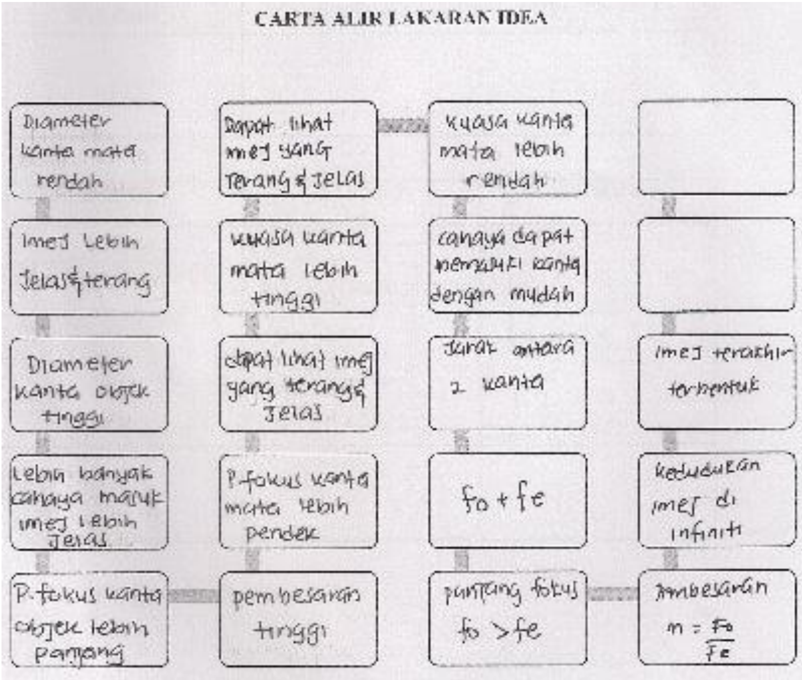


Figure 7. Completed Flow Chart of Idea Sketch constructed by the students during Activity 3

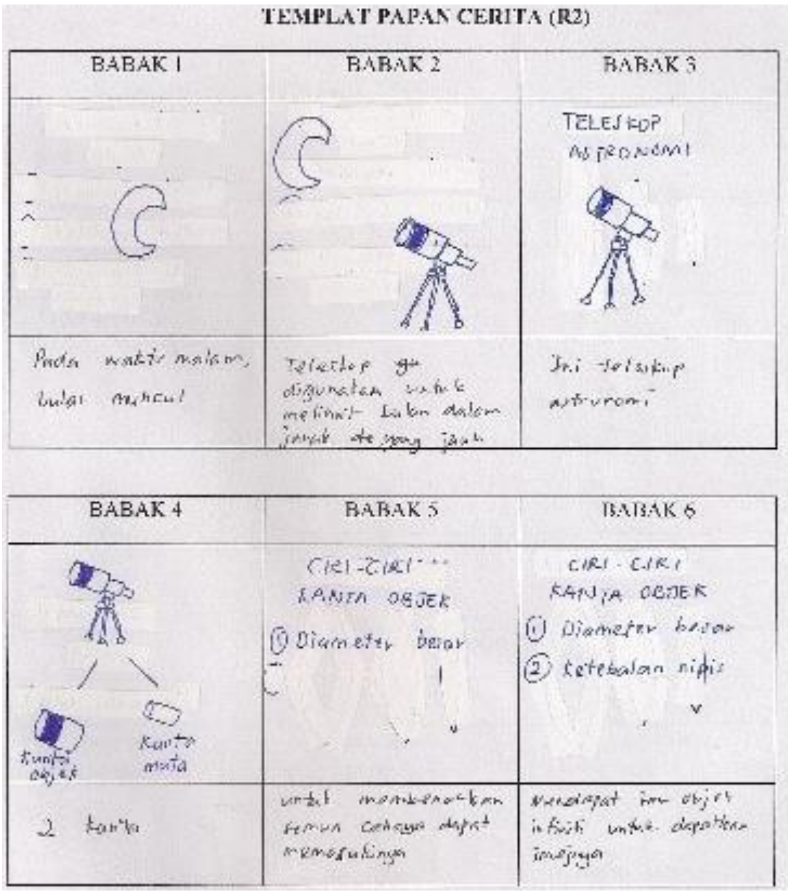


Figure 8. Storyboard (i.e. Representation 2) constructed by the students during Activity 3

Figure 9. Students built and run photography for model and texts for Representation 3 and 4

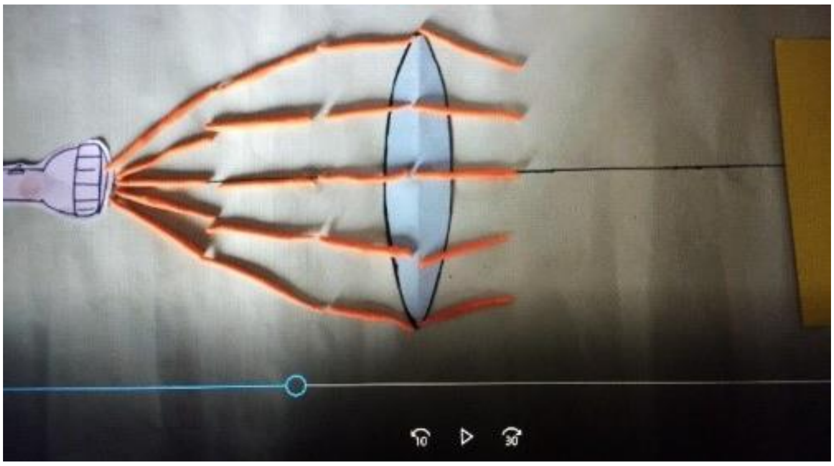


Figure 10. Students generate slowmation as artefact for Representation 5

The treatment group exhibited higher CPS skills in C2, C3, D1, D2 and D3 compared to the control group owing to the fact that most of the students in the treatment group demonstrated their abilities as in Table 12 below:

Table 12. List of C2 to D3 sub-skills shown by the students

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
C2	Enacting plans	The student takes actions that comply with the planned distribution of tasks but does not take actions to solve unexpected obstacles to the team plan.	The student takes actions that comply with the planned distribution of tasks and takes actions to solve unexpected obstacles to the team plan.
C3	Following rules of engagement (*e.g.* Taking actions to	The student takes actions that: (a) follow the planned tasks	The student takes actions that: (a) follow the planned

Code	CPS skills	Skill that have been shown by the students at at the standard level of proficiency	Skill that have been shown by the students above the standard level of proficiency
	fulfil team goals and prompting other team members to perform their tasks)	for particular roles and (b) responds appropriately when asked to complete the student's role assignment. However, the student does not take the initiative to prompt other team members to complete their assignments for particular roles.	tasks for particular roles and (b) responds appropriately when asked to complete the student's role assignment. The student also takes the initiative to prompt other team members to complete their assignments for particular roles.
D1	Monitoring and repairing the shared understanding	The student: (a) acknowledges or confirms deficits (gaps or errors) in shared understanding when prompted, but does not (b) take actions that troubleshoot potential gaps or errors in shared understanding and (c) take the initiative to repair deficits in shared understanding.	The student: (a) acknowledges or confirms deficits (gaps or errors) in shared understanding when prompted, (b) takes actions that troubleshoot potential gaps or errors in shared understanding, and (c) takes the initiative to repair deficits in shared understanding.
D2	Monitoring and describing the results of the actions, evaluating success in solving the problem	The student: (a) acknowledges or confirms obstacles in the PS process when prompted and (b) describes or otherwise expresses the occurrence of obstacles, but does not (c) take actions that troubleshoot potential obstacles and (d) take actions to replan the PS strategies to overcome the obstacles.	The student: (a) acknowledges or confirms obstacles in the PS process when prompted, (b) describes or otherwise expresses the occurrence of obstacles, (c) takes actions that troubleshoot potential obstacles, and (d) takes actions to replan the PS strategies to overcome the obstacles.
D3	Monitoring, providing feedback and adapting the team organisation and roles	The student: (a) acknowledges or confirms problems in the team organisation or roles when prompted, (b) describes or otherwise expresses problems in the team organisation or roles, but does not (c) take actions that troubleshoot potential problems in team organisation or roles, and (d) take actions or communicate with team members to change the team organisation or roles.	The student: (a) acknowledges or confirms problems in the team organisation or roles when prompted, (b) describes or otherwise expresses problems in the team organisation or roles, (c) takes actions that troubleshoot potential problems in team organisation or roles, and (d) takes actions or communicates with team members to change the team organisation or roles.

Based on Activity 1 to 4, the students implemented CPS skills at the standard level of proficiency and above the standard level of proficiency. Hence, it is evident that the innovative PS approach inculcated CPS skills among the students since they were able to implement three major CPS competencies as proposed in OECD (2013). The three major CPS competencies are:

1) Establishing and maintaining shared understanding:

During Activity 1 (i.e. A1 sub-skill was applied), Activity 2 (i.e. B1 and C1 sub-skills were applied) and Activity 3 and 4 (i.e. D1 sub-skill was applied), the students had identified their mutual knowledge. This indicates that each of the team member gained knowledge about the problem, was able to identify the perspectives of other team members during the collaboration and established a shared vision of the problems stated, as well as the activities. Apart from that, it is also believed that the students were able to monitor their abilities, knowledge and perspectives through their interaction with the other team members in relation to the given task. In the report from OECD (2013), as cited in Clark (1996) and Clark and Brennan (1991), theories of discourse processing embedded in the CPS theory have highlighted the importance of establishing common ground. Notably, it is a significant element in achieving effective communication and most of the key elements in CPS skills.

Throughout the activities, the students have shown that they had established, monitored and sustained the shared understanding. This is evidenced in the students' actions and communication in responding to requests for information, giving important information about tasks completed, establishing or negotiating shared meanings, verifying each other's knowledge and taking actions to repair deficits in shared knowledge. Moreover, the students showed their own self-awareness with regards to their proficiency level in performing the task, recognised their own strengths and weaknesses in relation to the task (i.e. metamemory) and recognised the team members' strengths and weaknesses (i.e. transactive memory).

2) Taking appropriate action to solve the problem:

In Activity 2 (A2 and B2 were applied) and Activity 3 and 4 (C2 and D2 were applied), the students had identified the type of CPS activities (consensus building) that was needed to solve the task and followed the proper steps to obtain a solution to the problem. As regards those activities, it is believed that the students had shown their efforts to understand the problem constraint, build team goals for the solution, act on the tasks and monitor the results in relation to the team and problem goals. In addition, the students were able to transfer complex information and perspective besides achieving more creative or optimal solution; the students were able to explain, justify, negotiate, debate and argue. Furthermore, the students were also guided to be proficient collaborative problem solvers who were able to recognise constraints in consensus building, follow relevant rules of engagement, troubleshoot problems and evaluate the success of the PS plan within those activities.

3) Establishing and maintaining group organisation:

In Activity 2 (A3 and B3 sub-skills were applied) and Activity 3 and 4 (C3 and D3 sub-skills were applied), the students were guided to build a team that can function effectively by means of team organization and adaption of structure to the PS task. The students were found to be able to understand their own role and the other team members' roles based on their knowledge of who is skilled at what in the team (i.e. transactive memory). Thus, based on their role, they tried to follow the rules of engagement and monitor the group organisation. If changes were needed, they exhibited actions to handle communication breakdowns, obstacles to the problem and performance optimisation. The problem situations experienced by each student may facilitate the other students to become a stronger leader in the team, as the process involved to solve the problem may require more democratic organisations. Moreover, the problem situations in this module were designed to educate the students to be a competent leader, in which they have to take steps to ensure that the team members are completing tasks and important information are being communicated. During the activities, the students were guided in order to provide feedback and reflections on the achievement of the team organisation in solving the problem.

Besides PS learning activities and steps that inculcate CPS skills, other factors that contributed to the findings of the present study are the students themselves, who are digital natives. Hence, they have the tendency to apply their ICT literacy to solve problems, especially problems related to their daily routine. According to Adolphus, Alamina and Aderonmu (2013), Basu et al., (2015) and Tissenbaum, Lui and Slotta (2012), students as young as 12 years old are capable of generating high level thinking skills through the aid of a computer. These students are able to design and generate the subject contents if they were given the appropriate support (Chang &

Quintana, 2006). Consequently, the implementation of the Lensmation CPS Module may guide students to apply their ICT literacy for PS learning and thus, inculcate CPS skills. As indicated by reference OECD (2013), the students' ability to apply their ICT literacy may contribute towards inculcation of CPS skills.

This finding has imperative implications for the researcher in putting forward a proposal or suggestion to the MOE, which is to update the physics PS learning process and approaches besides focusing on inculcating CPS skills among students. This may be accomplished by shifting the focus to CPS learning process and the idea of manipulating students' ICT literacy. In addition, the innovative approaches employed in the new pedagogy as suggested above may be integrated into physics curricula to inculcate CPS skills. The inculcation of CPS skills among students may facilitate them to relate what they have learned in physics PS learning to their daily lives and future work place. This in turn, may increase their interest in physics PS and most importantly, they may be able to see the relevance of education in their daily lives.

The human resource factor plays a vital role in order to enable an effective application of the above-mentioned modifications. The researcher believes that new and experienced physics teachers must be exposed and trained in inculcating CPS skills and knowledge in module implementation. Apart from that, teachers should be able to relate their skills and abilities of physics CPS to students' daily life. It should be noted that when learning is associated with current methods and is parallel with students' lifestyles and characteristics, the PS learning process becomes more effective, especially in inculcating CPS skills. Consequently, this may directly reduce negative feelings and enhance the level of confidence among teachers and students towards PS implementation, communication, teamwork and ICT application in learning.

Conclusion

It is noteworthy that the present study has reported significant issues of related to physics PS learning in secondary schools in Malaysia. One of the issues is that, in the current PS learning approach, physics students are at risk of being left behind. At the same time, they have had a lack of exposure to CPS computer-orientated learning and CPS skills. Subsequently, this may contribute to the low level of students' abilities to solve physics problems and may result in the heighten perception that physics PS is difficult. Therefore, the researcher deems that teachers should expose students to the current and innovative approaches of PS learning which take into consideration the students' learning styles and characteristics. It should be noted that students who were born in this era (i.e. the millennials) are able to solve problems by means of their ICT literacy in structured and collaborative manner.

As regards the findings of this research, Lens PS learning may improve by implemention of the Lensmation CPS Module, which effectively inculcates CPS skills than the conventional approach. A better understanding of how students solve problems collaboratively and manipulate their ICT literacy by generating animation to present their solutions may be expanded to all physics teachers and curriculum developers. Improvements and prompt actions to address issues in relation to teachers' role as facilitators to guide students in physics CPS learning with appropriate approach are deemed necessary. Future research should be focused on utilizing the slowmation as evidences generated by the students to be analysed in terms of the quality of their CPS solutions. One method suggested by the OECD is the emphasis on the quality of CPS solutions for assessing the inculcation of CPS skills.

In a nutshell, it is of utmost importance to consider several efforts in improving the learning process of physics PS, specifically in inculcating CPS skills. Notably, the mismatch of physics PS learning approach at the secondary level need to be solved so that current and innovative learning process can be implemented effectively which subsequently could contribute to enhancing a high level of ICT literacy among students.

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An Analysis of Scale Adaptation Studies in Science Education: Meta-Synthesis Study

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Abstract

The purpose of this study was to examine scale adaptation studies in the field of science education in terms of content, method as well as to determine the general guidelines used in the scale adaptation process. The population of this study included a total of 145 journals published in the field of science education in Turkey. A total of 46 adaptation studies which were published in 25 journals were selected from this population by using the purposive sampling methods comprise of the study sample. Meta-synthesis method was used for the data analysis in this study. Results of the study showed that adaptation studies in Turkey were mostly conducted in the self-efficacy area. It was determined that all studies calculated the internal consistency coefficient and that likert-type scales were commonly used. This study also determined that the language validity stage was not sufficiently discussed and was only briefly mentioned in the examined adaptation studies. It was found that none of the studies translated original test guidelines to target language. This study concluded that all of the adapted studies did not get official permissions for the pilot study. In addition, it was found that the researchers preferred to use CFA (Confirmatory Factor Analysis) and EFA (Exploratory Factor Analysis) methods together for the construct validity.

Introduction

There are many assessment tools in social sciences to measure a variable. However, it is important to find the most reliable and valid tool for the study objective (Atilgan 2015). This scale can either be developed when needed or adapted from another language. Secer (2015) described scale adaption studies as the use of a valid and reliable scale, which was developed in a foreign language, in a different language and culture by conducting its validity and reliability analyses.

In the relevant literature, the first scale adaptation was made by Lewis M. Terman in 1916. Terman adapted the Intelligence Test, which was developed in French by Alfred Binet and Theodore Simon in 1905, and changed the name to the Measurement of Intelligence for the American Culture (Tsagari and Floros, 2013). Nowadays, there is a growing need to compare the success of students from different countries (Deniz 2007; Sireci 1995). One of the main goals of comparing is to share educational practice and promote growth and improvement, i.e., to learn from each other. There have been many studies comparing students' academic success in different cultures since 1970s. In 1995, for instance, 40 countries participated in the Third International Mathematics and Science Study, and the scale was adapted to 30 languages (de Vijver and Hambleton, 1996). In 2015, fourth- and eighth-grade students from 57 countries participated in the Trends in International Mathematics and Science Study (TIMSS), and the test was adapted to 43 languages (Deniz 2007; Ebbs and Korsnakova, 2015; Polat, Gonen, Parlak, Yildirim, and Ozgurluk, 2015). The Programme for International Student Assessment (PISA) is one of the internationally accepted largest-scale of standardized assessment tool for 15-year olds. PISA was used for 72 countries in 2015 to evaluate students’ skills and knowledge (the Organisation for Economic Co-operation and Development [OECD] 2017).

In the *Standards for Educational and Psychological Tests and Manuals*, which was revised by the American Psychological Association (APA), American Educational Research Association (AERA) and National Council on Measurement in Education (NCME) in 2014, it states that the main purpose for developing “Educational and Psychological Tests” is to develop a universal method that is accessible to researchers from all countries (AERA, APA and NCME 2014).

The International Test Commission (ITC) emphasized the importance of language translations made in scale adaptations in 1993, and published their first draft report in 1994. The commission completed their report in 1996, and explained 22 binding rules in detail (de Vijver and Hambleton 1996). The ITC classified these rules, which were developed for scale adaptation, under five titles (de Vijer and Hambleton, 1996; Hambleton, Merenda and Speilberger 2009): (1) context, (2) test development and adaptation, (3) application of test, (4) documentation/score evaluation, and (5) general and professional conditions.

Within the scope of *context*, the effect of cultural differences should be minimized as much as possible. The selected sample and the sample to which the original sample is applied should be in accordance with each other (de Vijver and Hambleton 1996; Plake and Wise 2014). During the *test development and adaptation* stage, researcher(s) should consider that this test may be adapted to a different culture and/or language in the future. Test developers should prepare directions, a scoring table and items of the test considering the cultural and linguistic characteristics of the sample. The selected test method, item format and other procedures should comply with the target group. They should also ensure that item content is suitable for the target group. They should test whether the scale, which is adapted in linguistic and psychological aspects, complies with the original scale. Appropriate statistical methods should be used. At the end of the statistical analysis, conflicting items should be excluded from the test. Validity and reliability of the adapted scale should be ensured, and according to analyses results, items determined to be inappropriate for the target group should be excluded from the test (Hambleton, Merenda and Speilberger 2009; Plake and Wise 2014). In the *test application* stage, the selected framework should be similar to the original scale. In this stage, possible problems that might emerge during the use of the scale should be determined and solved in advance. Researchers should also review the materials and application procedures that may affect the validity of the test. Test directions in the original and translated scales should be similar to each other. Test booklets should be suitable for the target culture. Rules to be followed during the application stage should be specified clearly. If the test is applied to a sample group that is different than the original, the reason for this change should be specified in the *documentation/score evaluation* stage. The researcher is responsible for score differences that may occur between the samples. In the event that the scores obtained from the sample comparison are similar, results should be reported. The researcher should state that socio-cultural and ecological effects on the test results can affect the performance of the sample group, and also state how the results can be affected In context of *general and professional conditions*, test developers should be aware of the fact that linguistic and cultural differences of the target group are important in test adaptation studies (Hambleton, Merenda and Speilberger 2009).

The Advantages and Disadvantages of Scale Adaptation Studies

The negative aspects of scale adaptation:

- There may be difficulty in ensuring cultural and linguistic equivalency (Cha, Kim and Erlen 2007; Grisay, 2000; Secer 2015, Seker and Gencdogan 2006),
- There is a possibility that a number of items and factors in the original version change as a result of adaptation process (Secer 2015; Seker and Gencdogan 2006),
- If original version of the scale has more than five-point Likert-type options, it is not suitable for Turkish language (de Vijver and Hambleton 1996; Secer 2015; Seker and Gencdogan 2006).

The positive aspects of scale adaptation:

- It is convenient for researchers in terms of time, effort and economic aspects (Cha, Kim and Erlen 2007; Savasir 1994) since the examination of the theoretical background is a time-consuming, difficult and expensive process (Deniz 2007).
- It is probable that the researcher does not have the technical information related to the subject. In this case, adaptation of the scale is more suitable (Deniz 2007; Savasir 1994; Secer 2015).
- Adaptation studies allow researchers to make comparisons between different cultures (Deniz 2007; Hambleton et al. 2009; Secer 2015; Seker and Gencdogan 2006).
- In countries where different languages are spoken, similar versions of the same scale that are developed for the spoken languages will enable analyzing study results in a more efficient way (Savasir 1994).
- An adaptation of a widely-known and commonly-used scale will be trusted more than a newly developed test (Deniz 2007).

The Primary Stages Followed in Scale Adaptation Studies

Preparation Stage: In this stage, the researcher determines the need for scale adaptation (Akbas and Korkmaz 2007), decides which scale to translate, obtains the permissions for the adaptation study, and forms the translation team (Gudmundsson 2009; Secer 2013).

Language Validity: This stage includes translating the scale items and directions from the source language to the target language, examining and comparing these translations, making a backward translation, giving its first form to the translated scale, performing an application for language validity, performing statistical analyses for language validity, and giving its form to the scale of which the language validity is constructed (Geisinger 1994; Gudmundsson 2009; Savasir 1994; Seker and Gencdogan 2006).

Ensuring cultural and linguistic equivalency is the most important process in scale adaptation studies (Cha et al. 2007; Deniz 2007; Secer 2015; Savasir 1994) because the translation team including field experts having a good command of both languages is the most efficient factor to make the adaptation study successful. According to the Standards for Educational and Psychological Testing which was develop from AERA, APA and NCME the validity and reliability of a test should be tested by applying it to a group comprising of linguists when it is translated from one language to another language or dialect (Hambleton 2009; Tsagari and Floros 2013).

According to Tsagari and Floros (2013), popular translation methods in test adaptations are forward translation, which means translating test from the source language to the target language, and backward translation, which means translating the scale –which is already translated to the target language– back to the source language (Grisay 2000; Savasir 1994). Cha, Kim and Erlen (2007) stated that backward translation is the most important step in scale adaptation studies. Independent linguists should work on the translation in these two translation processes. However, Tsagari and Floros (2013) believe that these adaptation studies are challenging in any circumstances since there is a possibility for the linguists who make the translation to make subjective decisions, and ignore some points even if they speak the source language. Therefore, Maxwell (1996) and Savaşir (1994) stated that a good translator should have an excellent knowledge of both the source and adaptation languages, have enough experience to recognize the cultural structures of both languages as well as the sample group to which the scale is to be adapted, and skills for test development.

Pilot Study: This stage comprises of obtaining official permissions for a pilot study, carrying out the pilot study, and, performing validity and reliability analyses after the pilot study (Geisinger 1994; Gudmundsson 2009; Savasir 1994; Seker and Gencdogan 2006).

It is required to obtain official permissions for the sample group to which the application will be performed in order to conduct the pilot study of the adapted form of the scale. After receiving the necessary permissions, the pilot study is conducted and the obtained data are analyzed using the SPSS, AMOS or LISREL software.
To determine the sample size, the Kaiser-Meyer-Olkin (KMO) value is calculated. KMO values higher than 0.60 show that the sample size is suitable (Buyukozturk 2009). Barlett's test is used to determine whether data are suitable for factor analysis, and they will be if the test result is significant (Secer 2013). For item analysis of the test, differences between items mean scores of 27% sub above groups are calculated using an unrelated t-test (Büyüköztürk 2009).

For the validity analyses; content, structure and criterion validity are calculated. Content validity is calculated in the original form; thus, it is not necessary to calculate it again in adaptation studies. In the content validity step, a table of specifications is created for matching between target behaviors and items of the measurement tool. Field experts examine the table of specifications and report their opinions for the content validity. The inter-rater reliability level is expected to be 90-100% (Buyukozturk 2009; Turgut and Baykul 2012). Criterion validity is divided into two: concurrent validity and predictive validity (Turgut and Baykul 2012). Two types of factor analyses are performed for construct validity of the scale in the measurement tool development and adaptation stage:

Exploratory Factor Analysis (EFA): This is generally used for scale development. Its purpose is to determine the implicit structure of the scale (Secer 2015). This analysis is performed to test the appropriateness of scale items to the predefined theoretical structure. It is used to determine the number of sub dimensions in which the scale items can be included. Moreover, this analysis is important for the determination of the relationship between scale items (Secer 2013).

Confirmatory Factor Analysis (CFA): This analysis is used for scale adaptation and scale development studies. Its purpose is to confirm the implicit structure which is determined using the EFA. It is used to determine which structures are identified by a series of items. In scale adaptation studies, it ensures the control of the model fit between factorial structures of the original version and the translated version (Secer 2015). While adapting a scale, some researchers prefer to perform a CFA only rather than performing both analyses (EFA and CFA) together. However, It is necessary to perform the CFA to determine whether there is a difference in the factorial structure of the two scales, if it is to be adequately adapted to a new language and culture. In addition to enabling researchers to test the hypotheses for factor structure and model fit, it provides more informative analytic options.

For *reliability* calculations; internal consistency coefficient, split-half reliability, and test-retest calculations are conducted. Reliability is used in the meaning of consistency during developing and adapting a measurement tool. Consistency is receiving similar or the same results when measurements are repeated (Buyukozturk 2009). Kuder Richardson-20 (KR-20) and Cronbach's alpha internal consistency value (Atilgan 2015) are used as evidence for the content validity. The KR-20 is used in the scoring of two categories. KR-20 statistics are calculated when variance is determined. Item difficulty statistics should be known for this calculation. It is performed in one-dimension scales. If there are raw scores, then it is calculated. The Cronbach's alpha reliability coefficient is calculated in likert-type scales with three or more points (Gomleksiz and Erkan 2010).

As reliability estimation techniques; test-retest, equivalent forms, and test-split test methods are preferred. The *test-retest method* is explained with the Pearson product-moment correlation which is obtained as a result of administering a test to the same group periodically (Atilgan 2015). For the *equivalent (alternative/parallel) forms method* two equivalent forms, which are developed to measure the same characteristic, are administered to the same group at the same or different times, and the consistency between scales are calculated by applying the Pearson product-moment correlation on the results (Buyukozturk 2009). The *test-split test method (equivalent splits – split-half),* is important for calculating the consistency between test scores. It is appropriate for one-dimension tests. Items in the test split in equivalent halves as odd-even or first half-last half (Atilgan 2015). The Pearson product-moment correlation is calculated using scores obtained from both halves of the test. The obtained value is accepted as the reliability of either one of the halves. The reliability for the entire scale is calculated using the Spearman-Brown formula (Atilgan 2015). If test items show a heterogeneous distribution in terms of the measured characteristic, it will be appropriate to determine reliability using the test-split test method rather than using an internal consistency coefficient (Gomleksiz and Erkan 2010).

The Studies Conducted in Turkey

By using thematic content analysis (meta-synthesis), Gul and Sozbilir (2015) analyzed 22 scale-development studies in science and mathematics education field, which were published between the years 2000 and 2013 in six primary academic journals in Turkey focusing on educational sciences, and selected based on the pre-determined criteria. They found that attitude scale was the most commonly developed type of scale, and these studies were mainly conducted in mathematics education field. Of the validity analyses, researchers mainly worked on construct validity, while confirmatory and exploratory analyses were studied at a moderate level. Gul and Sozbilir (2015) explained that they analyzed validity of the 22 scale-development articles based on criterion validity which was found only in one article, content validity which was calculated more than half of the articles, face validity was calculated only in five articles. In addition in terms of construct validity the researchers found that only eight articles was used discriminant validity while there was no information about convergent validity. It was also determined that internal consistency methods were the favorite of researchers among reliability studies.

Guvendir and Ozkan (2015) examined studies which were conducted on scale development and adaptation in Turkey between the years of 2006 and 2014, and they aimed to determine stages used in scale development and adaptation processes. The researchers selected a total of 59 articles on scale adaptation and development, and these studies comprised the study sample. The study found that two or more translators worked in the adaptation studies, and the directions of the original scale were not translated in any of the articles. Only one article consulted assessment experts, and few studies calculated equivalent split-half reliability.

Boztunc-Ozturk, Eroglu and Kelecioglu (2015) examined scale adaptation studies which were conducted in the education field between the years of 2005 and 2014. A total of 108 article studies matching the determined criteria comprised the study sample. In the data analysis, the study used the "Control Form for the Scale Adaptation Process" form developed by the researchers. According to the study results, all studies used the backward translation method, and the language equivalency calculation used only the adapted form, while the original scale was used in none of the studies. For construct validity, an EFA and CFA were used together. None of the studies examined the criterion validity of the scale. As an internal consistency coefficient, the Cronbach's alpha value was calculated. According to the construct validity results, the adapted scales showed similarity with the original scale, and no new items were suggested to replace the excluded items.

Delice and Ergene (2015) examined scale development and adaptation studies, which were conducted in Turkey in mathematics education field between the years of 2005 and 2014, according to certain criteria. The study sample included 35 scale development and 18 scale adaptation studies. That study found that only two-thirds of these studies mentioned whether there was a need for a scale adaptation study. More than half of these studies did not mention that necessary permissions were obtained for the adaptation of the scale. The researchers made certain that the translation team created for the adaptation included only individuals that spoke the target language. It was determined that researchers were not careful enough to form their groups of experts that were sufficiently informed about both source and target languages and cultures as well as the characteristics of the scale to be adapted. All studies calculated the Cronbach's alpha value. It was found that the calculated Cronbach's alpha values were in compliance with the original scales. Some studies did not report their reliability analysis results (internal consistency coefficients). It was also reported that the sample size used in some studies was not big enough, while Delice and Ergene (2015) suggested that five to 25 subjects need for per variable. Costello and Osborne (2005) suggest a ratio of 10/1 as a minimum but recommend a ratio of 20/1 subject to variable" (p.7).

Cum and Koc (2013) examined scale development and adaptation studies which were conducted in the psychology and educational sciences field between the years of 2005 and 2013. The study sample included a total of 50 articles: 29 scale development and 21 scale adaptation studies. As a result of the study, it was determined that half of the adaptation studies reported data by following the accurate steps. These adaptation studies did not provide information about the decision to adapt the scale, half of them did not mention whether they obtained permission for adaptation, while none of the studies gave information about structural equivalency related to culture, and a majority of them changed the factor structure of the scale and removed too many items. Although the translators had sufficient skills, only three studies employed evaluation and assessment experts. Also, all of these studies conducted reliability analysis. Also, all studies used the Cronbach's alpha method, equivalent splits and test-retest methods. Most of the studies used the EFA. In the adaptation studies, it was not reported that the CFA was used. It was determined that none of these studies conducted a statistical analysis to determine language equivalency.

According to Hambleton et al. (2009), there will be more scale adaptation studies conducted in the future due to the popularization of using the same scales in the international arena, the necessity of tests that fit international assessment and evaluation criteria, and the interest in cross-cultural studies. Scale adaptations are advantageous in financial and temporal grounds. There is no dominantly accepted method in the relevant literature related to scale adaptation studies. This situation improved in 2000s as a result of the developments in measurement and evaluation techniques (SPSS, LISREL, etc.) (Hambleton et al. 2009).

Aim of the Study

With regard to scale adaptation studies in the field of science education in Turkey, only five study done focusing only papers published in short period of time in limited number of journals. Based on our meta-synthesis study, we aimed to provide more conclusive results by reviewing all of the physical science education journals beginning of their first issue. Therefore, aim of this study was to examine scale adaptation studies in Turkey in sciences education area considering content and methodology, and to determine the stages commonly used in the scale adaptation process using the meta-synthesis method. With this objective, this study sought answers for the research questions below:

1) What is the situation of scale adaptation studies in Turkey in physical sciences education area in terms of content (area of scale, the year when the scale is published, type of scale, number of items, general reliability coefficient, number of samples and sample level)?
2) What is the situation of scale adaptation studies in Turkey in physical sciences education area in terms of methodology?
3) What are the frequently followed steps in scale adaptation studies in the field of physical sciences education in Turkey?

Method

This study used the meta-synthesis method which is called thematic content analysis (Walsh and Downe 2005). Calik and Sozbilir (2014) classified the content analysis into three categories: meta-synthesis, meta-analysis, and descriptive content analysis. Thematic content analysis is a useful tool for identifying, analyzing and reporting themes in detail (Braun and Clark 2006). Meta-synthesis is a critical review of different studies conducted on the same subject, and the summary of its results (Calik and Sozbilir 2014; Higgns 2016).

The Population and Sample of This Study

The study population included 145 free journals which were published in the field of physical sciences education in Turkey, and full texts of which are accessible in Istanbul University Library online. The researchers examined these journals from their first issue to April 2016. To access the articles selected for the sample on the websites of the journals, the researcher used these keywords: *scale, scale adaptation, physical sciences, Turkish form, adapting to Turkish, scale adaptation study, adaptation of scale to Turkish, study for adaptation to Turkish, creating a Turkish form, physics, chemistry, biology, physical sciences, science, teacher, pre-service teacher, primary school, secondary school, high school* and *university students*.

The content analysis found 25 journals containing 46 scale adaptation studies. The journals including the adaptation studies that were analyzed in context of this study were categorized as ULAKBIM (Turkish Academic Network and Information Center), EBSCO, ERIC, SSCI and other indices (Table 1) before examination. In this examination, the indices DOAJ, ACARINDEX, ASOS, OAJI, DRJI, Arastirmax, SIS, IBSS, Web of Science, ERA, Google Scholar and ISI were classified under the title of "other indices". Of the analyzed journals, 81 (46%) are scanned by ULAKBIM, 39 (22%) are scanned by EBSCO, 3 (2%) are scanned by SSCI, 8 (%5) are scanned by ERIC, and 44 (25%) are scanned by other indices.

Table 1. Population index

Indexing	Number of studies
SSCI	3 (%2)
ERIC	8 (%5)
ULAKBIM	81 (%46)
EBSCO	39 (%22)
Other	44 (%25)

*Some journals are scanned by multiple indices.

This study examined a total of 43 articles published in 25 journals which were selected from this population by using the criterion sampling method, one of the purposeful sampling methods (Table 2). Some of these articles include multiple scale adaptations. Thus, the sample of this study included 46 scale adaptation studies (see Appendix). According to Buyukozturk (2009), the units meeting the criteria which were determined by researchers considering the study objective are included in the sample in criterion sampling.

The inclusion criteria for articles:

1. Having been published until April 2016 without any restriction for the initial date,
2. Having been scanned by SSCI, EBSCO, ERIC or other indices in the field of education,
3. Having Turkish origin,
4. Being free of charge,
5. Providing online access to the full manuscript of the articles in the journal,
6. Presence of a scale adaptation study that is conducted in relation with them,
7. Being included in any of physics, chemistry, biology and science teaching areas,
8. Having been conducted with a sample including pre-school, primary school, middle school, high school or university students.

Table 2. Information of journals which comprised the study sample

	Journal Name	First Issue (Year)	Last Issue (Year)	Indexing	Number of adaptation studies	
					Year	**Number of studies**
1	Bilgisayar ve Eğitim Araştırmaları Dergisi	2013	2016	ULAKBIM	2013	1
2	Buca Eğitim Fakültesi Dergisi	1994	2015	EBSCO	2010	1
3	Eğitim Bilimleri ve Uygulama	2002	2014	EBSCO	2002	1
					2003	1
4	Eğitim ve Bilim	1976	2016	ULAKBIM	2005	1
					2013	1
					2014	1
5	Eğitimde Kuram ve Uygulama	2005	2016	EBSCO	2016	1
6	Erzincan Üniversitesi Eğitim Fakültesi	2002	2015	ULAKBIM	2013	2
				EBSCO	2015	1
7	Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi	2000	2015	ULAKBIM	2011	1
8	Gazi Üniversitesi Eğitim Fakültesi Dergisi	1985	2015	ULAKBIM	2013	1
9	Hacettepe Üniversitesi Eğitim Fakültesi Dergisi	1986	2016	ULAKBIM	2004	1
				EBSCO	2007	1
10	International Journal of Assessment Tools in Education	2014	2016	Other	2015	1
11	International Journal of Human Sciences	2004	2016	ULAKBIM EBSCO	2016	2
12	İlköğretim Online	2002	2016	ULAKBIM	2007	1
				EBSCO	2013	1
					2014	2
					2015	2
13	İnönü Üniversitesi Eğitim Fakültesi Dergisi	2007	2016	ULAKBIM EBSCO	2010	1
14	Kırşehir Eğitim Fakültesi Dergisi	2000	2016	ULAKBIM	2009	1
					2013	2
15	Kuram ve Uygulamada Eğitim Bilimleri	2001	2016	ULAKBIM	2004	1
				EBSCO	2005	1
				SSCI ERIC	2011	1
16	Kuram ve Uygulamada Eğitim Yönetimi	1995	2016	ULAKBIM	2008	1
17	Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi	2011	2015	ULAKBIM	2015	1
18	Milli Eğitim Dergisi	1971	2015	ULAKBIM	2002	1
					2013	1
19	Pegem Eğitim ve Öğretim Dergisi	2011	2016	Other	2015	1
20	Trakya Üniversitesi Eğitim Fakültesi Dergisi	2011	2016	ULAKBIM	2013	1
21	Turkish Journal of Education (TURJE)	2012	2016	ULAKBIM	2013	1
22	Turkish Studies	2006	2016	ULAKBIM EBSCO	2015	1
23	Türk Eğitim Bilimleri Dergisi	2003	2014	Other	2009	1
24	Türk Fen Eğitimi Dergisi	2004	2015	ULAKBIM	2010	1
				EBSCO	2011	1
					2012	1
					2013	1
					2014	1
25	Uşak Üniversitesi Sosyal Bilimler Dergisi	2008	2016	ULAKBIM	2012	1
					Total	**46**

Data Collection Tool

Articles meeting the inclusion criteria were analyzed using three forms which were developed by researchers: “Sample Analysis Table” (Table 3), “Scale Information” (Table 4) and “The Analyses Performed after the Pilot Study” (Table 5). Final versions of these forms were included in the study after the researchers consulted educational measurement experts for their opinions. The creation of these forms is important for the study in terms of meeting the validity and reliability criteria (Buyukozturk 2009). These forms allowed the researchers to standardize the process and carry out an evaluation according to the same criteria.

Table 3. Sample analysis table

Scale	Sample																	
	Elem. sch. (1-4 grades)	Middle school (5-8grade)	High school (9-12 grade)	Pre-service teachers				In-service teachers				Other	Number of sample					
				Science	Physics	Chemistry	Biology	Science	Physics	Chemistry	Biology		0-200	201-400	401-600	601-800	801-1000	1001 and above
Scale-1																		
Scale-2																		
Scale-3																		

Table 4. Scale information

Scales	Scale								Publication yera	Scale type						Number of item		Reliability coefficient	
										Likert				Multiple choices	Dichatomic				
	Attitude	Self-efficacy	Anxiety	Motivation	Interest	Perception	Epistemological beliefs	Other		4	5	7	9			Orginal scale	Adapted scale	Orginal scale	Adapted scale
Scale-1																			
Scale-2																			
Scale-3 . . .																			

Table 5. The analyses performed after the pilot study

	Suitability of factor analysis		Item discrimination		Reliabilty					Validity				
	KMO	Barlett	27% sub-above group	Total item correlation	Cronbach Alpha	KR 20/21				CFA	EFA		Concurrent	Predictive
Scale					Internal consistency coefficient		Split- half	Test re-test	Paralel forms	Construct		Content	Criterion	
Scale -1														
Scale -2														
Scale -3														

Data Analysis

The data obtained in this study were analyzed considering the following steps (Sandelowski and Barroso 2007):

1. Designing the synthesis. In this step, the study designs a unique meta-synthesis which will be able to fill a gap in the literature. This meta-synthesis study revealed the purpose and the study question after conducting a literature review on whether there are similar studies.

2. Deciding what is important and necessary for synthesis. In this step, researchers determine the way to collect the studies that are needed for meta-synthesis. This study revealed the study population, keywords and inclusion criteria after the researchers' meticulous assessments.

3. Inclusion of studies. In this step, studies to be included in the meta-synthesis are critically analyzed, and the studies to be included in the meta-synthesis are determined. Of the adaptation studies which were accessed using the chosen keywords in this study, 46 adaptation studies meeting the inclusion criteria were included in the meta-synthesis.

4. Determining the relations of the studies with each other. In this stage, the similarities and differences of the studies included in the meta-synthesis are demonstrated. In this study, the studies included in the meta-synthesis were analyzed using three forms: Sample Analysis Table, Scale Information and the Analyses Performed after Pilot Study.

5. Creating a qualitative meta-synthesis. In this step, an inductive method is followed and the similarities of the studies are combined. This study examined and summarized the data collected with the three forms as data collection tools.

6. Expressing and presenting meta-synthesis. In this step, interpretive explanations of the results, which were achieved as a result of the meta-synthesis, are asserted. This study's findings were associated with the literature, and it was revealed which steps should be taken regarding the scale adaptation process.

To conduct a valid and reliable meta-synthesis study, it is required for the researchers to objectively report the methods followed in the study to the readers, to express inclusion criteria clearly, to include at least 10 studies, selected using the purposeful sampling method, in the meta-synthesis and to examine each of the studies without disrupting the integrity. In this way, the cogency of the study is strengthened (Sandelowski, Docherty and Emden 1997). In this study, the researchers expressed all steps followed in the whole meta-synthesis process in detail, and a total of 46 studies included in the meta-synthesis were objectively analyzed.

Results

This study analyzed articles included in the meta-synthesis method within the scope of the research questions. Initially, content analyses were performed on the articles, which were analyzed for the first study question, by using the “Sample Analysis Table” and “Scale Information” forms. Data obtained are explained below:

Area of Scale

This study assessed adaptation scales in 8 different areas: attitude, self-efficacy, anxiety, motivation, interest, perception, epistemological belief and other areas. In this study, learning environment, competence, distinction between science and pseudoscience, self-regulation, cognitive evaluation, scientific creativity, behavior, learning styles, student assessment in the period of education, argumentation, learning engagement in science, motivation and learning strategies, constructivist thinking, sense of learning and teaching, teacher competence and engagement to integrative STEM teaching areas are discussed as “other areas”. As a result of the analysis performed, it was determined that 8 (17%) adaptation studies were in the attitude area, 10 (22%) adaptation studies were in the self-efficacy area, 6 (13%) adaptation studies were in the motivation area, 4 (9%) adaptation studies were in the perception area, 5 (11%) adaptation studies were in the epistemological belief area, 2 (4%) adaptation studies were in the engagement area, and 11 (24%) adaptation studies were in the other areas. No studies in the area of interest have been encountered. Moreover, there is no scale adaptation study about anxiety.

Publishing Year

The analysis which was performed according to publishing years found that there were 1 (2%), 1 (2%), 3 (7%), 2 (4%), 2 (4%), 1 (2%), 2 (4%), 3 (7%), 3 (7%), 2 (4%), 13 (28%), 3 (7%), 7 (15%) and 3 (7%) adaptation studies in 2002, 2003, 2004, 2005, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015 and in April 2016, respectively (Figure 1).

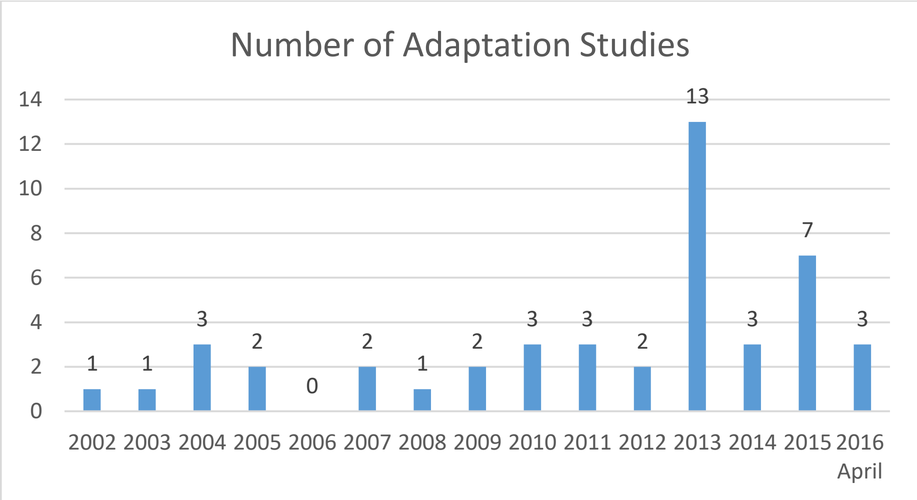

Figure 1. Adaptation studies by year

Type of Scale

Adaptation scales were analyzed under three categories: likert, multiple choice, dichotomous (two-option). Likert-type scales were analyzed under five sub-categories: 4-point, 5-point, 6-point, 7-point, and 9-point. As a result of this analysis, it was found that there were three 4-point likert-type adaptation studies, 29 5-point likert-type adaptation studies, one 6-point likert-type adaptation study and seven 7-point likert-type adaptation studies. There were no adaptation study under the categories of 9-point likert scale and multiple choice. However, a total of four adaptation scales were included in the category of yes-no. The researchers also determined that one study did not mention the type of the scale.

Number of Items

According to number of items, the adaptation scales were examined under two categories: number of items in the original scale and number of items in the adapted version. After this examination, it was found that three studies did not mention number of items in the original scale, and two studies did not mention number of items in the adapted scale. The researchers determined that there was a decrease in number of items in 26 studies

General Reliability Coefficient

According to general reliability coefficients, the adaptation scales were examined under two categories: reliability coefficient of the original scale and reliability coefficient of the adapted version. According to the analysis results, the researchers did not determine any reliability coefficient regarding the original scale in 39 studies, while 7 studies stated the reliability coefficient of the original scale. Moreover, it was determined that the reliability coefficient of the original scale was not included in 6 studies; therefore, the reliability coefficient of 40 adapted scales was accessed. It was determined that the reliability coefficients of the adapted scales in which the (original version) reliability coefficient took place differed between 0.81 and 0.96. It was also determined that, of the seven studies which gave both the original and the adapted scales' reliability coefficients, as a result of adaptation, five studies experienced a decrease in the reliability coefficient, one experienced an increase in the reliability coefficient, and there was no change in one study. It was found that the reliability coefficients of the adapted scales were calculated between 0.71 and 0.94.

Sample Level and Number of Samples

The sample level was categorized as primary school (1-4th grade), middle school (5-8th grade) and high school (9-12th grade) students, pre-service teachers and in-service teachers. Some studies used more than one study sample (for example, using teachers and teacher candidates together). The researchers did not encounter any adaptation study having a sample at the primary school level. A total of 10 and 8 adaptation studies were determined at the middle and high school levels, respectively. Pre-service teachers were classified to be physical sciences, physics, chemistry and biology. A total of 20, 3, 5, and 5 studies were adapted for teachers in the field of physical sciences, physics, chemistry, and biology, respectively. In-service teachers were selected as a sample in 7 studies. Some parts of the examined articles adapted the scale for more than one sample level (Figure 2).

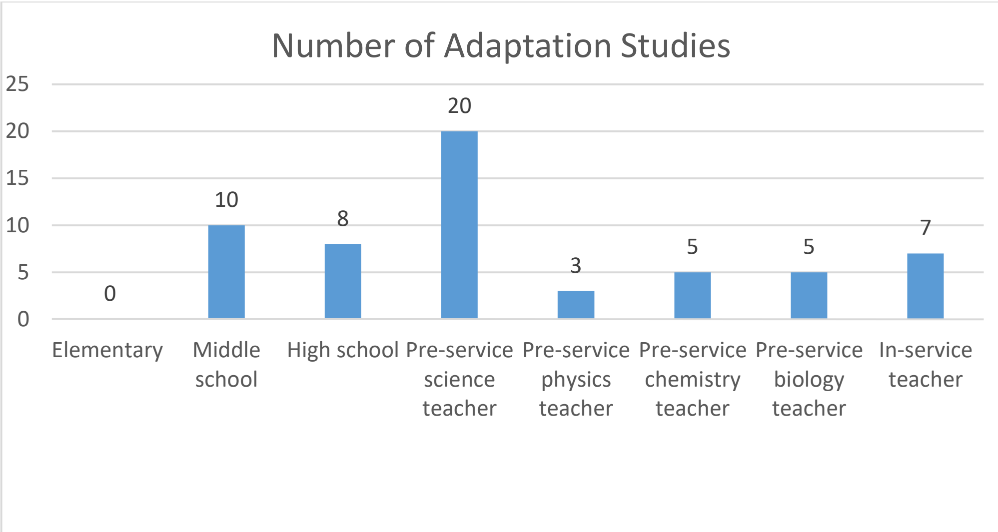

Figure 2. Adaptation studies by sample level

According to sample sizes, adaptation studies were examined under six categories: 0 to 200, 201 to 400, 401 to 600, 601 to 800, 801 to 1000 and 1000 and over. As a result of this examination, it was found that there were 4 (9%), 20 (43%), 11 (24%), 5 (11%), 2 (4%), and 4 (9%) adaptation studies including 0 to 200, 201 to 400, 401 to 600, 601 to 800, 801 to 1000, and 1000 and over respectively. The researchers determined that studies including the number of items of the Turkish form of the scale (44 studies) had seven or more times the sample size for the pilot study (Figure 3).

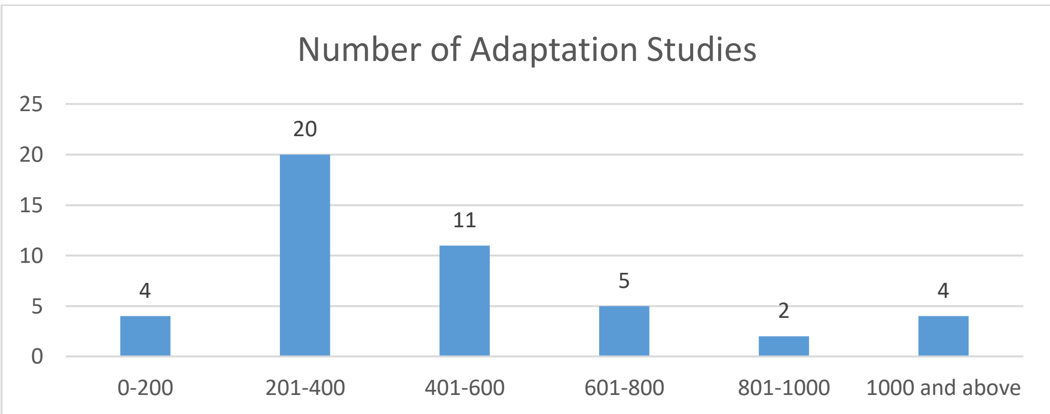

Figure 3. Adaptation studies by sample size

The content analyses were performed on the adaptation articles, which were analyzed within the scope of the second research question, using the “Analyses Performed after the Pilot Study” form. The collected findings are explained below:

For all of the analyzed adaptation studies, the Cronbach's alpha was calculated as an internal consistency coefficient for reliability. Only two (2) studies calculated both the KR-20 and Cronbach's alpha value. The test-retest and split-half reliability methods were calculated in only 15% of studies. Of the 46 studies included in this study, only 28 performed the CFA. The number of studies in which the EFA and CFA analyses were used together was 18. Of the analyzed studies, 5 performed only the EFA and did not perform the CFA. Moreover, 10 studies performed only the CFA and did not perform the EFA. In 8 studies, the validity analysis was not mentioned; it was only stated that the factor analysis was performed (Table 6). It was determined that the KMO and Barlett values were not given in more than 50% of the analyzed studies.

Table 6. Statistical analyses after the pilot study

Statistical Analysis			f
KMO			21
Bartlett			21
Item discrimination	27% sub-above groups		18
	Item correlation		31
Validity	Construct	CFA	10
		EFA	5
		CFA+EFA	18
		Unknown	8
	Criterion	Concurrent	2
		Predictive	0
		Unknown	3
	Content		
	Internal Coefficient	Alpha	46
Reliability		KR-20/21	2
	Split-half		7
	Test re-test		8

The adaptation articles that were examined in framework of the third research question were analyzed in three stages (Table 7). Here are the findings derived from these analyses:

1. Preparation for the adaptation study
    - Determining the need,
    - Selected the scale to be translated,
    - Obtaining the permissions required for the adaptation study,
    - Forming the translation team.

2. Language validity
    - Translating scale items from the original language to Turkish,
    - Translating scale instructions from the original language to Turkish,
    - Analyzing and comparing the translations,
    - Conducting a backward translation,
    - Giving its first form to the scale translated to Turkish,
    - Implementing the language validity,
    - Performing statistical analysis for the language validity,
    - Giving its first form to the scale of which the language validity is performed.

3. Pilot study

- Obtaining the permissions required for the pilot study,
- Conducting the pilot study,
- Performing a statistical analysis after the pilot study,
- Attaching the final version of the scale to the article.

Table 7. Analysis of the stages in adaptation studies

Stages		**Yes f**	**No f**
Preparation for the adaptation study	Determining the need	**46**	0
	Selecting the scale to be translated	**46**	0
	Obtaining the permissions required for the adaptation study	**34**	12
	Forming the translation team.	**46**	0
Language validity	Translating scale items from the original language to Turkish	**46**	0
	Translating scale instructions from the original language to Turkish	**0**	46
	Analyzing and comparing the translations	**46**	0
	Conducting a backward translation	**32**	14
	Giving its first form to the scale translated to Turkish	**46**	0
	Implementing the language validity	**20**	26
	Performing statistical analysis for the language validity	**19**	27
	Giving its first form to the scale of which the language validity is performed	**46**	0
Pilot study	Obtaining the permissions required for the pilot study,	**0**	46
	Conducting the pilot study	**46**	0
	Performing a statistical analysis after the pilot study	**46**	0
	Attaching the final version of the scale to the article.	**24**	22

Preparation for the Adaptation Study

This stage was assessed in four aspects. Determining the need, selecting the scale to be translated and forming the translation team were performed for all studies. However, 74% of the studies reported the stage of obtaining the necessary permissions, one of the most important stages to initiate an adaptation study, and 26% did not obtain these permissions.

Language Validity

Translating scale items from the original language to Turkish, performing language consistency (analyzing and comparing translations), giving its first form to the translated test, and giving its first form to the scale of which the language validity is performed were available in all studies. Of the studies, 70% did a backward translation. In terms of language validity, 43% of the analyzed studies were carried out in philology or English language teaching departments that have a command of both languages. Of the adaptation studies which were analyzed, 41% performed a statistical analysis for the language validity. No studies mentioned the translation of the instructions.

Pilot Study

No studies mentioned obtaining permission for the pilot study. All studies conducted a pilot study and performed statistical analyses for it. Only 52% of studies included the original scale.

Discussion and Conclusion

In this study, the analyzed adaptation studies were examined in three stages. Firstly, "scale information" were revealed in all of the analyzed studies. Areas of the scales, publishing dates, types, number of items included and general reliability coefficients were determined. Then, *sample analyses* were performed on the analyzed articles. In this way, sample size and sample type were determined. Finally, the method followed by each study was analyzed after the pilot study.

This study found that adaptation studies are mostly conducted in the self-efficacy area. As it was reported in the studies of Karaca et al. (2008), Boztunc - Ozturk, Eroglu and Kelecioglu (2015), Delice and Ergene (2015) and Gul and Sozbilir (2015b), this study found that the internal consistency coefficients were calculated in all examined studies. It was seen that the likert type was used significantly more than the dicothomic scales. While the Cronbach's alpha value was calculated for reliability in the likert-type scales, the dichotomous scales calculated KR-20/21 for reliability (Secer 2015). In four studies determined as dichotomous, two calculated the KR-20 and Cronbach's alpha together although the KR-20 value should be calculated as a reliability coefficient. However, the other two studies only calculated the Cronbach's alpha value, but did not calculate the KR-20 value. This showed that some researchers did not have sufficient statistical information on internal consistency calculations. This study determined that there were no significant differences between the internal consistency coefficients of the original scale and the adapted scale. It was found that some items were excluded from the scale as a result of the adaptation study, while no items were added to the scales in the adaptation studies. These findings are mainly consistent with the studies of Boztunc-Ozturk et al. (2015).

This study showed that pre-service physical sciences teachers were selected as a sample level in the adaptation studies, and no sample at the primary school level was used. Moreover, it was found that the sample size was at least 7 times or bigger than the number of items. It was determined that the researchers exercised due diligence regarding this issue. However, Delice and Ergene (2015) reported that some studies which they analyzed had a deficient sample size while it is supposed to be five times bigger than the number of items.

According to the analysis performed by the publishing date, it was found that the first adaptation study was conducted in the field of physical sciences in 2012. In Turkey, teacher training programs were reformed as a 4-year program by the Council of Higher Education (YOK) in 1989. Gazi and Ege Universities' Education Faculties began to train physical sciences teachers in 1992. Between the years of 1992 and 1998, these faculties trained physical science teachers according to the curricula that they prepared. In the 1998 – 1999 academic year, courses and their content followed in the faculties of education were reviewed, and the prepared physical science teaching curricula was sent to other faculties (Kizilcaoglu 2006; Meric and Tezcan 2005). Therefore, scale adaptation and development studies in the field of physical sciences education began to be conducted after the 2000s. While only 2 adaptations of articles were conducted before 2004, there were no adaptation scales in 2006. In 2013 and 2015, the number of adaptations of article studies increased dramatically.

As a result of the analysis, which was performed to determine the stages followed in adaptation studies, this study found that these studies gathered under three main headings of "preparation for the adaptation study", "language validity" and "pilot study". The "preparation for the adaptation study" stage includes determining the needs, selecting the scale to be translated, obtaining the necessary permissions and forming the translation team. This study determined that all analyzed studies had steps of determining the needs, selecting the scale and forming the translation team. However, some studies did not obtain permission from the developers of the original scale. Similarly, Cum and Koc (2013) reported in their studies that half of the researchers did not obtain permission for adaptation of the scale.

The literature has stated that the most important issue is "validity of language" while adapting the scale (Delice and Ergene 2015; Tsagari and Floros 2013). Backward translation, the most important step in determining the validity of the language, and the examination of an expert team who makes this translation have been frequently emphasized in the literature (Cha et al. 2007; Grisay 2000; Maxwell 1996; Tsagari and Floros 2013). This study determined that the analyzed adaptation studies did not mention this stage sufficiently, it was discussed superficially, and even 14 adaptation studies (30% of the adaptation studies) did not give detailed information about the backward translation. The fact that the pilot study stage, which is required to be performed on a group having a command of both two languages and cultures for the validity of the language, was determined in only 20 of the adaptation studies (43% of the analyzed studies) is an indicator that in Turkey, researchers do not give due importance and sensitivity to the validity of the language. Savasir (1994) reported that less than half of the 33 scale adaptation studies published in the Journal of Psychology and the Turkish Journal of Psychiatry did not give information about the translation; other studies mentioned this issue only briefly. Cum and Koc (2013), Delice and Ergene (2015), Guvendir and Ozkan (2015) examined adaptation studies and found that the studies did not form an expert group having a command of both languages and cultures for the validity of the language. Being largely in agreement with the study of Guvendir and Ozkan (2015), the present study determined that no researcher adapted the instructions to the target language.

The last stage of the adaptation studies, the "pilot study", was available in all analyzed studies. This study concluded that all studies did not obtain relevant official permissions for the pilot study. Similarly, Delice and Ergene (2015) reported that more than half of the adaptation studies did not obtain necessary permissions. While it is commonly preferred by the researchers to perform only the CFA analyses in scale adaptation studies, there are studies in the literature where both analysis methods were preferred (Atilgan 2015). At the end of this study, being largely in agreement with the studies of Boztunc-Ozturk et al. (2015), it was determined that researchers preferred to use the EFA and CFA methods together. Guvendir and Ozkan (2015), Cum and Koc (2013) found in their studies that the researchers preferred the EFA method to the CFA method.
A study of Boztunc-Ozturk et al. (2014) determined that adaptation studies generally did not examine the scale validity. Similarly, the present study also found that the researchers calculated the construct validity, but did not perform the analyses required for the scale validity. It was observed that more than half of the studies gave the adapted scale together with the article.

Similarly; Tavsancil, Guler and Ayan (2014) examined adaptation studies conducted in the field of education in Turkey. They determined that most of the followed steps had wrong and incomplete information. Cum and Koc (2013) also examined adaptation studies and reported that the followed steps in these studies were inappropriate. Therefore, researchers who will conduct an adaptation study should have basic statistical skills, and studies should be conducted according to test development stages which are nationally/internationally determined. These will help future adaptation studies be more productive.

Limitations of this study include focusing on only scale adaptation studies in the field of science education published in the journals and excluding Master and PhD Theses. Especially in Turkey, becoming very popular to develop or adapt a scale for Master and PhD theses. Therefore, future studies could be focus on detailed examinations of these theses in terms of scale adaptation and scale development studies in the field of science, mathematics and technology education.

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Appendix. List of Adaptation Studies

Scale-1	Yılmaz, M., Gürçay, D., & Ekici, G. (2007). Akademik Özyeterlik Ölçeğinin Türkçe'ye Uyarlanması. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 33,* 253-259.
Scale -2	Yılmaz, M., Köseoğlu, P., Gerçek, C., & Soran, H. (2004). Yabancı Dilde Hazırlanan Bir Öğretmen Öz-Yeterlik Ölçeğinin Türkçeye Uygulanması. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 27,* 260-267.
Scale -3	Yapalak, S., & Ilgaz, G. (2013). The Adaptation Of "Attitudes Toward Research (ATR)" Scale İnto Turkish. *Journal Of Kirsehir Education Faculty, 14*(2), 79-90.
Ölçek-4	Tosun, C., Şenocak, E., & Taşkesenligil, Y. (2009). Endüstriyel Kimya Dersi Öğrenme Ortamı Ölçeğinin Türkçeye Uyarlanması Çalışması. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 10*(2), 111-117.
Scale -5	Özel, M., Timur, B., Timur, S., & Bilen, K. (2013). Öğretim Elemanlarının Pedagojik Alan Bilgilerini Değerlendirme Anketinin Türkçeye Uyarlanması Çalışması. *Journal Of Kirsehir Education Faculty, 14*(1), 407-428.
Scale -6	Dindar, A. Ç., & Geban, Ö. (2015). Fen Bilimleri Motivasyon Ölçeğinin Türkçe'ye ve Kimya'ya Uyarlanması: Geçerlilik Çalışması. *Pegem Eğitim ve Öğretim Dergisi, 5*(1), 15-34.
Scale -7	Çetinkaya, E. K., Şimşek, C. L., & Çalışkan, H. (2013). Bilim ve Sözde-Bilim Ayrımı İçin Bir Ölçek Uyarlama Çalışması. *Trakya Üniversitesi Eğitim Fakültesi Dergisi, 3*(2), 31-43.
Scale -8	Aydın, S., Keskin, M. Ö., & Yel, M. (2015). Öz-Düzenleme Ölçeğinin Türkçe Uyarlaması: Geçerlik ve Güvenirlik Çalışması. *Turkish Journal Of Education, 3*(1), 24-33.
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Scale -10	Çeliker, H. D., & Balım, A. G. (2012). Bilimsel Yaratıcılık Ölçeğinin Türkçeye Uyarlama Süreci ve Değerlendirme Ölçütleri. *Uşak Üniversitesi Sosyal Bilimler Dergisi, 5*(2), 1-21.
Scale -11	Deryakulu, D., & Bıkmaz, H. F. (2003). Bilimsel Epistemolojik İnançlar Ölçeğinin Geçerlik ve Güvenirlik Çalışması. *Eğitim Bilimleri ve Uygulama, 2*(4), 243-257.
Scale -12	Timur, S., & Yılmaz, M. (2013). Çevre Davranış Ölçeğinin Türkçe'ye Uyarlanması. *Gazi Üniversitesi Gazi Eğitim Fakültesi Dergisi, 33*(2), 317-333.
Scale -13	Totan, T., İkiz, E., & Karaca, R. (2010). Duygusal Öz-Yeterlik Ölçeğinin Türkçeye Uyarlanarak Tek ve Dört Faktörlü Yapısının Psikometrik Özelliklerinin İncelenmesi. *Buca Eğitim Fakültesi Dergisi, 28,* 71-95.
Scale -14	Candan, D. G., & Gencel, İ. E. (2015). Öğretme Motivasyonu Ölçeği'nin Türkçe'ye Uyarlama Çalışması. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi, 1*(36), 72-89.
Scale -15	Yapıcı, İ. Ü., & Hevedanlı, M. (2013). Biyoloji Öğretiminde BİT Kullanımı Tutum Ölçeğinin Türkçeye Uyarlanması: Geçerlik ve Güvenirlik Çalışması. *Journal Of Computer And Education Research, 1*(2), 21-37.
Scale -16	Aypay, A. (2010). General Self-Efficacy (GSE) Scale To Turkish. *Inonu Unıversıty Journal Of The Faculty Of Educatıon, 11*(2), 113-131.
Scale -17	Tosun, C. (2013). Kimya Motivasyon Ölçeği-II'nin Türkçe'ye Uyarlanması: Geçerlik ve Güvenirlik Çalışması. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 15*(1), 173-202.
Scale -18	Tosun, C. (2013). Kimya Motivasyon Ölçeği-II'nin Türkçe'ye Uyarlanması: Geçerlik ve Güvenirlik Çalışması. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 15*(1), 173-202.
Scale -19	Tosun, C., & Şekerci, A. R. (2015). Sekizinci Sınıf Öğrencilerinin Fen Derslerine Karşı Öz Düzenleme Becerilerinde Motivasyonun Rolü. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 17*(1), 1-29.
Scale -20	Arhan, S., Gültekin, İ. (2013). Türkçe Dersi İlköğretim Programlarında Benimsenen Tematik Yaklaşımın Metin Seçimine Etkileri Yönünden Değerlendirilmesi. *Milli Eğitim Dergisi, 119.*
Scale -21	Aypay, A. (2011). Epistemolojik İnançlar Ölçeğinin Türkiye Uyarlaması ve Öğretmen Adaylarının Epistemolojik İnançlarının İncelenmesi. *Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi, 12*(1), 1-15.
Scale -22	Hazır-Bıkmaz, F. (2004). Sınıf Öğretmenlerinin Fen Öğretiminde Öz Yeterlilik İnancı Ölçeğinin Geçerlik ve Güvenirlik Çalışması. *Milli Eğitim Dergisi, 161.*
Scale-23	Bıkmaz, F. H. (2002). Fen Öğretiminde Öz-Yeterlik İnancı Ölçeği. *Eğitim Bilimleri ve Uygulama, 1*(2), 197-210.
Scale -24	Çapa, Y., Çakıroğlu, J., & Sarıkaya, H. (2005). Öğretmen Özyeterlik Ölçeği Türkçe Uyarlamasının Geçerlik ve Güvenirlik Çalışması. *Eğitim ve Bilim, 137*(30), 74-81.
Scale -25	Özgüngör, S. (2013). Eğitim Süreci Öğrenci Değerlendirmeleri Ölçeği'nin Türkçeye Uyarlama

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Scale -26	Buldur, S., & Doğan, A. (2014). Fen ve Teknoloji Dersinde Öğrencilerin Sınıf-İçi Değerlendirme Ortamına İlişkin Algıları Ölçeğinin Türkçeye Uyarlanması. *Eğitim ve Bilim, 176*(39), 199-211.
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Scale -28	Çapa-Aydın, Y., Uzuntiryaki-Kondakçı, E., Temli, Y., & Tarkın, A. (2013). Adaptation Of Sources Of Self-Efficacy İnventory İnto Turkish. *Elementary Education Online, 12*(3), 749-758.
Scale -29	Kaya, E., Cetin, P. S., & Erduran, S. (2014). Adaptation Of Two Argumentation Tests İnto Turkish. *Elementary Education Online, 13*(3), 1014-1032.
Scale -30	Kaya, E., Cetin, P. S., & Erduran, S. (2014). Adaptation Of Two Argumentation Tests İnto Turkish. *Elementary Education Online, 13*(3), 1014-1032.
Scale -31	Tosun, C., & Genç, M. (2015). Adaptation Of Science Attitude Scale Developed For Elementary School Students To Turkish: Validity and Reliability Study. *Elementary Education Online, 14*(3), 946-960.
Scale -32	Yetişir, M. İ., & Ceylan, E. (2015). The Adaptation Of Students' Adaptive Learning Engagement İn Science Scale İnto Turkish. *Elementary Education Online, 14*(2), 657-670.
Scale -33	Bayar, A., & Karamustafaoğlu, O. (2015). The Colorado Learning Attitudes About Science Survey (CLASS): The Study Of Validity and Reliability. *International Journal Of Assessment Tools İn Education (IJATE), 2*(1), 40-57.
Scale -34	Büyüköztürk, Ş., Akgün, Ö. E., Kahveci, Ö., & Demirel, F. (2004). Güdülenme ve Öğrenme Stratejileri Ölçeğinin Türkçe Formunun Geçerlik ve Güvenirlik Çalışması. *Kuram ve Uygulamada Eğitim Bilimleri, 4*(2), 207-239.
Scale -35	Tosun, Ü., & Karadağ, E. (2008). Yapılandırmacı Düşünme Envanterinin Türkçeye Uyarlanması Dil Geçerliği ve Psikometrik İncelemesi. *Kuram ve Uygulamada Eğitim Bilimleri, 8*(1), 225-264.
Scale -36	Aypay, A. (2011). Öğretme ve Öğrenme Anlayışları Ölçeği'nin Türkiye Uyarlaması ve Epistemolojik İnançlar İle Öğretme ve Öğrenme Anlayışları Arasındaki İlişkiler. *Kuram ve Uygulamada Eğitim Bilimleri, 11*(1), 7-29.
Scale -37	Baloğlu, N., & Karadağ, E. (2008). Öğretmen Yetkinliğinin Tarihsel Gelişimi ve Ohio Öğretmen Yetkinlik Ölçeği: Türk Kültürüne Uyarlama, Dil Geçerliği ve Faktör Yapısının İncelenmesi. *Kuram ve Uygulamada Eğitim Yönetimi, 56*, 571-606.
Scale -38	Acat, M. B., Tüken, G., & Karadağ, E. (2010). Bilimsel Epistemolojik İnançlar Ölçeği: Türk Kültürüne Uyarlama, Dil Geçerliği ve Faktör Yapısının İncelenmesi. *Türk Fen Eğitimi Dergisi, 7*(4), 67-89.
Scale -39	Şenocak, E. (2011). Kimya Dersi Tutum Ölçeğinin Türkçeye Uyarlanması Çalışması. *Türk Fen Eğitimi Dergisi, 8*(2), 114-129.
Scale -40	Bilici, S. C., Armağan, F. Ö., Çakır, N. K., & Yürük, N. (2012). Astronomi Tutum Ölçeğinin Türkçe'ye Uyarlanması: Geçerlik ve Güvenirlik Çalışması. *Journal Of Turkish Science Education, 9*(2), 116-127.
Scale -41	Timur, B., & Taşar, M. F. (2013). Fen Öğretiminde Bilgisayar Kullanımına Yönelik Öz Yeterlik İnancı Ölçeğinin Türkçe'ye Uyarlanması. *Türk Fen Eğitimi Dergisi, 10*(3), 59-72.
Scale -42	Yaman, S., & Köksal, M. S. (2014). Fen Öğrenmede Zihinsel Risk Alma ve Yordayıcılarına İlişkin Algı Ölçeği Türkçe Formunun Uyarlanması: Geçerlik ve Güvenirlik Çalışması. *Journal Of Turkish Science Education, 11*(3), 119-142.
Scale -43	Yıldırım, B., & Selvi, M. (2015). Adaptatıon Of STEM Attıtude Scale To Turkish. *Electronic Turkish Studies, 10*(3), 1117-1130.
Scale -44	Gülhan, F., & Şahin, F. (2016). Fen-teknoloji-mühendislik-matematik entegrasyonunun (STEM) 5. Sınıf öğrencilerinin bu alanlarla ilgili algı ve tutumlarına etkisi. *İnternational Journal Of Human Science, 13*(1), 602-620.
Scale -45	Gülhan, F., & Şahin, F. (2016). Fen-teknoloji-mühendislik-matematik entegrasyonunun (STEM) 5. Sınıf öğrencilerinin bu alanlarla ilgili algı ve tutumlarına etkisi. *İnternational Journal Of Human Science, 13*(1), 602-620.
Scale -46	Hacıömeroğlu, G., & Bulut, A. S. (2016). Integrative STEM Teaching İntention Questionnaire: A Validity and Relaibility Study Of The Turkish Form. *Eğitimde Kuram ve Uygulama, 12*(3), 654-669.

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A Metaphor Analysis Study Related to STEM Subjects Based on Middle School Students' Perceptions

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Abstract

The aim of this study is to determine what metaphors seventh and eighth grade students have when they identify STEM subjects. For this purpose, a form was developed to provide students to write their own metaphors related to STEM subjects. Qualitative research method was used and this research was conducted as a phenomenological study. 94 seventh and eighth grade students participated in this study from two different middle schools, which are located in the center of Ankara, Turkey. Students were encouraged to write their metaphors to identify STEM subjects. It has been seen that both seventh and eighth grade students had complexity while they were identifying science and technology subjects. Students used technology metaphor eleven times while they identified science, and they used science metaphor five times while they identified technology. It has also been learnt from students' metaphors that students have not had enough information on math and engineering since the metaphors could not explain these subjects. It is recommended that some courses might be given to students within STEM subjects to provide them to learn those subjects.

Introduction

The scientific and technological developments have been changing many applications in our daily lives. We see these changes also in education systems. The number of planets, the number of elements and exploration a new element can be given as some changes that are carried out in both science and technology. Those mentioned changes cause some changes in engineering, as well. Within this context, it can be seen that changes affect many different disciplines especially science, technology, engineering and math. Because these four disciplines cannot be separated from each other. At this point, we have an approach which is called STEM Approach. National Research Council (1996) defines that STEM is an educational and teaching approach which integrates both the content and skills of science, technology, engineering and math. İdin (2017), states that STEM is an integration of science, technology, engineering and math which includes process between pre-school and higher education and it donates learners with 21st century skills. The content of STEM and the relationships of STEM's subjects are shown in a model that is given below. As it can be seen in the STEM Model that STEM subjects must foster

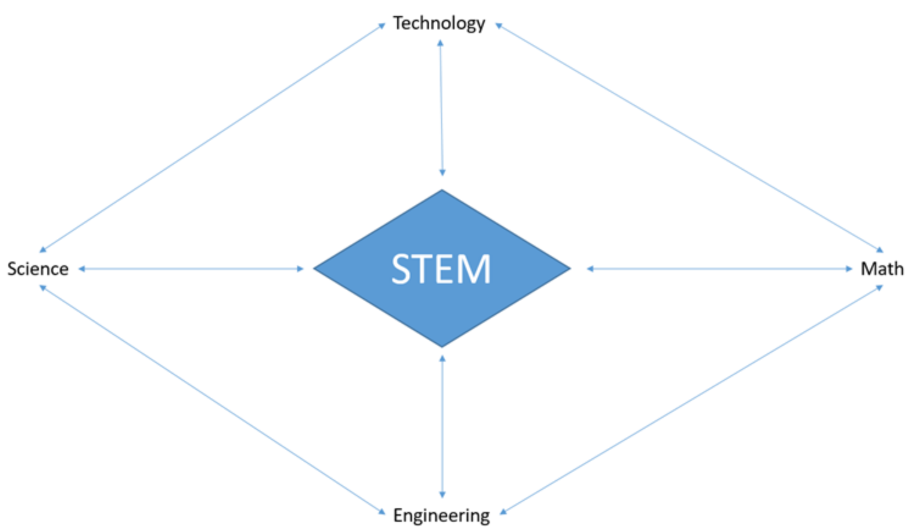

Figure 1. STEM model

to each other individually during whole educational process. For instance, science is relevant with technology and engineering and when this relevance combines with math STEM Approach is created. This means if a successful STEM Education is asked to create more attention should be paid to integration of all STEM's disciplines.

Another important point within STEM Education is why education system needs STEM Approach. We understand this from international studies such as, reports, articles, dissertations and others. According to World Economic Forum (2016), it is stated that technological drivers of change, "Mobile internet and cloud technology (34%), Advances in computing power and Big Data (26%), New energy supplies and Technologies (22%), The Internet of Things (14%), Advanced robotics and autonomous transport (9%), Artificial intelligence and machine learning (7%), Advanced manufacturing and 3D printing (6%), Advanced materials, biotechnology and genomics (6%). Another report created by TUSIAD (2016) points out that we are in Industry 4.0 so we will have new applications within Industry 4.0. Those mentioned Technologies of Industry 4.0 are given below.

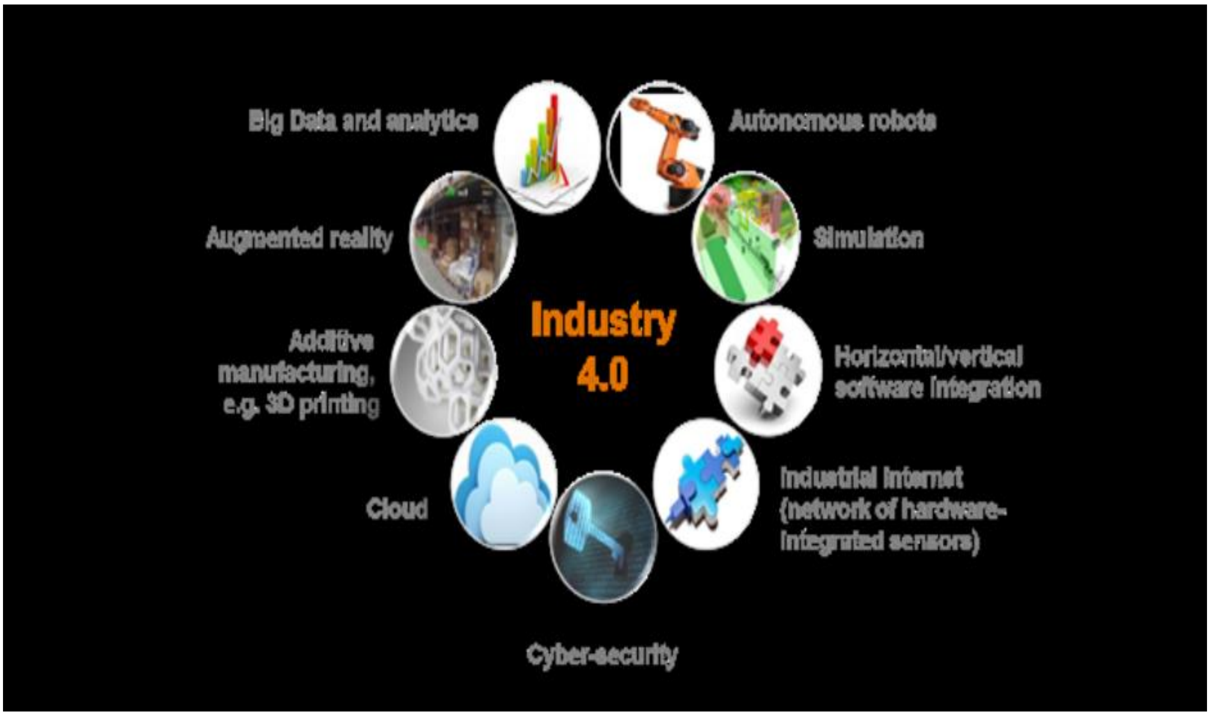

Figure 2. Technologies of industry 4.0

As it can be seen from the figure2 that the elements of Industry 4.0 are the cloud, additive manufacturing, augmented reality, big data and analytics, autonomous robots, simulation, horizontal vertical system integration, the industrial internet of things and cyber-security. Industry 4.0 has nine advanced technological products and already some of them have been used in manufacturing. It is seen that within Industry 4.0 new technological developments will be used in our daily lives.

We know that 21st century skills are paid attention to donate today's students for the future workforce. Beyond this, students should be done STEM literate people. A common definition of STEM literacy is to define, implement and integrate science, technology, engineering and mathematical concepts to solve complex problems and to renew them (Balka, 2011). To reach this aim, they should be educated under STEM Approach. To do this, 21st century skills can be given during whole the process. 21st century skills are collaborating, communication, critical thinking and creativity (The Partnership for 21st Century Skills, 2011). Besides, employability, innovation and team working can also be given as 21st century's skills (İdin, 2017). Those mentioned skills are significant because if a today's learner faces with a problem she/he can solve it and have some more option/options for solving the problem. To zoom in some of 21st century skills such as, creativity and innovation can be taken to have much more information why they are significant for the future people. Because it is expected there will be seen many new applications, which we will use, so we need to have some skills to control them all. STEM Education offers to have 21st century skills and before starting STEM Education we have to know our students' current information level of each STEM's disciplines. We will also be able to understand that these students' approximately knowledge level of 21st skills within STEM disciplines. When asked them on STEM's disciplines what they can say to tell them by using some metaphors. Because it cannot be so easy to tell STEM disciplines by using words directly. Metaphor is employed when one wants to explore and understand something esoteric, abstract, novel, or highly speculative. As a general rule, the more abstract or speculative it is, the greater the variety of metaphors needed to grapple with it (Yob, 2003). Metaphors are thought that they are easy to be determined students' knowledge of STEM disciplines.

At this point, it is important that to determine what studies have been carried out by using metaphors in STEM Education. It is also known that there are too many studies in STEM Education but there have been been found limited direct studies related to both metaphors and STEM Education. Because of this reason, researches thought to find some studies which are related to science, technology, math and engineering separately and education, as well. It has been found some studies within those mentioned fields of education. In his study Ogborn (1997), tried to learn what is valuable in constructivism for a pupil own thinking, and on the high priority needed for ideas taught to make sense to pupils, together with the reminder that science is a human product. Lın, Shein & Yang (2012), investigated how pre-service teachers view English as a Foreign Language (EFL) courses at the beginning of their teacher education programs by using metaphorical analysis. Erdogan, Yazlik, Erdik (2014), investigated mathematics teacher candidates' perceptions about the concept of "mathematics" through the use of metaphors. They found that 77% of mathematics teacher candidates perceived mathematics as "Limitless", "Interconnected", "Basically needed", "Fun", "Cumulative", "Indispensable" figure and as a figure which laid the "foundation for other sciences". Taylor and Haydon (2016), in their study, described the process of developing, testing, and refining an explanatory metaphor to communicate the science of resilience to the public and policymakers. Yee (2017), identified how students and teachers contextualize mathematical problem solving through their choice of metaphors.

However, there can be seen some studies related to both metaphors and STEM Education, as mentioned above. Roehrig, Wang, Moore & Park (2006), investigated the need for research to explore the translation of broad, national-level policy statements regarding STEM education and integration to state-level policies and implementation in K-12 classrooms. Pillat, Negendran & Lindgren (2012), described the development of Magnetic Resonance (MR) environment which could be used in teaching STEM subjects. They basically seeked to create a space for facilitating whole-body metaphors where learners use the physical movement and positioning of their entire bodies to enact their understanding of complex concepts. Cannady, Greenwald & Harris (2014), interrogated the appropriateness of the STEM pipeline as the dominant frame for understanding and making policies related to STEM career trajectories. Rappaport, Richter and Kennedy (2016), created a model for teaching STEM which enhanced students' choice to progress their career in STEM fields. Their model created anologies and metaphors for various STEM for career enhancement and these analogies and metaphors for some STEM topics used contents of popular music videos. Çalışıcı and Sümen (2018), investigated classroom teachers' perceptions of prospective classroom teachers on STEM Education by using metaphors. They conducted the study with 138 teachers and the teachers were firstly educated in STEM fields. Then a form was given them, the statement was constructed as "STEM Education is like ...because ... ", and they were asked to write their metaphor on STEM. Henriksen and Mishra (2018), think that educators have unclear information on STEAM so the unclear can be caused from "Art". To be able to solve the problem they focused in their study and also offer figurative language for framing STEM teaching and learning, illustrated in samples of metaphor.

Significance of the Study

It is understood that importance of STEM subjects has been increasing so that students could have 21st skills. STEM is an interdisciplinary approach to learning in which science, technology, engineering and mathematics that makes integration between school, community, work and global enterprise and the ability to compete in the new economy (Tsupros, Kohler, & Hallinen, 2009). In the Programme for International Student Assessment (PISA) 2015, asked questions are taken from daily life within STEM subjects. Within the scope of STEM Education, if a student faces any problem in his/her daily life he/she can solve the problem. PISA already asks this kind of questions to students and it is paid attention to learn students' answers on daily life problems. As we know that PISA focuses on daily life real complex problem. In PISA, it is expected that students can use their knowledge to solve PISA questions, which they learn in schools. To be able to solve a problem asked in PISA, students should donate themselves with critical thinking skills, team working, efficient communication, innovation, creativity. If not students are not able to respond some difficult questions, which are asked in PISA, we already know this from Turkish students' PISA scores which have been carried out till now. To illustrate this statement PISA 2015 scores can be given as an example. PISA 2015 science scores of Turkish students are under OECD science test average and Turkish students are not able to solve scientific and daily life problems (OECD, 2016). Turkish 4th grade students' science score (483) is under Trends in International Mathematics and Science Study (TIMSS) average (500), and 8th grade students' science score is 493 is under TIMSS science score (500). These indicators show us Turkish students have difficulty in STEM fields. Therefore, we decided to determine Turkish students' metaphors on STEM subjects. By this means, overarching qualitative data will be more easy to understand what can be done to enhance students' both achievement and understanding of STEM. The literature which is interested in both STEM Education and Metaphors has been studied but there have not been found any enough studies within those mentioned subjects. To be able to understand what kind of metaphors our students have in their minds the study was conducted. Because, both STEM's aims and metaphors can some deep information of the students' current situations of those disciplines. This gives us some chance to understand our students' level within their science, mathematics, engineering, and technology concepts. The study is thought that as a significant study so it is one of the study which based both STEM Education and metaphors.

Aim of the Study

The aim of this study is to determine what metaphors seventh and eighth grade students have when they identify STEM subjects.

Method

This section is seen accompanying some sub-chapters, research method of the study, participants of the study, data collection tool, data analyses and ethics of study.

Research Method

In this study, qualitative research method was used, and within this context this research was conducted as phenomenography study. To determine and understand the meaning of students' metaphors with regard to STEM subjects were used. Phenomenographic qualitative research method as describes by Marton (1981). The purpose of Phenomenography is to describe some variations of conception that students have some specific phenomenon. Patton (2002), metaphors can help researchers to make some connections between things they may know and things less familiar.

Participants of the Study

The study was conducted in two different public middle schools, which are located in Ankara, during 2016-2017education year spring term. The schools are in Keçiören and Altındağ district. It can be said that these two schools located in the similar areas within socio-economic, socio-cultural issues. Besides, it is also known that students' science, math and reading achievements are at the similar rate that we know this by looking national exams' results such as TEOG and SBS. The results of the exams' were reached by schools' administrations. 50 seventh grade and 44 eight grade students participated to the study. 45 of them were boys and 49 of them were girls. The real name of students is not given in the article. So their names are given under codes as student 1, student 2 and etc.

Data Collection Tool

A form was created which has four boxes related to science, technology, mathematics and engineering to be able to written on, those boxes. The data was collected through the participants' completion of the prompt "Science/Tech/Engineering/Math is like . . . because. " 94 seventh and eighth grade students were asked to write their metaphors on STEM subjects. Data collection tool was prepared within document analyze technique. It is known and used one of qualitative research method. 50 seventh grade and 44 eighth grade students, wrote their metaphors in STEM subjects on the forms. Students were asked to write their metaphors on each space. After that, it was asked to complete the statement, from students to write their metaphor After all, students were asked to complete the statement. Some of their answers are given directly as the same they wrote in the results to be understood resources of the answers.

Data Analysis

The data were obtained from students' metaphors and they were sent to two measurement and evaluation specialists to provide them to be investigated of the data. The data sent to two field specialists for providing validity and reliability. They are specialists in the study fields and specialists in qualitative studies. Specialists took all metaphors and then they determined and classified metaphors under STEM disciplines such as science, technology engineering and math. They put all given metaphors by STEM disciplines. The data was analyzed by using document analyze technique. Specialists did their analyses, independently, and to determine reliability of the data based on Miles and Huberman (1994) compatibility percentage formula was used. It was found 92.48. It can be said if a compatibility percentage is at 70 and above .70, it might be used (Yıldırım ve Şimşek, 2011) and that value should be above 80 % (Miles and Huberman, 1994; Patton 2002). As it can be seen that 92.48 is much higher than .80 so it can be said that this value is enough for the reliability of the data.

Ethics

After necessary permission was taken from the schools' administrations, school students were informed about the study such as its content, the reason, period of study and which applications would be done during the study. Students were also provided to participate in the study voluntarily. Within this context they were given "Volunteer Participation Form".

Results

In this section, both the data of the study and included these middle school students' metaphors are given, which were developed STEM subjects, the evaluation and explanations of these metaphors are also given under the relevant categories. To tell all data of the study, there have been created four tables of each disciplines of STEM. In the table1, it is given all metaphors that are created by students on science. In the table 1, it is given all metaphors that are created by students on science.

Table 1. Metaphors of science

Metaphor	f	%	Metaphor	f	%
Technology	11	11,95	Test tube	1	1,08
Art	7	7,60	People	1	1,08
Life	6	6,52	Bright spark	1	1,08
Invention	6	6,52	Biology	1	1,08
Creativity	5	5,43	Einstein	1	1,08
Research	5	5,43	Chemistry	1	1,08
Information	4	4,34	Computer	1	1,08
Experiment	4	4,34	An amazing place	1	1,08
Finding	4	4,34	Inventor	1	1,08
Intelligence	3	3,26	Productiveness	1	1,08
Space	2	2,17	Cook	1	1,08
Nature	2	2,17	Learning new things	1	1,08
Design	2	2,17	Product	1	1,08
House	2	2,17	Living	1	1,08
Human	2	2,17	Konowledge	1	1,08
Garden	1	1,08	Researcher	1	1,08
Laboratory	1	1,08	Puzzle	1	1,08
Trying	1	1,08	Deadlock	1	1,08
Cloud	1	1,08	Pencil	1	1,08
Science	1	1,08	School	1	1,08
Sun	1	1,08	Earth	1	1,08
			Total	92	100

It was determined that the participants constituted 42 different metaphors of "science" subject. It is seen that students mostly used technology (f =11) metaphor when they identified science via that metaphor. Besides, it has been determined that, art (f = 7), life (f=6), invention (f=6), creativity (f=5), research (f=5), information (f=4), experiment (f = 4), finding (f = 4), intelligence (f = 3), research (f = 5) and invention (f = 4). Participants have formed 46 different metaphors about "science" subject. It is also seen that some used metaphors are not directly related to science such as garden (f=1), cloud (f=1), an amazing place(f=1) , deadlock(f=1) , pencil (f=1). All given concepts have also been classified under some larger concepts which they involve them. These mentioned concepts are “Objectivity, Scientist or some features of scientists, the equipment of laboratories, Productivity, Observation, Relation with other areas, Scientific Research Method, Science, Technological Dimension, Other”. So, main concepts and sub-concepts have been created as “Aliveness (life and human), Objectivity (space, Earth, nature, Sun, cloud and garden), Scientist or some features of scientists (intelligence, Einstein, inventor, intelligence human, productiveness, researcher), the Equipment of laboratories (experiment, experiment tube, laboratory) Productivity (invention, creativity, discovery, design, learning new things, house and school), Observation (research), Relation with other areas (technology and art), Scientific Research Method (knowledge), Science (Biology and chemistry), Technological dimension (computer and pencil) and Other (deadlock, puzzle and an amusing place). The reason of some students’ answers were asked and their thoughts are directly given below.

> Science is like technology because it creates new machines and equipment. (Student 1, School A)
>
> Science is like laboratory because it applies to many experiments. (Student 3, School A)
>
> Science is like experiment because it investigates everything within scientific issues. (Student 1, School B)
>
> Science is like a research because it wonders Earth. (Student 5, School B)

Four different answers related to science concept are given above. We see some concepts as “technology, laboratory, experiment and research”. We can explain first example, Student 1 thinks that science is as <u>technology</u> so it <u>creates</u> new machines and equipment. It can be said this student thinks new machines and equipment cause technology and they feed each other. In the table 2, it is given all metaphors that are created by students on technology.

Table 2. Metaphors of technology

Metaphor	**f**	**%**	**Metaphor**	**f**	**%**
Invention	8	10,12	Skill	1	1,26
Reproductivity	6	7,59	Progress	1	1,26
Design	5	6,32	Electric	1	1,26
Science	5	6,32	Oxygen	1	1,26
Life	4	5,06	Colour	1	1,26
Phone	4	5,06	Equipment	1	1,26
Development	4	5,06	Creativity	1	1,26
Internet	3	3,79	Aim	1	1,26
Wisdom	2	2,53	Tool	1	1,26
Digital	2	2,53	Ambulance	1	1,26
Deliberation	2	2,53	Research	1	1,26
Art	2	2,53	Communication	1	1,26
Inventor	2	2,53	Mathematic	1	1,26
Life	2	2,53	Knowledge	1	1,26
Future	2	2,53	Calculator	1	1,26
Clock	2	2,53	Cycle	1	1,26
Newspaper	1	1,26	Imagination	1	1,26
Eternity	1	1,26	Formation	1	1,26
Chemistry	1	1,26	Project	1	1,26
Water	1	1,26	Cell Phone	1	1,26
			Total	79	100

It was determined that the participants constituted 40 different metaphors of “technology” subject. It is seen that students mostly used invention (f =18) metaphor while they identified technology via that metaphor. Besides, it has been determined that, reproductivity (f = 6), design (f=5), science (f=5), life (f=4), phone (f=4), development (f=4), internet (f = 3), digital (f = 2), inventor (f = 2), life (f = 2) and invention (f = 2). Participants have formed 79 different metaphors about “technology” subject. It is also seen that some used metaphors are not directly related to technology such as water (f=1), formation (f=1), newspaper (f=1), art (f=1), aim (f=1) and so on. All given concepts have also been classified under some larger concepts which they involve them. These mentioned concepts are “Product, Idiosyncrasy, Relation with other areas, Innovation, Relation with science and

Other." So those mentioned main concepts categorized as Product (invention, phone, internet, watch, discovery, equipment, calculator, tool, newspaper and ambulance), Idiosyncrasy (mind, reproductivity, inventor, information, imagination), Relation with other areas (art), Innovation (design, improvement, creativity, research, formation, progress and processing), Relation with science (science, Oxygen, electric, chemistry and mathematics) and Other (colour, aim, communication, hind-and seek, cycle project and fast food). The reason of some students' answers were asked and their thoughts are directly given below.

> Technology is like invention because it products new things which are very useful for people. (Student 7, School A)
>
> Technology is like design because it creates many different products. (Student 11, School A)
>
> Technology is like tool because it makes tools. (Student 6, School B)
>
> Technology is like life because we use it everywhere for our lives... (Student 20, School B)

Four different answers related to technology concept are given above. We see some concepts as "invention, design, tool and life". We can explain fourth example, Student 20 thinks that technology is like life so we see it and its products in our lives everywhere. In the table 3, it is given all metaphors that are created by students on engineering.

Table 3. Metaphors of engineering

Metaphor	**f**	**%**	**Metaphor**	**f**	**%**
Design	9	11,84	Earn	1	1,31
Tree	6	7,89	Wisdom	1	1,31
Drawing	4	5,26	Inventor	1	1,31
Figure	3	3,94	Line	1	1,31
Building	3	3,94	Invent	1	1,31
Structure	3	3,94	Occupation	1	1,31
Course	3	3,94	Sedulity	1	1,31
Mathematics	2	2,63	Work	1	1,31
Worker	2	2,63	Ruler	1	1,31
Tool	2	2,63	Environment	1	1,31
Jigsaw	2	2,63	Labour	1	1,31
Science	2	2,63	Technology	1	1,31
Robot	2	2,63	Humankind	1	1,31
Art	2	2,63	Repair the building	1	1,31
Balance	2	2,63	Application	1	1,31
Imagination	2	2,63	Improvization	1	1,31
Painter	2	2,63	House	1	1,31
Architect	2	2,63	Model	1	1,31
Decoration	1	1,31	Preoccupy	1	1,31
Fundamental Structure	1	1,31	Block	1	1,31
			Total	76	100

It was determined that the participants constituted 40 different metaphors of "engineering" subject. It is seen that students mostly used design (f =9) metaphor while they identified engineering via that metaphor. Besides, it has been determined that tree (6), drawing (f=4), figure (f=3), building (f=3), structure (f=3), course (f=3), math (f=2), jigsaw (f=2), science (f=2). Participants have formed 76 different metaphors about "engineering" subject. It is also seen that some used metaphors are not directly related to engineering such as course (f=3), ruler (f=1), humankind (f=1), earn (f=1) , balance (f=1) and so on. All given concepts have also been classified under some larger concepts which they involve them. These mentioned concepts are "Professional, Structure, Plan, Nature, Relation with other areas, Technological, Creavity, Human characteristics and Other." So those mentioned main concepts categorized as Professional (worker, artist, architect, president, tutorage, work, writer, head of schools and job), Structure (construction, mould, repair the building, model and block), Plan (design, drawing, mold and application), Nature (tree and environment), Relation with other areas (mathematics, science, watch and technology), Technological (tool, jigsaw, robot, ruler, arrow and house), Creavity (imagination, invention), Human characteristics to be successful, earn, occupation, labour, mind, inventor, sedulity, mankind, improvisation and preoccupy) and Other (lesson, balance, game, decoration, warm and potty putty). The reason of some students' answers were asked and their thoughts are directly given below.

> Engineering is like design because it designs and prepares. (Student 11, School A)
>
> Engineering is like building because it builds schools and factories. (Student 30, School A)
>
> Engineering is like imagination because it presents us many things which we use them. (Student 25, School B)
>
> Engineering is like a robot because it creates robots for our works. (Student 17, School B)

Four different answers related to engineering concept are given above. We see some concepts as "design, building, imagination and robot". We can explain second example. Student 30 thinks engineering is building so it builds new structures. In the Table 4, it is given all metaphors that are created by students on math.

Table 4. Metaphors of math

Metaphor	**f**	**%**	**Metaphor**	**f**	**%**
Operation	15	21,12	Wisdom	1	1,40
Life	14	19,71	Transition from primary to secondary education	1	1,40
Count	12	16,90	Human	1	1,40
Question	3	4,22	Brain	1	1,40
Science	3	4,22	Architect	1	1,40
Puzzle	2	2,81	Noun	1	1,40
Teacher	2	2,81	Geometry	1	1,40
Future	2	2,81	Course	1	1,40
Node	2	2,81	Light	1	1,40
Sleep	1	1,40	Nature	1	1,40
Guide	1	1,40	Clock	1	1,40
Flag	1	4,40	Tree	1	1,40
			Total	71	100

It was determined that the participants constituted 71 different metaphors of "math" subject. It is seen that students mostly used operation (f =15) metaphor while they identified math via that metaphor. Besides, it has been determined that life (f=6), count (f=4), question (f=3), science (f=3), puzzle (f=2), teacher (f=2), node (f=2). It is also seen that some used metaphors are not directly related to math such as tree (f=1), clock (f=1), noun (f=1) and so on. All given concepts have also been classified under some larger concepts which they involve them. These mentioned concepts are "Qualitative tools, Relation with other sciences, Idiosyncrasy, Professional dimension, Concrete features and Other". So those mentioned main concepts categorized as qualitative tools (operation, count, question, geometry, course), relation with other sciences (science), real life (life) idiosyncrasy (human, sedulity and wisdom), professional dimension (teacher and architect), concrete features (tree, nature, watch, rose, storm and flag) and other (puzzle, name, node, food, brain, TEOG, light, future, guide and to sleep). The reason of some students' answers were asked and their thoughts are directly given below.

> Math is like operation because ıt focuses on numbers. (Student 37, School A)
>
> Math is like life because we see it everywhere in our lives. (Student 22, School A)
>
> Math is like count because it is a kind of art. (Student 38, School B)
>
> Math is like a puzzle because ıt solves our problems which we face in our daily lives. (Student 19, School B)

Four different answers related to math concept are given above. We see some concepts as "operation, life, count and puzzle". We can explain third example. Student 38 thinks math is like count so it has some aesthetic within art. We can also look at a general view to metaphors within all disciplines that are included in STEM. It is seen all those mentioned metaphors in figure 3, and their relation to each other within STEM.

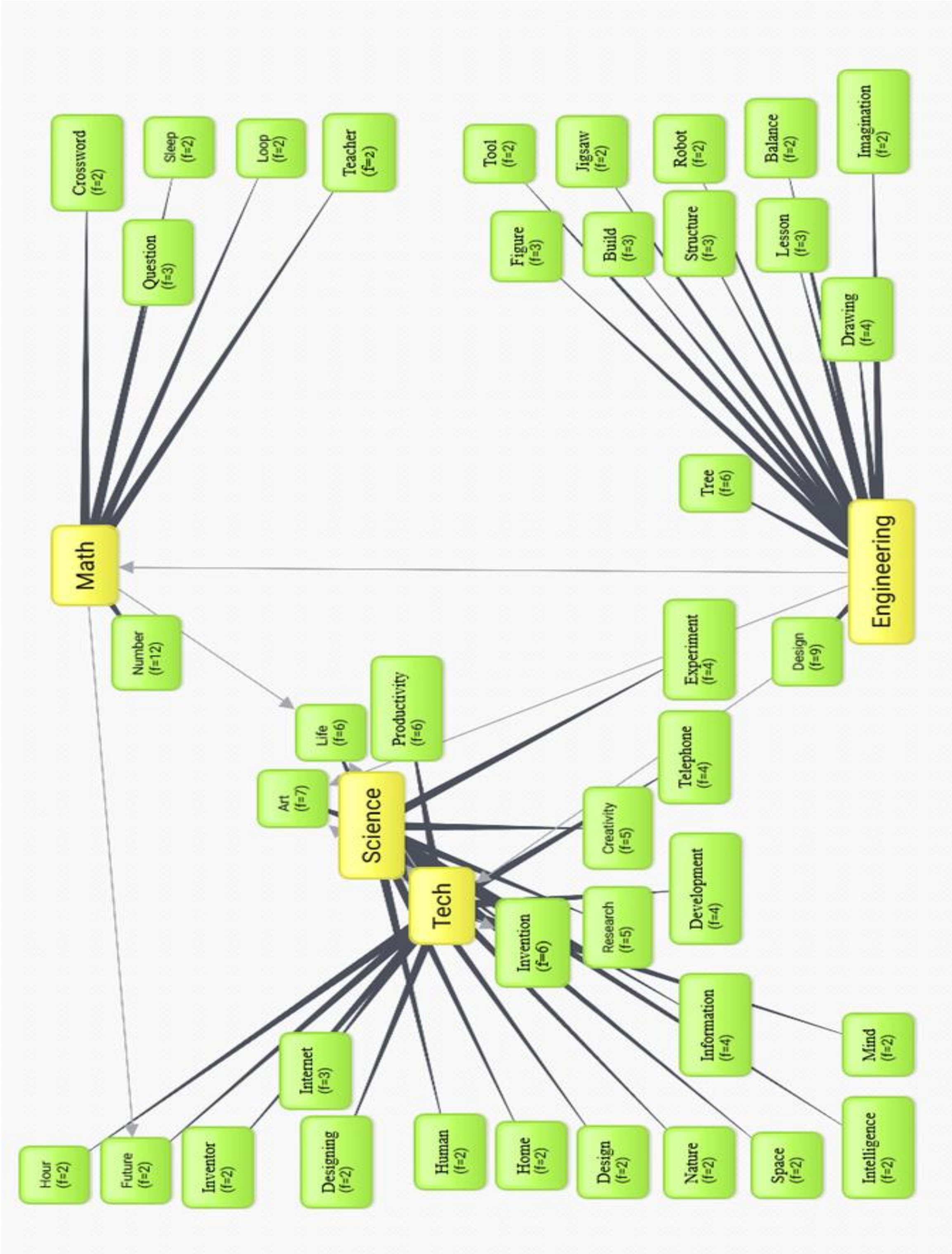

Figure 3. The metaphors developed by middle school students toward science, technology, math and engineering subjects

In figure 3, STEM subjects are given with their metaphors together. Each metaphor is given under the STEM subject which they are related to. The relation of STEM subjects can be seen via figure 3. It is seen some metaphors have been used to each other to identify different STEM concepts. There can be seen some interesting results within the study of students' data of STEM subjects. It is determined that students have complexity when they identify science and technology. It is understood that students have not enough information about the meaning of science and technology subjects. Because students substitute some both science and technology. To exemplify this, we see that creativity, invention (f=6) information (f=4), mind (f=2) are used for both science and technology. Students have complexity while they identify science so most of them (11,95 %) stated this. Another interesting result is art (7,60 %) respondents were given by students within their metaphors. However, there are some metaphors, which are clearly right to identify science concept, such as invention (6,52 %), research (5,43 %) and laboratory (1,08 %). Another interesting result is some metaphors are not directly related to science concept such as pencil (1,08 %), house (1,08%) and garden (1,08 %). When we focus on technology concept it can be seen most of metaphors are right to identify technology such as invention (10,12 %), reproductivity (7,59 %) and design (6,32 %). However, it is again seen that science was used as a metaphor to identify technology concept. We know both science and technology used to each other within metaphors. We have also found that some metaphors are not related to technology concept such as water (1,26 %), color (1,26 %) and Oxygen (1,26 %).

"Future" metaphor is seen that it has been used to identify both math and science. Another example can be given for math and science. It can be claimed that those students would want to show the relation between math and science. So, some metaphors are not related to math such as tree (1,40 %), noun (1,40 %) and flag (4,40 %). Some metaphors such as life (f=6) and figure (f=2) are used for both science and mathematics. Students created some right metaphors to identify engineering such as design (11,84 %), figure (3,94 %), structure (3,94 %). However, it is also seen that students use math (2,63 %) and science (2,63 %) to identify engineering concept. Besides, some students have complexity while they identify engineering concept via metaphors such as, block (1,31%), humankind (1,31 %) and ruler (1,31 %). Students used some metaphors which are directly related to math concept such as operation (21,12 %), count (16,90 %) and geometry (1,40 %). It has been found that students used science (4,22 %) metaphor to identify math. Besides these, it is also known students have complication on technology and engineering. Because it seen that they used some metaphors to each other as metaphors such as design (f=9), telephone (f=4). All these metaphors show us that students do not know the meaning of STEM subjects enough.

Discussion and Conclusion

It has been understood from the results that students have complexity when they use their metaphors to identify science, technology, engineering and math. It is also seen from students' statements about their metaphors. All given results let us know that participant students have limited knowledge on STEM subjects. This means they do not know those disciplines' real meaning. It can also be seen from their metaphors. They were asked to identify science, technology, engineering and math. There are some points which strength this statement since some irrelevant metaphors were given under STEM subjects. It can be illustrated for all STEM disciplines within the study framework based results. Science has (pencil and school), technology (ambulance and colour), engineering (ruler and block) and math (noun and light). However, it has not been found many studies on metaphors related to STEM, in literature, there are some studies on metaphors within education. Martinez, Sauleda and Huberb (2001), found in a study which they conducted with teachers that metaphors were achieved by collaboration and majority of those teachers shares traditional metaphors depicting teaching learning as transmission of knowledge. In our study, we also found that the students were not able to write their metaphors easily on STEM subjects. It can be thought that students cannot use their creativity while they have been writing metaphors. It is suggested that some small group activities might be done via using brainstorming, constructivist approach and Inquiry Based Learning approach. It is also seen by looking results of the study that at least confusion has been seen between science and mathematics. There just two metaphors with limited numbers of frequency. Niebert, Marsch, Treagust (2012), claim that it is not possible to think about and understand science without metaphors and analogies. This statement provides us to think that metaphors can be used as important tools to teach STEM subjects. We can strengthen this with a study conducted by Pellas, Kazanidis, Konstantinou & Georgiou (2017) and they state that pupils may co-construct, co-manipulate and examine in collaborative settings in world metaphorical representations, artifacts or primitives to design an innovative knowledge domain using (socio-) cognitive theoretical underpinnings.

Recommendations

In this study, it was seen that most of students were not able to create true metaphors on STEM subjects when they were asked to write them to identify. As a solution, it can be recommended that students can be supported within STEM applications within selective courses. In this way, they do not do any mistake while they identify STEM metaphors. Besides, teachers can also be supported within STEM Education to get their students to the right way on STEM subjects.

Note

A part of this study was presented in an international conference "International Conference on Science and Education (ICONSE)" 26-29 October, 2017, Antalya, Turkey.

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