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Newspapers in Science Education: A Study Involving Sixth Grade Students

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Abstract

The purpose of this study was to explore the learning performance of sixth grade elementary school students using newspapers in science teaching. A quasi-experimental design with a single group was used in this study. Thirty-three sixth grade elementary school students participated in this study. The research instruments consisted of three questionnaires, a "Learning Attitude toward Newspapers in Education Scale" (29 items, Cronbach's α = .90), a "Science Reading Attitude Scale" (15 items, Cronbach's α = .93), and an "Attitude toward Science Scale" (27 items, Cronbach's α = .92). All three questionnaires have good reliabilities. Furthermore, the validity of these questionnaires has been confirmed by three science educators. The results showed that the use of newspapers in education and multiple instructional strategies can (1) effectively enhance the sixth graders' learning attitudes towards the use of newspapers in science education and enhance their reading of science articles and involvement in science experiments; (2) effectively promote the sixth graders' attitudes toward science reading and enhance their science reading understanding; and (3) enhance the sixth graders' performance in scientific attitudes and significantly strengthen their science learning and interest. The research results showed that the use of newspapers in science teaching effectively enhances the science learning performance of the sixth grade students.

Key words: Attitude toward science, Newspapers in education, Science education, Science learning, Science reading

Introduction

Science teaching emphasizes conducting science experiments and inquiry activities and encourages explorations to assist elementary school students to recognize and explore natural science and verify scientific laws through science experiments. Lai (2012) pointed out that although the science textbooks for elementary schools are filled with new and novel science experiments, inquiry activities that encourage students to explore the historical facts of the natural sciences are limited. Therefore, it is difficult for students to deal with science concepts and develop their science understanding, resulting in some students rejecting science learning.

Along with the ever-increasing emphasis on national reading activities involving elementary school students, a number of teachers have already integrated science history, science readings, or science writing strategies into their teaching activities and have acquired relatively good outcomes (Chang, 2010; Chin, Yang & Tuan, 2010; Chiu & Koa, 2006; Chiu & Yu, 2005; Lai, 2006, 2008, 2009, 2012; Lai & Wu, 2010; Li & Wu, 2009; Lin, Cheng & Chang, 2009; Lo & Chang, 2004; Yang & Chin, 2006).

Reading literacy and scientific literacy are key capabilities required of students, and are basic qualities that need to be continually strengthened. The purpose of this study is to explore the science learning performance of sixth grade elementary school students based on the introduction of newspapers together with multiple instructional strategies in science teaching.

Literature Review

Newspapers in Science Education

Along with the increasing attention given to the evaluation of the results of PISA and reading education in science, it is becoming increasingly common to introduce newspapers in teaching science. Lee (2007) pointed out that this method uses newspapers as textbooks for students to learn new knowledge, and to enhance their reading capacity, verbal ability and civic literacy.

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Regarding the teaching and learning of science from newspapers and other media resources, the Ministry of Education in Taiwan published a Media Literacy Education Policy White Paper in 2002. The Ministry pointed out that modern citizen should have better understanding of the media and be able to highlight the role it plays in serving the social public affairs, and to strengthen and empower the public so as to develop a healthy media community (Ministry of Education, 2002).

Feng (2004) pointed out that, compared to book reading, there are several special features in reading newspapers. For example, newspapers offer the latest daily information, which can help students establish reading habits. Furthermore, newspapers are equipped with the latest information on a multitude of subjects, which can supplement the shortcomings of textbooks. Finally, the current news in newspapers can be used for discussion, which is conducive to cultivating media literacy and civic literacy.

Regarding the implementation of teaching based on newspapers in science education, Li & Lin (2005) pointed out that there are about 1,000 different newspapers that offer periodicals, which can be regarded as textbooks for 390,000 teachers in over 10,000 schools. For example, the New York Times offers daily teaching cases and a learning sheet, enabling teachers to directly spread the content from the New York Times to the Learning Network after integration with courses (the New York Times includes special notes as to which news items are suitable for students at a particular grade). In addition, Zhang (2005) pointed out that Japan is also actively promoting the use of newspapers in education, and that Japan expects Japanese children to be actively involved in learning from newspapers. Moreover, the results for using newspapers in education can enhance learning outcomes of students (Jarman & McClune, 2005; Kahveci, 2015; Kirikkaya & Bozkurt, 2011; Oliveras, Márquez, & Sanmartí, 2013; Tuten & Temesvari, 2013).

In summary, the use of newspapers in education is an important project and one which can cultivate media literacy. It is worthy to explore the integration of newspapers in education. Students are likely to acquire new knowledge from current news about scientific information in newspapers. They are also likely to enhance their reading capacities, verbal ability and civic qualities.

Science Reading

Along with the increasing attention given to the poor performance of Taiwanese students in PISA, the topic of science reading is becoming increasingly important. Lai (2006) pointed out that science reading refers to the adoption of science reading materials. These include popular science readings, science articles, science nursery tales and stories, and science paintings, all of which are used in teaching activities that will enrich the understanding of students about science topics and enhance the science learning outcome of students.

Thompson and Mixon (1996) pointed out that when readers with a positive reading attitude become involved in reading about certain topics, they will invest more attention and find the reading more significant because when readers are equipped with positive reading attitudes, they will acquire enjoyable reading experiences and active perceptions of reading behavior. As Ross and Frey (2002) explained, popular science books can involve topics from single science concepts, to more in-depth perspectives and interpretations. Popular science books can also provide for the different reading abilities of students, enabling them to choose their own books; popular science books can be less difficult and more interesting than other textbooks.

Secondly, science reading can explore science history or can enhance science concepts and the thinking abilities of students (Chiu & Koa, 2006; Lai 2008, 2012; Lai & Wu, 2010; Shiau & Hung, 2000). Science reading activities are conducive to the development of science concepts (Chiu & Koa, 2006; Lin, Cheng & Chang, 2009). In addition, the integration of the teaching of popular science readings can offer inquiry methods for teachers, help to enhance science concepts and promote the growth of problem-solving skills by teaching science laws. It can also provide surprises and wonder for the students. These activities enrich students' creative and thinking abilities (Chin, Yang & Tuan, 2010; Ediger, 1995; Lai, 2008, 2009, 2012; Lo & Chang, 2004; Nordstorm, 1992; Rice, 2002; Rice & Rainsford, 1996; Rice & Snipes, 1997; Scott, 1993; Short & Armstrong, 1993).

Inspired by the related researches on science reading, we can enhance the application of science reading into teaching. This study strongly believes that teachers can offer teaching that is more in-depth and rich in exploration and that will help to develop students' life-long learning through science reading, further enhancing elementary school students' learning performances in science.

Research Methods

A quasi-experimental design with a single group was used in this study. There were 33 sixth grade elementary school students who participated in this study. Regarding the teaching design of newspapers in education, based on the above-mentioned literature review, the key to using newspapers in education is to offer inspiring scientific inquiry learning together with the integration of multiple instructional strategies. This study mainly adopted reading, science experiments and group discussions utilizing newspapers in education, primarily the Mandarin Daily News. The important features of this study included: (1) the teacher photocopying science articles every day from the Mandarin Daily News for the whole class; (2) using hands-on science experiments based on published science experiments in the Mandarin Daily News, with students carrying out experiments once every two weeks; and (3) small group discussions and sharing in two sessions every week. In total, the teaching course was for 12 weeks.

The research instruments in this study consisted of the Learning Attitude toward Newspapers in Education Scale, the Science Reading Attitude Scale, and the Attitude toward Science Scale. Further information about the instruments is detailed below. (1) The Learning Attitude toward Newspapers in Education Scale: the aim of the design of the scale was to understand the ideas and attitudes of students towards the implementation of newspapers in education as teaching resources. This study adopted a five-point Likert-type scale, with a total of 29 items. The reliability of this scale, with a Cronbach's α of .90, indicates that this scale has good reliability. (2) The Science Reading Attitude Scale: the aim of the design of this scale was to explore the reading behavior and performance of students. The expectation was that students will become familiar with science reading after gaining access to the newspapers used in science teaching. This study adopted a five-point Likert-type scale with a total of 15 items. The reliability of this scale, with a Cronbach's α of .93, indicates that this scale has also good reliability. (3) The Attitude toward Science Scale: the purpose of this scale was to understand the students' attitude toward science after using newspapers in science teaching. This study adopted a five-point Likert-type scale with a total of 27 items. The reliability of this scale, with a Cronbach's α of .92, indicates that this scale has good reliability as well. The validity of these three research instruments was confirmed by three science educators. After having collected the research data, the SPSS statistics software package was used to perform t-tests to explore the learning performance of students in the experimental group on the pre- and post-test.

Results and Discussion

Performance on the Learning Attitude towards Newspapers in Education Instrument

Before and after the teaching of the students in the experimental group, the "Learning Attitude towards Newspapers in Education" scale was administered. A summary of the results of the t-test of this scale is shown below in Table 1.

Table 1 Table of t-test results of the Learning Attitude towards Newspapers in Education Instrument

	N	Mean	SD	t	p
Pre-test	33	121.121	14.133	6.110	.000***
Post-test	33	131.512	11.515		

*** $p < .001$

The results in Table 1 show that the outcomes of the Attitudes toward Newspapers in Education Instrument indicate that students did better on their post-test than on the pre-test (t = 6.110, $p < .001$). The research results show that, after using newspapers in science teaching, the experimental group students' learning attitudes towards newspapers in education showed remarkable advancement and growth.

After a further review of the teaching process, this study found that the students had always been interested in science articles featured in newspapers. The possible reason is that the content of the science articles in newspapers are usually vivid and understandable. In addition, in the past, students had lacked the opportunities for doing hands-on experiments. Even given such opportunities, these experiments in the textbooks were found to be less interesting for students. Consequently, students were indifferent towards the experiments. However, after implementation of the newspapers in science teaching, the arranged experimental activities were not only easy to conduct, but were also very interesting. Gradually, the students became more positive towards hands-on experiments and enjoyed a sense of accomplishment of their endeavors, indicating that the use of newspapers in teaching not only strengthened the learning interests of students towards science experiments, but also changed their perspective towards the use of newspapers in teaching.

Performance in the Science Reading Attitude Instrument

This study adopted the "Science Reading Attitude" scale both before and after the use of newspapers in teaching for students in the experimental group, and the summary of the t-test results are shown as Table 2.

Table 2 Table of t-test results of the Science Reading Attitude Instrument

	N	Mean	SD	t	p
Pre-test	33	52.909	7.358	9.264	.000***
Post-test	33	60.606	6.950		

*** $p < .001$

The results in Table 2 show that the attitudes toward science reading indicate that students did better in the post-test than in the pre-test (t = 9.264, p < .001). The research results show that, after the use of newspapers in science teaching, the students in the experimental group enjoyed positive progress and growth in science reading attitudes. After a further review of the teaching process, this study found that the students had acquired positive attitudes towards science reading. At the same time, the students had enriched their knowledge and changed their opinions about science reading.

Performance in the Attitude toward Science Instrument

Before and after the teaching of the students in the experimental group, the "Attitude toward Science" scale was administered. A summary of the t-test results is shown in Table 3.

Table 3 Table of t-test results of the Attitude toward Science Instrument

	N	Mean	SD	t	p
Pre-test	33	108.060	8.951	7.327	.000***
Post-test	33	116.121	9.600		

*** $p < .001$

The results in Table 3 show that the outcomes of attitudes toward science instrument indicate that students did better in the post-test than in the pre-test (t = 7.327, p < .001). The research results show that after the use of newspapers in science teaching, the attitude toward science of the students in the experimental group had experienced significantly positive progress and growth.

Overall, after the newspapers in science teaching had taken place, the attitude toward science of the students had been transformed into a positive attitude, which is one of the main reasons why students favor the use of newspapers in science teaching. The learning achievements were the biggest motivation in support of their studies and also a source for their active learning. At the same time, the attitude toward science of the students was enhanced.

Conclusion

With the integration of the use of newspapers in science education and the implementation of multiple instructional strategies, this study found that the science learning performance of the sixth grade elementary school students had been promoted, including: (1) effective promotion of the learning attitude toward the use of newspapers in education and enhancement of the students in the reading of science articles and undertaking of science experiments; (2) effective promotion of the science reading attitude of the sixth grade elementary school students and improvement of their science reading understanding; and (3) effective promotion of the attitude toward science of sixth grade elementary school students and enhancement of their interest in science learning. The research results show that the use of newspapers in science teaching with sixth grade elementary school students can help to effectively promote the science learning of children of that age. This study further explored and found possible reasons for effective teaching. These include how the use of newspapers in education begins with the reading of the science articles. This study also involved the use of small group discussions and hands-on experiments to assist the students. Therefore, it shows that this method can trigger the learning and interests of students and offer in-depth learning experiences. Through independent cooperative groups, the students can complete group reports and share them in class. Consequently, the use of newspapers in science education has proven to promote the science learning performance of students.

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Investigating Pre-Service Chemistry Teachers' Problem Solving Strategies: Towards Developing a Framework in Teaching Stoichiometry

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Abstract

The present study investigated pre-service chemistry teachers' problem solving strategies and alternative conceptions in solving stoichiometric problems and later on formulate a teaching framework based from the result of the study. The pre-service chemistry teachers were given four stoichiometric problems with increasing complexity and they need to write the process that they undertake to solve the problem. The study found out that the most prominent strategy among pre-service chemistry teachers is the mole method, which is algorithmic by nature. Very few of them used the proportionality method and none made use of the logical method. Alternative conception noted among the pre-service chemistry teachers is that some of them rely on Avogadro's number in converting between moles with a given mass. The results indicate that these pre-service chemistry teachers has the tendency to teach stoichiometry using the mole method only and that they might carry on the alternative conception about Avogadro's number as they start their teaching career. It is therefore suggested that the teaching of stoichiometry to pre-service chemistry teachers should not be confined to demonstration as they will imitate such technique when they are already a full pledged chemistry teacher. They should be involved in the process of thinking of ways to solve the stoichiometric problem in such a way that it will help them become independent thinkers and be responsible for their own learning by developing metacognitive and critical thinking strategies.

Key words: Stoichiometry, Avogadro's number, Mole method, Proportionality method, Pre-service chemistry teacher

Introduction

It is devastating that no matter how much effort the Philippine government exerts to improve the quality of science education, the country still gets dismal results in national and international competency-based examinations. In chemistry, specifically, the 2003 Trends in International Mathematics and Science Study (TIMSS) reported that Filipino students got 30% average correct answers, which is way below the international average of 45% (Martin, Mullis, Gonzales, Gregory & Smith, 2004).

As agreed upon by both teachers and researchers, one of the most difficult topics in chemistry is stoichimetry. Stoichiometry is a branch of chemistry evaluating the results of quantitative measurements connected to chemical compounds and reactions. Therefore, students find it as very mathematical and cumulative that one gets lost when a particular topic is missed (Schmidt & Jigneus, 2003). Recurring yearly, teachers observed that students have different strategies or approaches in solving stoichiometric problems. Some follows an algorithmic step-by-step procedure while some others deviate from the usual technique but still come up with the correct answer. This project would like to know the origin of how most students solve problems in stoichiometry – strategies which might have originated from their teachers during their pre-service preparation.

This exploratory study, therefore, seeks to answer the following research questions: (1) What are the problem solving strategies used by pre-service chemistry teachers in answering stoichiometric problems?; (2) What are the similarities and differences in the way pre-service chemistry teachers answer stoichiometric problems?; (3) What are the common errors committed by pre-service chemistry teachers in solving stoichiometric problems?; (4) What are the observations of chemistry education academics in the way pre-service chemistry teachers solve stoichiometric problems?; (5) What does the result imply to teaching and learning chemistry?; and (6) What teaching framework can be formulated based on the results of the study?.

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Literature Review

Recently, a number of literatures swarmed the research arena that entail the perpetual malady in Chemistry education, is solving Stoichiometric problems. Stoichiometry is a branch of chemistry, which provides quantitative information about chemical reactions that involves problem solving. In this regard, researchers claimed that the following are some of the reasons which impede to the understanding of Stoichiometry: (1) misconception to chemistry language (Glazar & Devtak, 2001; Okanlawon,2010); (2) no specific organization of thoughts in solving problems (Schmidt & Jigneus, 2003); (3) incorrect application of reasoning specially in solving very difficult tasks which involved Stoichiometry (Schmidt & Jigneus, 2003; Fach, De Boer, & Parchman, 2006); and (4) unsupportive environment.

One of the most pronounced deficiencies in understanding Chemistry that involves calculations is the illiteracy on the Chemistry language. Glazar and Devetak (2001) proved in their study that students even after long years of studying Chemistry, still, are having difficulty in writing symbols and equations and solving Chemistry mathematical problems. This is also true in the arguments made by Fatch, De Boer & Parchman (2006), where the learners' deficiency might have been rooted to misconception if not lacking on the knowledge of stoichiometric entities such as "molar masses and amounts of substance". Further, Johnstone (2006) claimed the same in his study, that learners acquired techniques but found short in acquiring fundamental concepts. For these reasons, learners' long-term memory couldn't be established because it could not make any connection to the basic skills, because they are hardly founded.

While students expressed a number of deficiencies in the underlying aspects of Chemistry, It is good to point out that there are also reports were students proved to be using varied strategies in solving Stoichiometric problems; however, these are not properly organized for they have only created their own based from the problems given at hand and did not utilize the ones that were taught in Chemistry classes (Schmidt, 1990 & Schmidt & Jigneus, 2003). In some cases where students found to be using the learned techniques in school, it is proved that that there were only two strategies taught in school that are commonly used: mole and proportionality methods (Toth & Sebestyen, 2009). Moreover, these techniques and the ones originally made by learners are used successfully only when dealing with simple mathematical problems but students cringed when faced with difficult ones (Schmidt & Jignéus, 2003; BouJaoude & Barakat, 2003).

Recently, reports proved that students seem fail to realize that they are already using the basic tenets of reasoning which are useful to solving Stoichiometric problems, yet afraid to take more risks in giving extra effort when faced with more challenging tasks. This was evident in the study made by Schmidt (1997), where most students apply reasoning strategies to easy problems but tend to go back to algorithmic skills ones the task becomes challenging. This was substantiated by the recent study of Schmidt and Jigneus, (2003) among Swedish learners. They are confident in adopting logical strategy when solving easy chemistry problems; however, most of them recoiled and utilized "mathematical strategy" when answering the complicated ones. Not surprisingly, in the recent interview results of Fach, De Boer, & Parchman (2006), there were only few among those who participated used "reflective strategies" and the rest failed to do so but applied Algorithm.

Moreover, literature speaks that educators have a great impact on the success and the failure of mathematical skills acquisition among students that is relative to understanding the aspects of Stoichiometry. It is believed that whatever strategies developed by students, these could always be thrown back to the teachers. Interview reports revealed that students don't conceptualize formula but simply memorize what has been commonly taught to use (Howe & Johnstone, 1971 as cited in Johnstone, 2005). On the historical aspect, since the early of 1900s rote learning had received a lot of favour from educators and this had been instilled into the minds of students that it in the process of repetition comes learning (Roediger, 2013). This idea contradicted the beliefs of Piaget that to facilitate learning, students should be provided with tangible "hands on" and challenging tasks. This was also corroborated in the study made by Feyzioğlu (2009), where the efficient utilization of laboratory skills proved a significant progress on the solving problem skills among learners. Therefore, it is best to emphasize that knowledge on theories and how the effective process of transferring specific skills to students must be well underpinned and fossilized among educators, specifically Chemistry teachers to fully grasp the idea of solving Stiochiometric problems correctly (Okanlawon, 2010).

Methods

Research Design

The study utilized the case study qualitative research design to formulate a teaching framework for stoichiometry by investigating pre-service chemistry teacher's problem solving strategies in solving stoichiometric problems as well as their common errors in solving.

Participants

The study involved thirty three (33) junior pre-service chemistry teachers who are currently enrolled in Analytical Chemistry course during the first semester of school year 2014-2015.

Stoichiometry Questionnaire

The researchers developed the stoichiometry questionnaire intentionally for this study. The questionnaire was content and face validated by panel of experts coming from the fields of chemistry and chemistry education. Moreover, the questionnaire was pilot tested to senior pre-service chemistry teachers from a state university in Manila during the first semester of school year 2014-2015. The pilot testing was conducted to determine the readability of the questionnaire and the approximate length of time the students need to answer it. On the average, students finish answering the questionnaire in sixty (60) minutes.

The questionnaire contains three problems about stoichiometry with increasing complexity. Pre-service chemistry teachers need to solve each problem and show their complete solutions for each on the leftmost box. On the rightmost box, students need to explain how they come up with their answer by describing the procedure they undertake to solve it.

The first problem is the simplest among the three because the chemical equation is already given as part of the problem. They just need to balance the equation and solve the questions that follow. The given equation though is already balanced. The questions that follow are mole-to-mole conversion, mass-to-mole conversion, and mass-to-mass conversion. Below is problem number 1.

Heating calcium carbonate ($CaCO_3$) or limestone at a very high temperature yields calcium oxide (CaO) or lime and carbon dioxide (CO_2). Lime is used in industry for the manufacture of plaster of paris, mortar, and cement. The decomposition of limestone to lime is given by the chemical equation below.

$$CaCO_{3\,(s)} \rightarrow CaO_{\,(s)} + CO_{2\,(g)}$$

1. Rewrite and balance the chemical equation.
2. How many moles of $CaCO_3$ are heated to produce 1.25 moles of CaO?
3. How many grams of CaO do 2.75 moles of CaCO3 produce?
4. How many grams of $CaCO_3$ are needed to produce 9.50 grams of CaO?

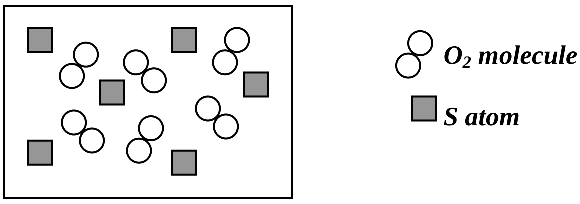
The second problem gave a situation about two different substances than when in contact with each other reacts to form a new compound. The chemical equation for the reaction was not given as part of the problem. Pre-service chemistry teachers need to formulate the chemical equation and balance it as well. This time, they really need to balance the chemical equation. The questions that follow are mole-to-mole conversion, mole-to-mass conversion, and mass-to-mass conversion. Below is problem number 2.

Zinc (Zn) is a metal used in the automotive industry, building industry, and construction industry, for hot tip galvanizing, for zinc castings, brass making, bronze making, and in steel making. Hydrochloric acid (HCl) or commonly known as muriatic acid, on the other hand, is a popular cleaning agent. Anything that is made of zinc should not be cleaned with muriatic acid because they react drastically to produce a zinc chloride residue ($ZnCl_2$).

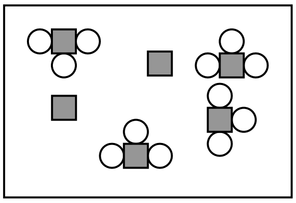
1. Write the chemical equation for the reaction of zinc and hydrochloric acid. Balance the equation.
2. How many moles of $ZnCl_2$ do 2.0 moles of Zn produce?
3. How many grams of HCl are needed to produce 3.15 moles of $ZnCl_2$?
4. How many grams of Zn are needed to produce 7.35 grams of $ZnCl_2$?

The third problem is a visual conception one. Pre-service chemistry teachers were given mental models of the reactants and products and they need to formulate a chemical equation from it. They also need to balance the chemical equation that they have formulated. The questions that follow are mole-to-mole conversion, mass-to-mole conversion, and mass-to-mass conversion. The name and the formula of the product are not given. So, they still have to predict what the product is. The problem is a revised form of a question in the Chemical Concepts Inventory (CCI), which was developed by Doug Mulford in 1996 and was published in *Journal of Chemical Education On-Line: Library of Conceptual Questions* in 2001. Below is problem number 3.

The diagram below represents a mixture of sulfur (S) atoms and molecular oxygen (O_2) in a closed container.



The diagram below, on the other hand, shows the product after the mixture reacts as completely as possible.



1. Write the chemical equation for the reaction of sulfur atom and molecular oxygen. Balance the equation.
2. How many moles of molecular oxygen are needed to produce the 2.35 moles of the product?
3. How many moles of the product will be produced by 4.21 grams of the sulfur atom?
4. How many grams of the product will be produced by 5.89 grams of the sulfur atom?

Results and Discussion

Data were gathered during the prelims grading period of the first semester of school year 2014-2015 in in a state university in Manila. The stoichiometry questionnaire was administered to pre-service chemistry teachers. After checking, an interview was conducted to each pre-service chemistry teacher who participated in the study. All interviews were digitally recorded and were fully transcribed in accordance with the guidelines presented by Bogdan and Biklen (2007) that interview lengths should range from 30 to 55 minutes, with 38 minutes being the suggested average. The protocols and the accompanying written explanations on the answer sheets served as sources of data for the study.

Table 1. Percentage of correct response

Problem		**Correct Response N=33**	**Percentage (%)**
1	1	33	100
	2	10	30
	3	14	42
	4	17	52
2	1	14	42
	2	9	27
	3	10	30
	4	19	58
3	1	3	9
	2	6	18
	3	4	12
	4	6	18

Apparently, the correct responses of pre-service chemistry teachers decrease with increasing complexity of the given problem. In table 1, since problem 1 is the easiest, most students got it correctly followed by problem 2. Students find it difficult to solve problem 3 though. Their strategy or way of solving the problem might have affected their scores – starting from how they balance chemical equations to how they utilize dimensional analysis or factor-label method to solve stoichiometric problems. Another hindrance is their misconceptions when solving problems in stoichiometry.

Strategies of Students in Balancing Chemical Equations

It was not a surprise that all of the students balanced the chemical equation by trial and error. Trial and error means manipulating the coefficients of a chemical equation until such time that the numbers of atoms in the reactant and product sides are the same or equal. Below are selected unedited responses of students on how they balance a chemical equation with exception to problem 1-1 since it is already balanced.

Problem 2-1

Student 3

1. Write the reactants to the left side of the equation and products to the right side. ($Zn + HCl \rightarrow ZnCl_2$).
2. Count the no. of Zn, H and Cl atom on the left side and compare to that of the right side.
3. If the numbers on the left are not equal to the right, manipulate the coefficients. You can notice that H_2 will be released because there is no H atom on the product side.

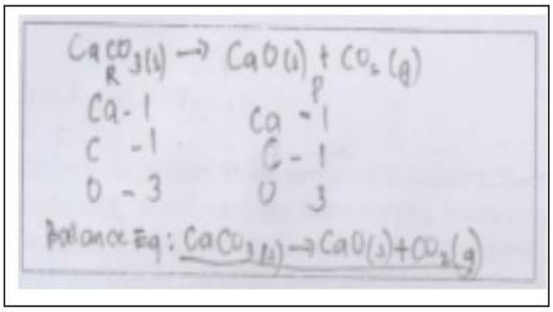


Figure 1. Answer of student 3 to problem 2-1

Student 10

1. Write the equation.
2. Count the number of each atom in the equation.
3. Compare the number of each atom in the reactant and the product.
4. Multiply the no. of atom to the number of which is needed to equalize the no. of atom in the reactant and in the product.

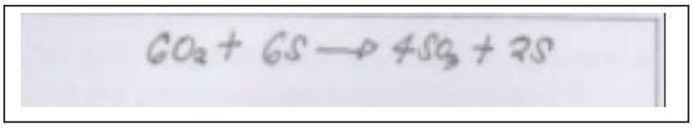


Figure 2. Answer of student 10 to problem 2-1

Student 19:

The given equation for the chemical reaction is a single replacement reaction wherein there is 1 mol of Zn, H, and Cl on the primary reaction while on the secondary reaction there is 1 mol of Zn and 2 mols of Cl and H. To balance the equation we simply add the coefficient “2” to HCl.

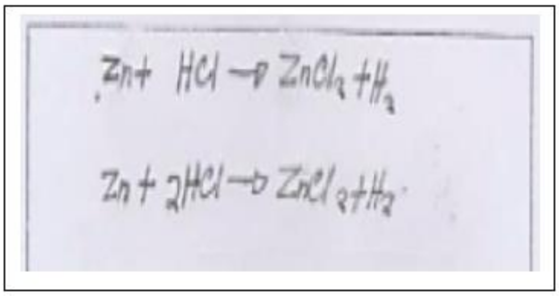


Figure 3. Answer of student 19 to problem 2-1

Problem 3-1

Student 3

1. Write the chemical equation based on the diagram.
2. Compare the number of S and O atoms from the reactant side to that of the product side.
3. Manipulate the coefficients of the elements/compounds in the equation until it became balanced.

Student 14

In writing the chemical equation if the reaction of sulfur atom and molecular oxygen, first count the number of individual atoms for each element or compound. After writing the chemical equation, count the number of atoms for each part (Reactant and products). And lastly, balanced it by comparing the number of atoms comprising in each part.

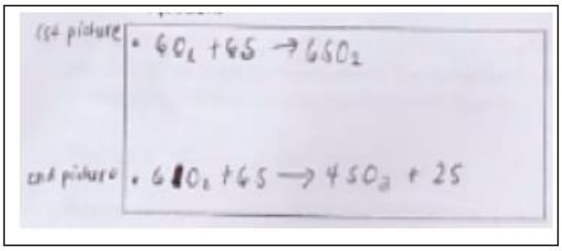


Figure 4. Answer of student 3 to problem 3-1

Student 25

Count the number of atoms to the left and compare it to product side put the appropriate coefficient to make a balance number of every atom.

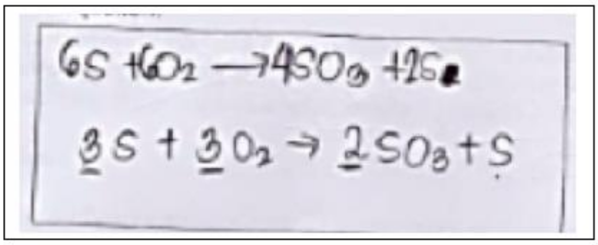


Figure 5. Answer of student 25 to problem 3-1

Strategies of Students in Solving Mole-to-Mole Stoichiometric Problems

Results of the study confirms the work of Schmidt and Jigneus (2003), Gabel and Bunce (1994) and Nakleh and Mitchell (1993) that students tend to use algorithmic methods when solving problems in chemistry. Algorithmic methods are an established step-by-step problem-solving procedure that are recursive computational procedure for solving a problem in a finite number of steps (The Free Dictionary, 2014).

In the case of mole-to-mole stoichiometric problems, pre-service chemistry teachers tend to rely on the balanced chemical equation to convert the given mole to the mole that is required to find. Students check the mole ratio of the two given substances from the balanced chemical equation. After getting the mole ratio, they perform a dimensional analysis or factor-label method to arrive at the number of moles of the unknown. Below are selected unedited explanations of students on how they solved problems 1-2, 2-2 and 3-2. All of which are mole-to-mole conversion problems. No other strategies of solving mole-to-mole conversion problems was noted in the accompanying written explanations on the answer sheets of students or even during the interview.

Problem 1-2

Student 26

- Start the computation with the given moles of CaO.
- To find out the number of moles of $CaCO_3$, use the number of moles of $CaCO_3$ and the number of moles of CaO in the equation.
- Write the unit for the answer.
- Box the final answer.

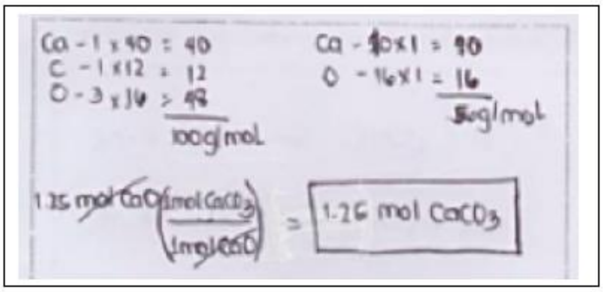


Figure 6. Answer of student 26 to problem 1-2

Student 28

I just multiply the no. of moles of the product CaO to the ratio of $CaCO_3$ and CaO (which) can be identify on the chemical equation.

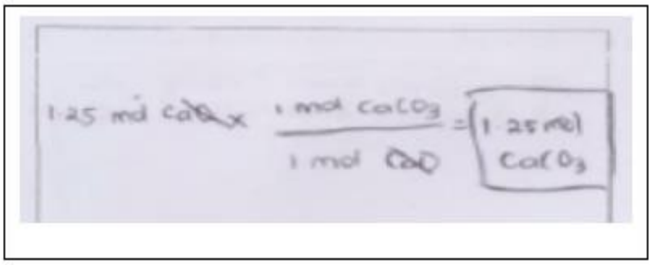


Figure 7. Answer of student 28 to problem 1-2

Student 32

First, since the chemical equation is already balanced. I made the ratio based on it that for every mole of $CaCO_3$ it is equal to mol of CaO also. So, I used that ratio to expressed the # of moles of $CaCO_3$ if 1.25 moles of CaO is produced.

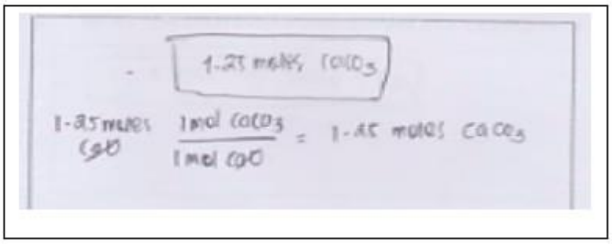


Figure 8. Answer of student 32 to problem 1-2

Problem 2-2

Student 14

In finding the number of moles of $ZnCl_2$ produced by 2.0 moles of Zn, the first thing you have to do is to find the number of moles per $ZnCl_2$ and Zn using the balanced equation for item#1 ($ZnCl_2$= 1mole; Zn = 1mole). Using factor label method, multiply the given amount of Zn to the number of mole of $ZnCl_2$ over number of mole of Zn to cancel the mole unit of Zn and simplify using arithmetic. And now you'll get the answer.

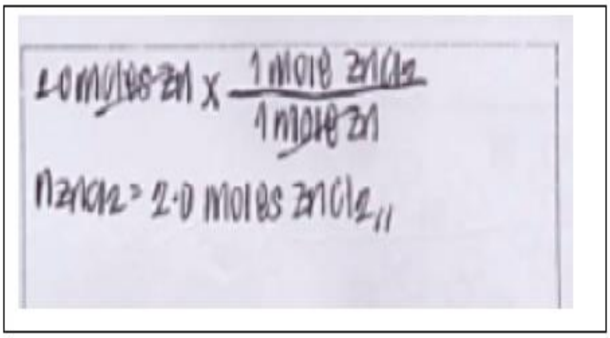


Figure 9. Answer of student 14 to problem 2-2

Student 27

The ratio of the equation is 1 Zn: 2HCl : 1 ZnCl :2H . Showing that in every 1 mole Zn will produced 1 mole ZnCl so that I did the mole to mole stoichiometry and do the cancelation process the result is 2.0 moles of ZnCl will produced by 2.0 moles of Zn.

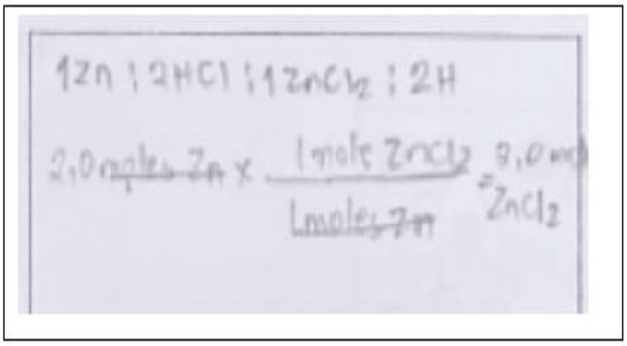


Figure 10. Answer of student 27 on problem 2-2

Problem 3-2

Student 3

1. Identify the number of moles of O_2 needed to produce 6 moles of product.
2. Use that as conversion factor.
3. Perform the operations and cancel units to get the final answer.

Student 14

In finding the moles of molecular oxygen needed to produce 2.35 moles of the product, find first the number of moles of O_2 and the product using the balanced equation in item #1. Then, multiply the given amount of the product to number of moles O_2 over the moles of the product to cancel the mole unit of SO_3. Then perform simple arithmetic to get the answer.

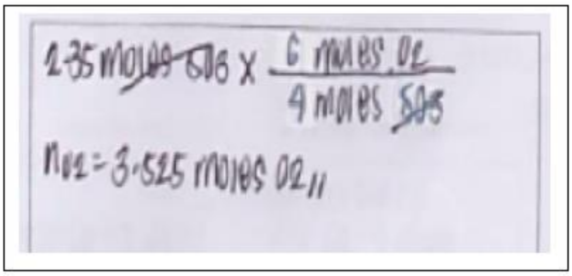


Figure 11. Answer of student 14 on problem 3-2

Student 26

- Start the computation with the given no. of moles of SO
- To find the number of moles of oxygen, use the number of mol of O and number of mol of SO in the balanced equation.
- Write the unit of the answer.
- Box the final answer.

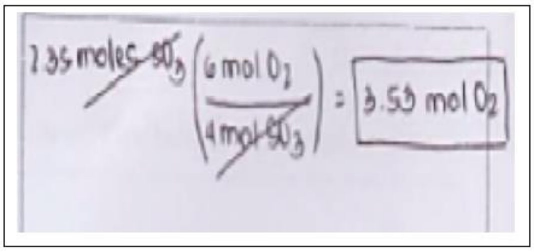


Figure 12. Answer of student 26 to problem 3-2

Strategies of Students in Solving Mole to Mass Stoichiometric Problems

The same result was noted in solving problems involving mole to mass conversions. Pre-service chemistry teachers used the algorithmic methods in solving the problem. The study also proves the work of Schmidt (1994) that the use of algorithmic methods deviates on the complexity of the problem. In this case, aside from checking the mole ratio from the balanced chemical equation, students also need to calculate the molar mass or formula mass of the unknown substance before performing dimensional analysis or the factor-label method. Below are selected unedited explanations of students for problems 1-3 and 2-3. Both are mole to mass conversion problems. No other strategies were noted on the answer sheets of the students.

Problem 1-3

Student 14

Find the number of moles of CaO. Then find the molar mass of CaO which is 56.077 g/mol. To find the grams of CaO produced by 2.75moles of $CaCO_3$, multiply the number of moles of CaO to the quotient of molar mass of CaO and number of mole of CaO. Cancel the same unit and multiply the remaining data and you’ll get the answer.

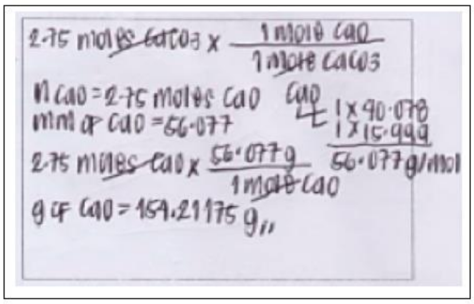


Figure 13. Answer of student 14 to problem 1-3

Student 24

- Determine the molar proportion of $CaCO_3$ and CaO in the balanced equation.
- Get the molar mass of CaO.
- Solve for the mass of CaO in terms of mole to gram conversion.

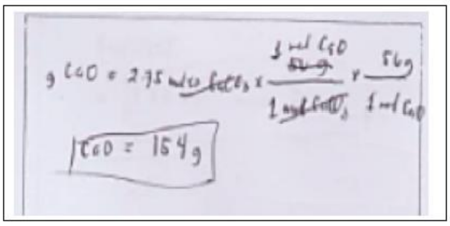


Figure 14. Answer of student 24 to problem 1-3

Student 26

- Start the computation with the given moles of CaO.
- To find out the number of moles of $CaCO_3$, use the number of moles of $CaCO_3$ and the number of moles of CaO in the equation.
- Write the unit for the answer.
- Box the final answer.

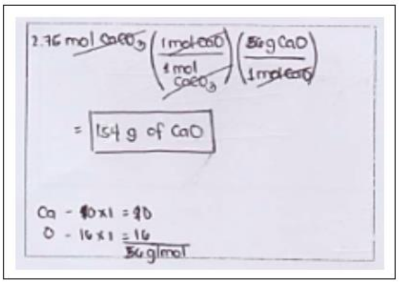


Figure 15. Answer of student 26 to problem 1-3

Problem 2-3

Student 24

- Determine the molar proportion of HCl and $ZnCl_2$ in the balanced equation.
- Find the molar mass of HCl.
- Solve for the mass of HCl through the mole to gram conversion.

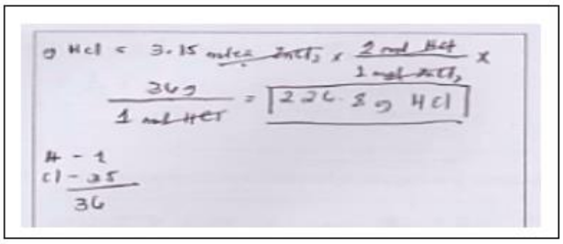


Figure 16. Answer of student 24 to problem 2-3

Student 26

- Get the molar mass of HCl.
- Start the computation with the given moles of $ZnCl_2$
- Use the no. of moles of HCl and no. of moles of $ZnCl_2$ in the balanced equation and the molar mass of HCl to get the mass in grams of HCl.
- Write the unit of the answer.
- Box the final answer.

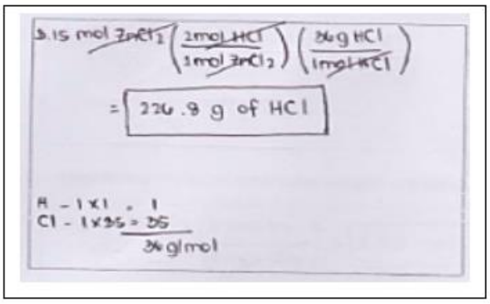


Figure 17. Answer of student 26 to problem 2-3

Student 27

- Find the no. of mole HCl that will produced in 3.15 mol ZnCl. There are 2 mole HCl in 1 mol ZnCl (ratio in the equation)
- Convert the moles of HCl to grams using mole to grams stoichiometry then the result is 229.635 g HCl.

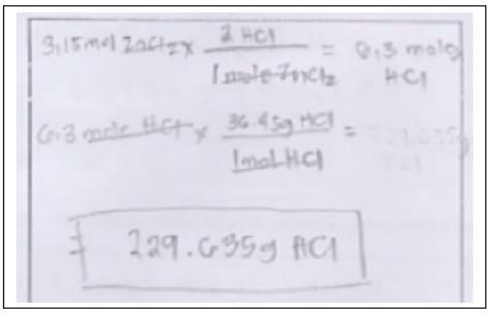


Figure 18. Answer of student 27 to problem 2-3

Strategies of Students in Solving Mass to Mole Stoichiometric Problems

This stoichiometric problem is the reverse of the previous one. Expectedly, students utilized the algorithmic methods in solving the problem. Pre-service chemistry teachers calculated the molar mass or formula mass of the known substance. Then, they checked the mole ratio from the balanced chemical equation and perform dimensional analysis or factor-label method to arrive at the answer. Below are selected unedited explanations of students on how they solved problem 3-3. Problem 3-3 is a mass to mole conversion problem. No other strategies were noted on the answer sheets though.

Problem 3-3

Student 14

In finding the moles of the product it will be produced by 4.21 g of S, you need to find the molar mass of S which is 32.05 g/mol. Then find the number of moles of SO_3 and S using the balanced equation in item no.1. Multiply the calculated answer to the number of moles of SO_3 over moles of S to cancel the mole unit of S. And lastly, perform simple arithmetic to get the answer.

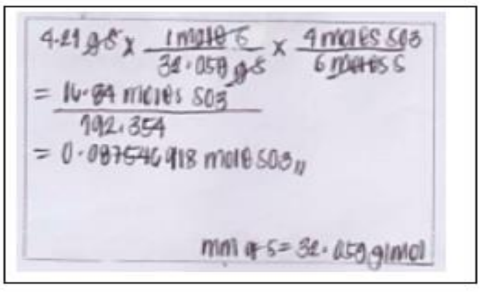


Figure 19. Answer of student 14 to problem 3-3

Student 26

- Find the molar mass of S.
- Start the computation with the given mass of sulfur in grams.
- Use the molar mass of S and the no. of moles of SO_3 and S in the balanced equation to get the number of SO_3
- Write the unit of the answer.
- Box the final answer.

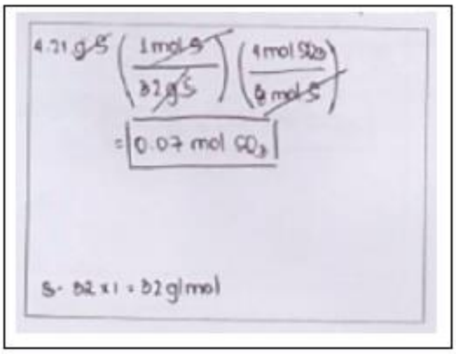


Figure 20. Asnwer of student 26 to problem 3-3

Strategies of Students in Solving Mass-to-Mass Stoichiometric Problems

Schmidt (1994) hypothesized that students tend to use different strategies conforming to the difficulty or complexity of the problem. This type of problem proves the study of Schmidt (1994) since students need to calculate two molar masses and they also need to look at the balanced chemical equation to get the mole ratio before they perform dimensional analysis or factor label method. Below are selected unedited explanations of pre-service chemistry teachers on how they solved problems 1-4, 2-4 and 3-4. All of these problems are mass-to-mass conversion problems. No other strategies were noted on the answer sheets though.

Problem 1-4

Student 14

In finding the grams of $CaCO_3$ needed to produce 9.50 grams of CaO. You need to find first the molar masses of $CaCO_3$and CaO. (CaO=56.077 g/mol and $CaCO_3$= 68.089 g/mol). Using factor label method, multiply the given mass to the number of moles of CaO over its molar mass. Using the balanced chemical equation in item #1, multiply the answer gathered to the number of mole of $CaCO_3$ over the numberof mole to cancel the mole unit of CaO. Lastly, multiply the answer calculated to the molar mass of $CaCO_3$, over its no number of mole to cancel the mole unit of $CaCO_{3.}$ Then simplify using simple arithmetic and you'll get the answer.

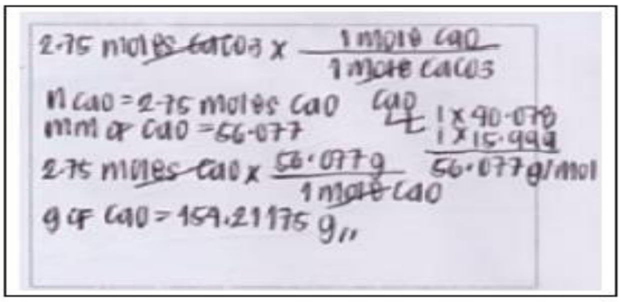


Figure 21. Answer of student 14 to problem 1-4

Student 32

The first thing is to make your chem. eq. balanced. Next is to create ratios. Since it is a mass to mass stoichiometry. I used 9.50 g of CaO as the starting value (in mass) then create ratios that for every 1 mol of CaO it is equal 56 g CaO. (you can check your P.T for molar masses) and for every 1 mole

$CaCO_3$ it is equal to 1 mol CaO. Lastly, for every 100 g of $CaCO_3$ it is equal to 1mol $CaCO_3$.I made these ratio to arrived at my answer.

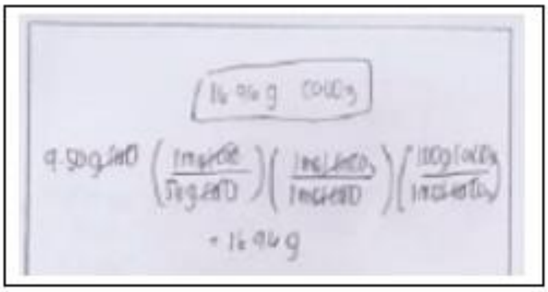


Figure 22. Answer of student 32 to problem 1-4

Problem 2-4

Student 3

1. Get the molar mass of the Zn and $ZnCl_2$.
2. Use the molar mass of the $ZnCl_2$ as conversion factor.
3. Identify the number of moles of Zn needed to produce 1 mole $ZnCl_2$and use as conversion factor (from balanced equation).
4. Use the molar mass of Zn as conversion factor to get the number of grams of Zn.
5. Perform the operations and cancel the units to come up with the final answer.

Student 14

In finding the grams of Zn needed to produce 7.35g of $ZnCl_2$, the first thing you have to do is to get the molar mass of Zn and $ZnCl_2$. After getting the molar masses, multiply the given mass of $ZnCl_2$ to 1 mole $ZnCl_2$ over its molar mass. After that, get the number of moles of Zn and $ZnCl_2$ using the balanced equation in item #1. To cancel the mole unit of $ZnCl_2$, multiply the calculated answer to number of mole of Zn over number of mole of $ZnCl_2$. And lastly, multiply the calculated answer to the molar mass of Zn over its number of mole. Perform simple arithmetic to get the final answer.

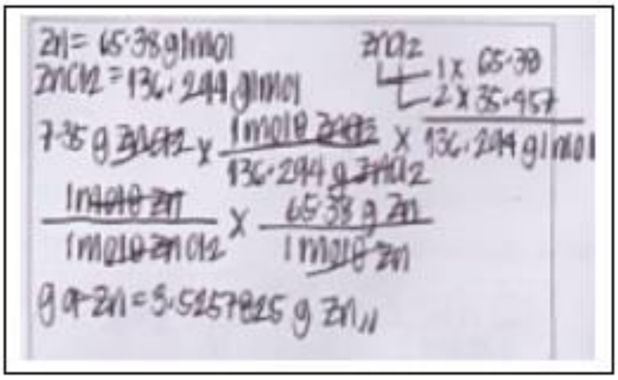


Figure 23. Answer of student 14 to problem 2-4

Student 26

- Get the molar mass of $ZnCl_2$
- Get the molar mass of Zn.
- Using the molar mass of $ZnCl_2$ and molar mass of Zn and the no. of moles of Zn and $ZnCl_2$ in the balanced equation, solve for the mass of Zn in grams.
- Start the computation with the given mass of $ZnCl_2$
- Write the unit of the answer.

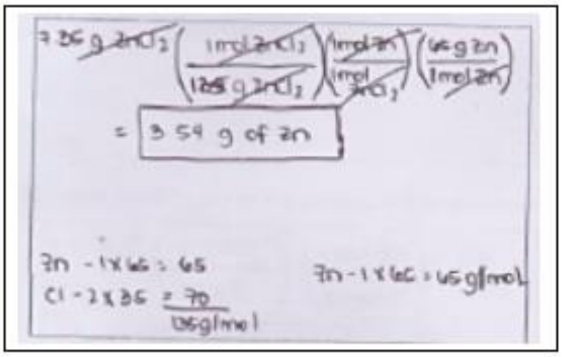


Figure 24. Answer of student 26 to problem 2-4

Problem 3-4

Student 14

In finding the grams of the product mole will be produced by 5.89g of S, find the molar mass of S and SO_3 because it is needed to the next step. Then multiply the given mass of S to mole of S over its molar mass. After that, multiply the calculated answer to the number of moles of SO_3 over moles of S (from the balanced equation) to cancel the mole unit of S and multiply the calculated answer to the molar mass of SO_3 over mole of SO_3 to cancel the mole unit of SO_3. Finally, perform simple arithmetic to get the final answer.

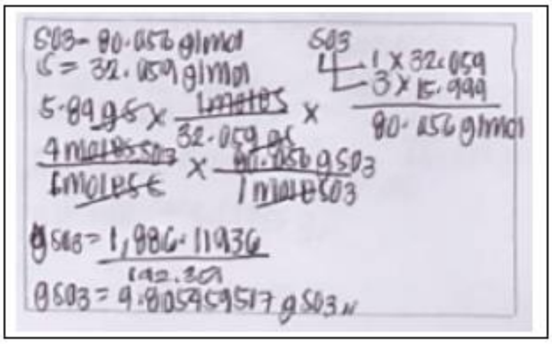


Figure 25. Answer of student 14 to problem 3-4

Student 26

- Find the molar mass of S and SO
- Start the computation with the given mass of sulfur in grams.
- Use the molar mass of S and SO and no. of moles of SO and S in the balanced equation to get the mass of SO in grams.
- Write the unit of the answer.
- Box the final answer.

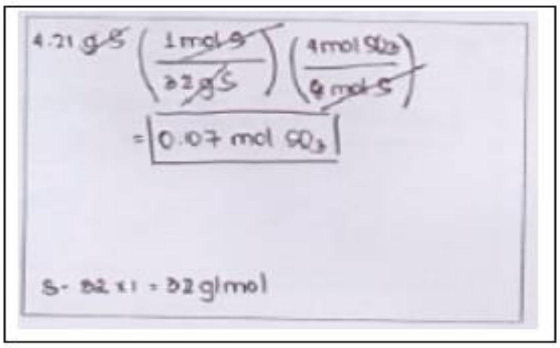


Figure 26. Answer of student 26 to problem 3-4

Student 28

- I look for the atomic mass of sulfur
- I multiply the given mass (g) of Sulfur atom to its atomic mass.
- I multiply the no. of mole of sulfur to the ratio of SO_3 and S.
- To find the no. of grams of product, I multiply no. of mol of SO_3 to if molar mass.

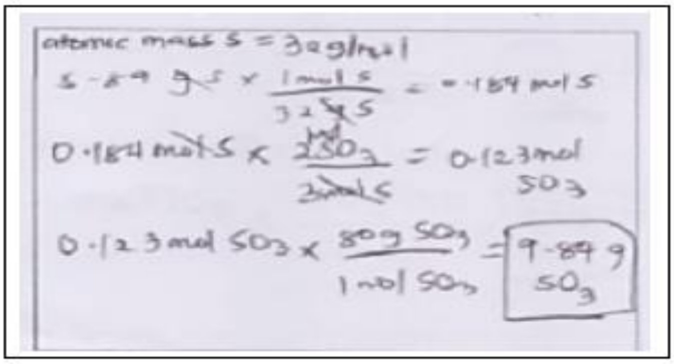


Figure 27. Answer of student 28 to problem 3-4

Misconceptions of Students in Balancing Chemical Equations

No misconception was noted in balancing chemical equations. Misconceptions noted were on writing chemical formulas from a sentence equation and from a visual conception model.

Misconceptions of Students in Solving Mole-to-Mole Stoichiometric Problems

No other problem solving strategies were noted but misconceptions are noticeable in some of the paper of pre-service chemistry teachers. In problem 1-2, instead of just checking the balanced chemical equation, some students computed for the molar masses of the two compounds and perform dimensional analysis or factor-label method to solve for the unknown mole. Below are selected unedited explanations of students.

Problem 1-2

Student 1

1. "Write the balanced equation.
2. Calculate the total number of the whole chemical formula.
3. Then, from the given there are 1.25 mol of CaO multiply by the sum of CaO. We find the 112.02 g of CaO over 1 mol and the answer will be 140.025 g of CaO.
4. From 140.025 g of CaO, we then get the sum of $CaCO_3$ molecules multiply by 140.025 CaO we get the final answer 0.700 mol $CaCO_3$"

Student 4

"First you must calculate the molar mass of the compound. Find the mole of the CaO, from that you can now look for the grams of $CaCO_3$ then convert grams to moles. You will find the answer."

In problem 2-2, three misconceptions were noted. The first is that instead of just checking the balanced chemical equation, some pre-service chemistry teachers computed for the molar masses of the two compounds and perform dimensional analysis or factor-label method to solve for the unknown mole. Students 1 and 5 apparently commit this mistake. The second is that students used the balanced equation but resorted to relate it to Avogadro's number to arrive at the answer. Student 24 represents this. The third one is that they computed for the molar mass but resorted to relate it to Avogadro's number too. Student 21 represents this.

Problem 2-2

Student 1

From the given 2.0 moles of Zn we need to get how many moles of $ZnCl_2$ to produce this and I come up with converting the given from the total atomic mass of the elements combined then I come up with the answer $5.817x10^{24}$mol $ZnCl_2$.

Student 5
2.0 mol of Zn times 1 mole of Zn over the molar mass of Zn times the molar mass of the $ZnCl_2$ over the 1 mol of Zn will result to the moles of $ZnCl_2$that is needed to produce 2.0 moles of Zn.

Student 21
Just divide the total grams of $ZnCl_2$ to Avogadro's number to get its mole.

Student 24

- Determine the molar proportion of Zn and $ZnCl_2$ in the balanced equation
- Use the Avogadro's mole constant to find the moles $ZnCl_2$.
- Solve for the mole of $ZnCl_2$ in terms of mole to mole conversion.

In problem 3-2, some students used the balanced equation but resorted to relate it to Avogadro's number to arrive at the answer as well. Student 24 represents this.
Problem 3-2
Student 24

- Use the Avogadro's number to find the moles of O_2. Refer to the balanced equation for the molar proportional.
- Solve for the mole of O_2 through mole to mole conversion.

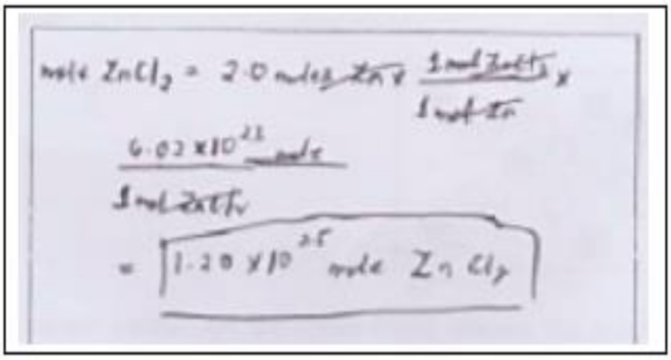


Figure 28. Answer of student 24 to problem 3-2

In problem 3-2, some students used the balanced equation but resorted to relate it to Avogadro's number to arrive at the answer as well. Student 24 represents this.
Problem 3-2
Student 24

- Use the Avogadro's number to find the moles of O_2. Refer to the balanced equation for the molar proportional.
- Solve for the mole of O_2 through mole to mole conversion.

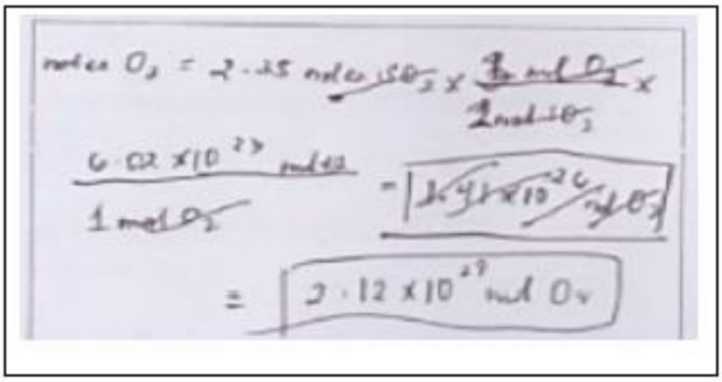


Figure 29. Answer of student 24 to problem 3-2

Misconceptions of Students in Solving Mole to Mass Stoichiometric Problems

In problem 1-3, it was noted that some pre-service chemistry teachers tend to forget to indicate where they got the mole ratio of the conversion factor, which is from the balanced chemical equation. If a person with no stoichiometry background will read his/her answer, he/she will not be able to grasp the explanation on how the problem was solved. Student 10 represents this.

A misconception was also noted in problem 1-3, some students, represented by student 18, solved the problem without using the balanced chemical equation. After using the molar mass of $CaCO_3$, they eventually resorted relating it to Avogadro's number to arrive at the number of moles of CaO. After that they relate the moles of CaO to its molar mass.

Problem 1-3

Student 10

1. Write first the given and the unknown.
2. Get the molar mass of the CaO and $CaCO_{3.}$
3. Solve for the mass of $CaCO_3$ by deriving the formula of getting the mass on the formula of getting the moles.
4. After getting the moles of $CaCO_3$, multiply it by the MM of $CaCO_{3.}$ (By the form of dimensional analysis) multiply the answer to the mol of CaO and the MM of CaO by the form dimensional analysis.

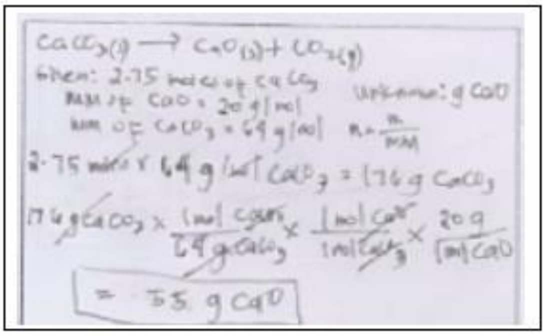


Figure 30. Answer of student 10 to problem 1-3

Student 18

Multiply the moles of $CaCO_3$ that is given by the mass of $CaCO_3$ then multiply with the avogadro's number then divide to the mass of CaO.

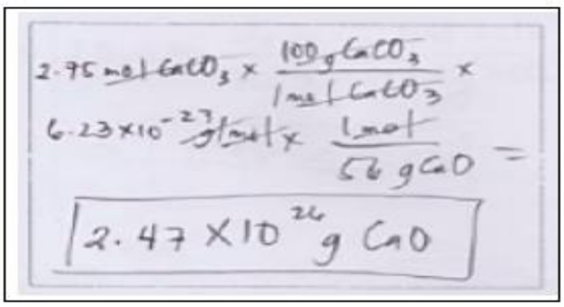


Figure 31. Answer of student 18 to problem 1-3

Problem 2-3 shows another misconception. Student 19 wrote on his paper that the molarity of $ZnCl_2$ would be multiplied with its atomic mass even though no molarity was given. In the interview, student 19 said that it was just a typographical error.

Problem 2-3

Student 19

To compute the amount on grams of HCl that will produce 3.15 moles of $ZnCl_2$, we multiply the molarity of $ZnCl_2$ with its atomic mass and the atomic mass of HCl.

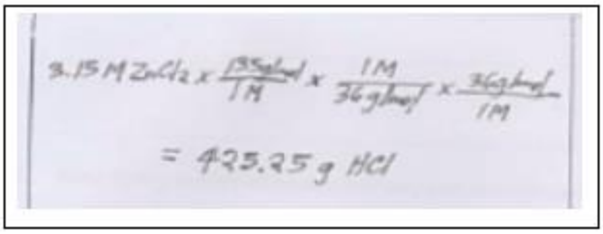


Figure 32. Answer of student 19 to problem 2-3

Misconceptions of Students in Solving Mass to Mole Stoichiometric Problems

The use of Avogadro's number was also noted in solving mass to mole problems. Student 18 resorted using the mole concept in getting the number of moles of sulfur instead of looking at the balanced chemical equation. Moreover, student 18 has also a misconception in writing chemical formula for sulfur trioxide. He/she placed a negative (-) sign on the molecule indicating that it is not a neutral species.

Problem 3-3

Student 18
Given of 4.21 g of S atom by multiply it by 1 mol of S in $2SO_3^-$ compound. Then using avogadro's number, multiply it to mole them divide by the mass of $2SO_3^-$.

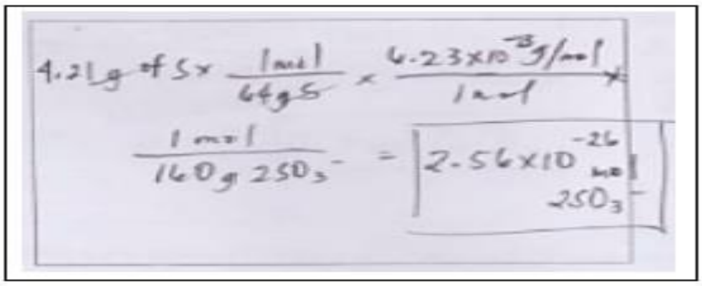


Figure 33. Answer of student 18 to pronlem 3-3

Misconceptions of Students in Solving Mass-to-Mass Stoichiometric Problems

The use of Avogadro's number is very noticeable among students' responses. Even in mass-to-mass conversion problems, some students still find the mole concept useful to convert moles of known compounds to moles of the unknown compound instead of just using the balanced equation. Student 1 committed this mistake in problem 1-4.

Problem 1-4

Student 1
From the given 9.50 g of CaO, we convert it to get the mol of CaO from 9.50 g CaO and we come up with 0.085 mol CaO. Then from 0.085 mol CaO we convert it again to find the moles of CaO, we use the avogadro's number to convert it then we come up with $5.119x10^{27}$ moles CaO answer then to get the grams $CaCO_3$ needed to produce 9.50 grams of CaO, we come up with the answer $1.024x10^{26}$

Implications for Teaching and Learning Chemistry

Schmidt (1994, 1997) found out in his studies about algorithmic strategies in solving stoichiometric problems that students usually use three ways in solving problems: (1) the mole method; (2) the proportionality method; and (3) the "logical method". The mole method describes the relations between the given and the required substance via amount of substance. Proportionality method, on the other hand, is a method used by creating a relationship between the given and the required substances via a proportion. The "logical method" described the relations between variables in their own words, for example "twice as much", "same proportion" instead of applying mathematical algorithms.

The mole method and the proportionality method were the most prominent strategies used by students in the present study. It confirms the work of Schmidt and Jigneus (2003), Gabel and Bunce (1994) and Nakleh and Mitchell (1993) that these algorithmic methods are indeed the methods used by most students in stoichiometric problems. The "logical method", on the other hand is limited to chemical compounds with a 1:1 mass ratio of its elements. The stoichiometry questionnaire did not provide problems with 1:1 mass ratio of elements so it is also expected that students will not rely on using the "logical method". Teachers should also expose students to simple stoichiometric problems to exercise the "logical method" among students.

In an interview with their teacher in general chemistry, where stoichiometry was first taught, the teacher mentioned that algorithmic methods was the prominent strategy of students in solving problems. In addition, the mole method was the most commonly used by students during class discourse. Proportionality method is the second widely used strategy. Students, on the other hand, least utilize the logical method, because the teacher gives them challenging problems instead of easy ones.

Misconceptions were also noted in solving stoichiometric problems. The most prominent is the use of Avogadro's number to convert moles of given substance to the moles of unknown substance. In some cases, students even use this converted moles to solve for the mass of the unknown substance, which is incorrect. Caution should be made when teaching the mole concept and stoichiometry.

In view of students' strategies and misconceptions in solving stoichiometric problems, the following teaching framework is suggested.

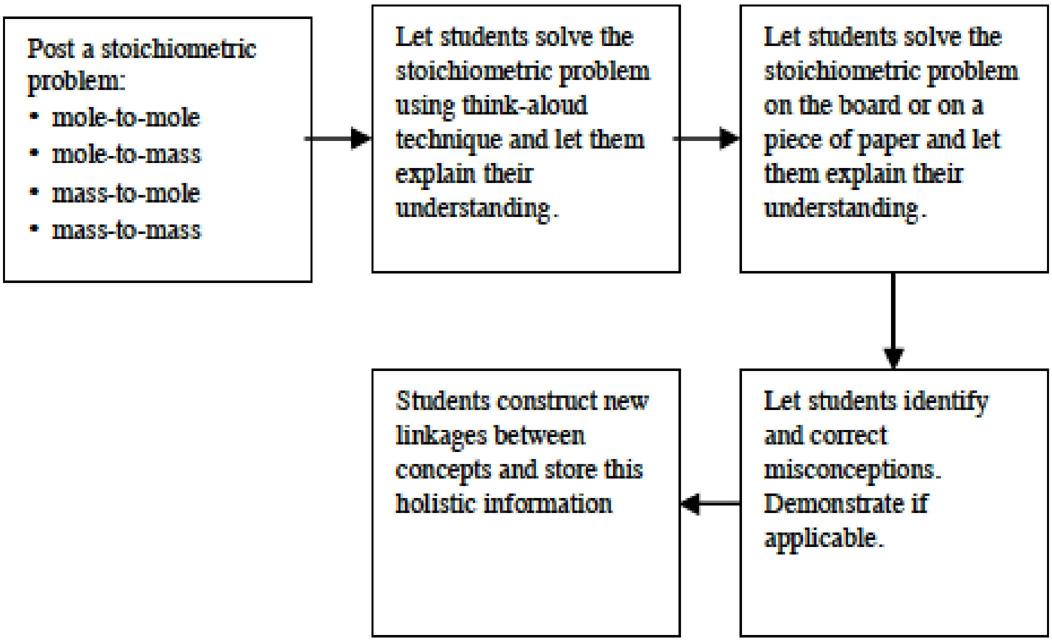


Figure 34. Suggested Teaching Framework

The above framework suggests that teachers should not demonstrate solving stoichiometric problems because students rely much on examples when they are doing it themselves. The tendency is that when they are exposed to a totally new form of problem, they easily get lost since their teacher did not demonstrate it to them. It's better to expose students to stoichiometric problems and let them think of ways on how they will solve it. In this manner, the higher order cognitive skills of students are harnessed instead of merely memorizing steps in problem solving. Misconceptions can also be detected and corrected by students themselves through careful facilitation of learning.

Conclusion

The algorithmic methods such as the mole method and the proportionality method were the most prominent strategies used by pre-service chemistry teachers in the present study. Misconceptions were also noted in solving stoichiometric problems. Students use Avogadro's number to convert moles of given substance to the moles of unknown substance. In some cases, students even use this converted moles to solve for the mass of the unknown substance, which is incorrect. A teaching framework was formulated from the result of the study wherein teachers are advised not to teach stoichiometry by demonstration instead let students think of ways to solve the problem in which their higher order cognitive skills are being developed.

Recommendations

It is suggested therefore to investigate the effectiveness of the formulated teaching framework both to the high school and collegiate levels. The same study is also suggested to be done with high school participants to find out if they have the same problem solving skills and misconceptions as collegiate students.

Acknowledgements

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Appropriating Epistemic Norms of Science through Sustained Practice with Argumentation: Can It Happen? A Learning Progressions Perspective

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Abstract

The purpose of this study was to explore the effect of sustained practice with argumentation on the quality of students' written arguments. Participants consisted of 37 students; 22 males and 15 females enrolled in a 6th grade middle school classroom. Students completed six argumentation tasks but only four of them were considered for data analyses as the first two tasks were used to get the students familiar with the language and structure of argumentation. Data were analyzed using the Claim, Evidence and Reasoning (CER) Framework. Findings reveal several patterns regarding students' use of claim, evidence, and reasoning across 4 tasks that were subject to our evaluation. First, there was not a consistent pattern of improvement in students' use of evidence. Second, there were not any consistent improvements in students' use of reasoning across four tasks. Our discussion focuses on the role of context, content knowledge and teacher framing in the quality of arguments developed by students.

Key words: Argumentation, Science, Middle school, Learning progressions, Learning

Introduction

There has been an increasing emphasis in helping students in science classrooms to engage in epistemic practices of science in recent years across the globe (Driver, Newton & Osborne, 2000; Duschl, Schweingruber, & Shouse, 2007; Erduran & Jime´nex-Aleixandre, 2008; Larrain, Freire, & Howe, 2014). Kelly (2008) defines epistemic practices as "discipline-specific ways of proposing, justifying and evaluating, knowledge claims" (Kelly, 2008). In the context of science education reform rhetoric, argumentation is viewed as an important epistemic practice that must be practiced by all students while learning science (Driver et al, 2002; Duschl et al., 2007; Kuhn, 2010; Osborne et al., 2013). Argumentation refers to the process whereby students engage in justification of claims to knowledge based on scientific evidence and through warrants that connect evidence to claims (Erduran & Jime´nex-Aleixandre, 2008). While some studies in science education focus on students' construction of written arguments (Chen, Hand, McDowell, 2013; Sampson, Enderle, Grooms & Witte, 2013), others focus on students' construction of scientific arguments verbally through a dialogical process, whereby students are deliberately trying to persuade each others of the validity of their claims (Berland, 2011; Osborne et al., 2013; Ryu & Sandavol, 2012). As Kelly and colleagues argue, studies of students' discourse in in the context of written and verbal argumentation allow us to examine how students appropriate epistemic norms of science (Schwarz, Neuman, Gil, & Ilya, 2003) and identify and characterize the types of challenges they experience and support they may need in constructing quality scientific arguments (Berland & McNeill, 2012).
While there has been a surge in argumentation studies in science education in recent years, the majority of studies focus on teachers' pedagogical knowledge of argumentation (Sampson & Blanchard, 2012; Simon, Erduran, & Osborne, 2006) or the effects of argumentation on students' conceptual understanding of scientific concepts (Venville & Dawson, 2010) or the nature of classroom discourse (Berland, 2011; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Kuhn, Shaw & Felton, 1997; Larrain, 2014). One of the questions that have not been fully answered in science education literature is whether quality of students' arguments changes over time and with practice. In this study, our analyses focused on students' written discourse in a 6th grade science classroom across five argumentation tasks and over the course of one semester. The research questions that guided our inquiry are:

I. How does the quality of students' written arguments change over time and through sustained practice? (i. e. progressions of the quality of students' written arguments).
II. Which aspects of written arguments did sustained practice help students improve on and which aspects proved to be challenging for students?

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Review of Relevant Literature

While most studies in science education point out the lack of argumentation in regular science classrooms (Berland, 2011; Larrain et al., 2014; Osborne et al., 2013; Sampson & Blanchard, 2012), some empirical research suggests that students' effective engagement in scientific discourse could be enhanced through scaffolding. Sampson et al. (2013) conducted a study in two middle and two high school classrooms in the U.S. The participants consisted of 67 students enrolled in a life science course, 52 students enrolled in a middle school physical science course, 94 students enrolled in a high school biology course and 81 students enrolled in a high school chemistry course. The authors sought to explore the effects of Argumentation-Driven Inquiry (ADI) curriculum on students' argumentation skills as well as their conceptual understanding as measured through students' responses to course specific open-ended questions. ADI is a writing intensive laboratory-based curriculum that engages students in inquiry (see Sampson et al for details). They engaged students in 4 ADI-based laboratory activities in all courses in the first semester. During the second semester, however, while students in enrolled in physical science and chemistry engaged in 2 ADI laboratories, students in life science and biology course engaged in 4 ADI laboratories. The results of their study showed that students made significant improvements in their content understandings between pre and post tests in all courses but middle school physical science course. The authors conducted a one-way, within-subjects analysis of variance (ANOVA) to see if the students made improvements in the quality of their written arguments over time. The results of their study showed that while all students made significant progress during the first semester, they did not observe the same trend in the second semester. While students in middle school life science course and biology course made significant improvements in both semesters, students enrolled in middle school physical science course and high school chemistry course did not make improvements in the second semester. The authors reasoned students' lack of improvement in physical science and chemistry course to "decreased opportunities to write" in the second semester (p. 658). The results of their study showed that the complexity of students' written arguments increased over time with students making most improvements in life science and biology course. The implication of this study is that when students engage in argumentative writing both quality of their arguments and conceptual understanding improves.

McNeill (2011) investigated 5th grade students' views of explanation, argument, and evidence as well as their abilities to engage in argumentation over the course of a year. Pre- and post-student interviews, videotapes of classroom instruction, and student writing were analyzed to understand students' views of explanation, argument, and evidence and improvement in their ability to effectively engage in argumentation. The results suggested that students' understanding of explanation, argument and evidence changed over a time, which highlighted the importance of instruction in supporting students' understanding of argumentation. Moreover, reportedly students were able to write stronger scientific arguments by the end of the school year in terms of the structure of an argument. However, the accuracy, appropriateness, and sufficiency of the arguments varied depending on the assessment task. Overall, the study has drawn attention to the importance of support that should be provided for students to more effectively engage in argumentation practices. Similarly, one such study (Songer, Shah, & Fick, 2013) highlighted the importance of scaffolding in elementary students' construction of written scientific explanations. The study focused on three elementary science classrooms in which students were provided written scaffolds to generate scientific explanations. Findings suggested that verbal scaffolds were more helpful for younger students while they were constructing scientific arguments. The work of Howe, Tolmie, Greer and Mackenzie, (1995) with young students has shown that engaging students in dialogical discussions around a scientific phenomenon can result in an improved conceptual understanding of the phenomenon under investigation.

While most theoretical arguments report positive effects of argumentation on students' conceptual understanding, negative cases also exist in the literature. For instance, Osborne and colleagues (2013) recently explored the impact of argumentation on conceptual understanding of more than150 year 7 and year 9 students in UK. Using a two-way ANOVA statistical procedure, they tested to see whether the students in argumentation-based classrooms showed better conceptual understanding of core scientific ideas taught. The results of their analyses showed that there was no significant difference between the experimental and control group students' performance scores because of the intervention for the Year 7 (age 11) students in the study. However, they reported a significant difference in students' test scores for the Year 9 (age 14) students, with control group students performing significantly better than the intervention group. The mixed reports on the effects of argumentation on students' conceptual understanding call for further investigations with young students and their ability to construct scientific arguments.

Theoretical Framework

The theoretical framework guiding this inquiry is Learning Progressions (Berland & McNeill, 2010; Duschl, Maeng & Sezen, 2011;Stevens, Shin, Delgado, Krajcik, & Pellegrino, 2007). While learning progressions have been discussed in mathematics education for quite a while, science educators have only recently adopted and used the language of learning progressions (Duschl et al, 2011). Taking Science to School (Duschl et al., 2007), a reform document, defines learning progressions as "descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time" (pp. 8-2). This position maintains that the complexity of the disciplinary knowledge and practices acquired by students increases as students receive exposure, experience and scaffolding (Berland & McNeill, 2010). From this perspective, learning is conceived as a continuum of increasing expertise in a specific domain or practice (Duschl et al, 2011). If indeed learning takes place through subsequent progressions, through adequate support and sufficient experience students should be able to make transition from less sophisticated ways of thinking to more complex and sophisticated ways of thinking. Similarly, students should be able to develop more sophisticated scientific arguments as a result of their experience with argumentation. Building on the work of (Berland & McNeill, 2010) we tested this assumption with a class of 6th graders in this study.

Method

This study took place at an urban elementary school located in major city in Turkey. The school primarily serves students coming from economically disadvantaged families**.** The school is a public school implementing the national science curriculum. Participants consisted of 37 students; 22 males and 15 females enrolled in a 6th grade middle school science classroom. Most had parents with no or low education (no college education). The teacher who implemented the intervention is a female with five years of teaching experience. She had both her bachelor degree and master degree in science teaching and currently in the early stages of her PhD in science education.

Intervention

The intervention teacher followed the national curriculum over the course of six weeks. The teacher mostly taught classes by using traditional instruction; power point lectures and worksheet completion. During the intervention students learned 5 core concepts through argumentation (see Table 1). All argumentation tasks were developed collaboratively with the researchers. During each week, researchers had online meetings on the concept of the week with the teacher, discussed the argumentation task and gave feedback to the teacher about her progress on the task design. Additionally, she was provided with extra resources and support if she needed during her preparation of the tasks. Each implementation was observed by one of the researchers.

The argumentation tasks consisted of competing claims around core curricular concepts. They were first asked to pick a claim from three claims provided, that appealed to them intellectually, then to develop written arguments, by identifying and using relevant evidence and constructing a warrant. Students were given 20 minutes to complete each task. After the students developed their written arguments individually, they were asked to engage in collective argumentation in groups of 4. The instructor walked around each group during these argumentation sessions and guided student discussions when deemed necessary. Students were given 15 minutes for group argumentations. This intervention was practiced for five argumentation tasks over 6 weeks in the spring semester of 2014. Table1 presents the time flow of each task conducted through intervention.

Table1.Timeline and argumentation tasks

Task #	Week I: Task 1	Week II: Task 2	WEEK III: Task 3	WEEK IV: Task 4
Activity	Classification of penguins as mammals or birds.	Lunar Eclipse	Simple Electric Circuits	Extinction of Dinosaurs

Data Collection and Analyses

The participants engaged in six argumentation tasks but four of them were used as data source. As the first two tasks were used to get the students familiar with the language and structure of written arguments, they were not used as data sources. Consistent with our research questions we used the Claim, Evidence and Reasoning

Framework (CER) (McNeill & Krajcik, 2012) to evaluate the quality of students' written arguments. We used the CER framework because we take a pragmatic perspective as suggested by (Braaten & Windschitl, 2011) in that instruction in Turkish elementary science classrooms is geared towards students' acquisition of factual knowledge that can be tested through standardized assessments. As a result, curriculum affords limited opportunities for students to engage in inquiry-based activities whereby students can design investigations, collect and analyze data. Consequently, the aim of instruction (i.e. argumentation) became using argumentation to help students develop a causal account of the scientific phenomena covered by curriculum using evidence conveyed through textbook, experience and the teacher instruction. As a result, we adopted a view that defines argumentation "as a knowledge building and validating practice, which individuals attempt to establish or validate a conclusion, explanation, conjecture" (Sampson & Blanchard, 2012, p. 1123). This focus on how and why of the scientific phenomena under study, made the use of CER framework appropriate for our data analyses.

First, we evaluated students' claims based on correctness. Second, we evaluated students' arguments based on the quality and quantity of evidence used by the students. Third, we evaluated students' reasoning skills based on their ability to link evidence and claim to develop a warrant to justify their claims. Students were given scores for each component of an argument based on their performance for each task, and an overall score for each argument they constructed. Then, we compared their scores across the tasks to evaluate the progress of quality of students' written arguments across claim, evidence and reasoning.

Results

Findings reveal several patterns regarding students' use of claim, evidence, and reasoning across 4 tasks. First, the results show that participants did not successfully use the scientifically accurate claim to justify. While they increasingly got better at picking the right claim to defend from task 1 to task 4 (as shown in Figure 1), this improvement was not significant in that students failed to score at level 2 in tasks 2, 3 and 4. The percent of students who scored 1 increased from %75 to % 93.75 from task 1 to task 4, but no student was able to receive a score of 2 on their claims.

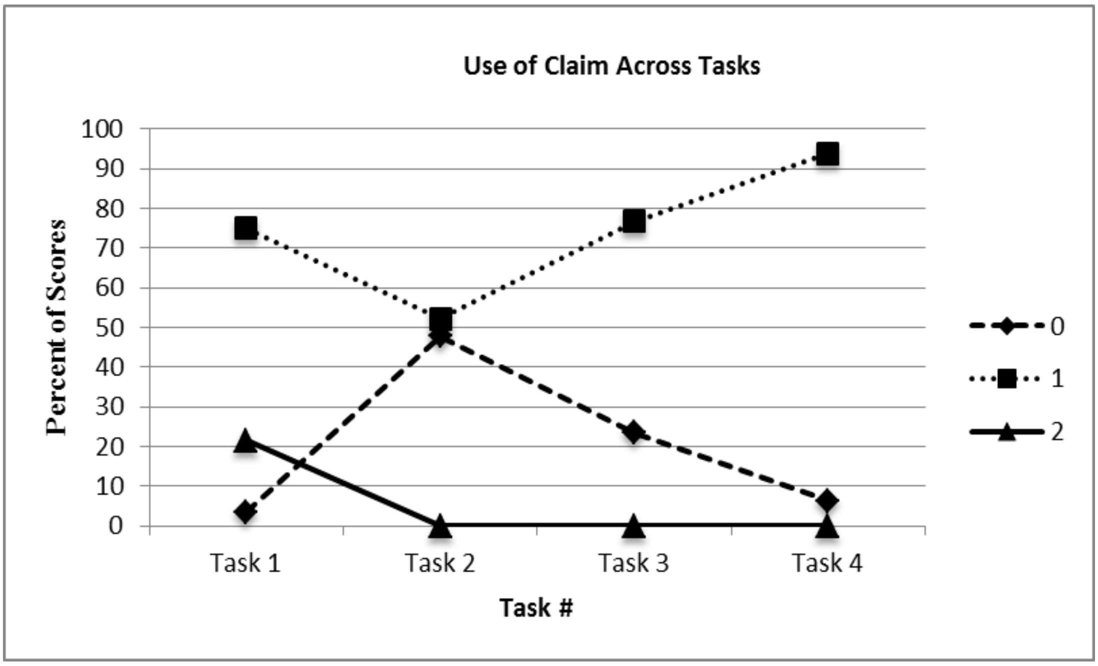

Figure 1. Performance on use of claim across tasks

Second, the results show that there was not a consistent pattern in students' use of evidence across four tasks as shown in Figure 2. While the majority of students (more than 60%) received a score of 1 and 2 combined on tasks 1, 2, and 3, only 46.7 received a score of 1 and 2 combined on task 3. We must note however that a greater number of students (31.25%) received a score of 2 on task 4 than any other tasks. Students performed very poorly on the use of evidence on task 3 compared to any other tasks including the first task.

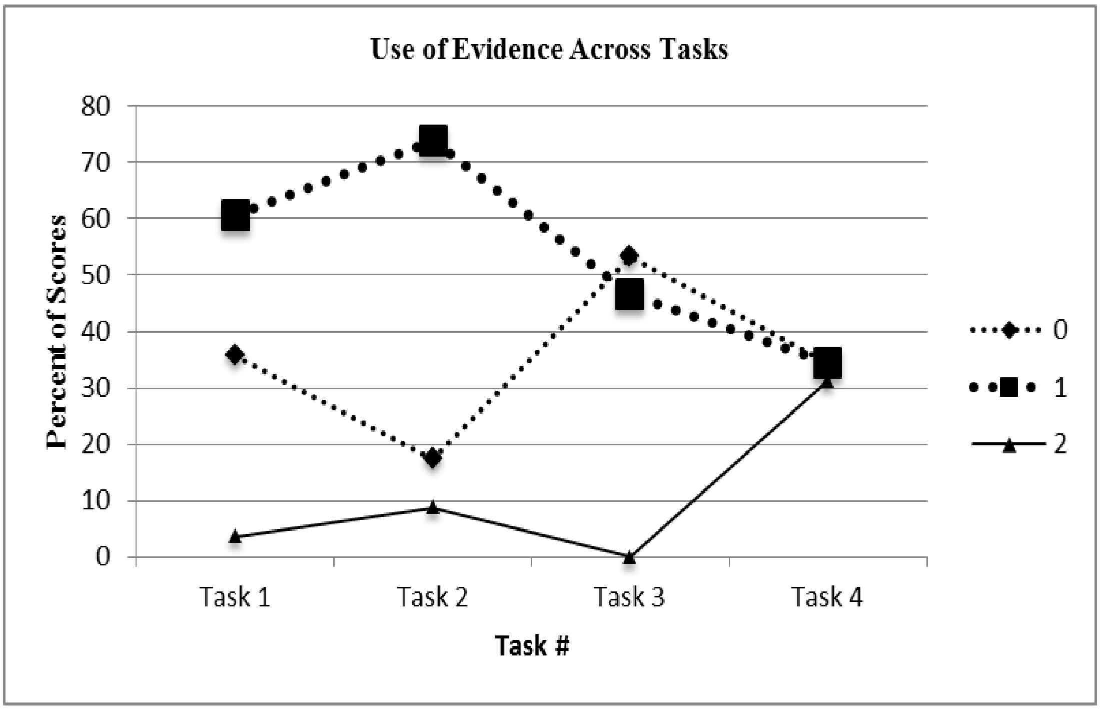

Figure 2. Performance on use of evidence across tasks

Finally, results show that students' performance on reasoning aspect of argumentation also did not lead to any consistent improvement patterns as shown in Figure 3. Students consistently scored low (at level 0 or 1) on most tasks except task 4. A greater number of students received a score of 2 (31.25%) on task 4. No one received a score of 2 on tasks 1 and 3, and only 4.35% received a score of 2 on ask 2. Overall, most students received either a score of 0 or a score of 1 on the remaining tasks.

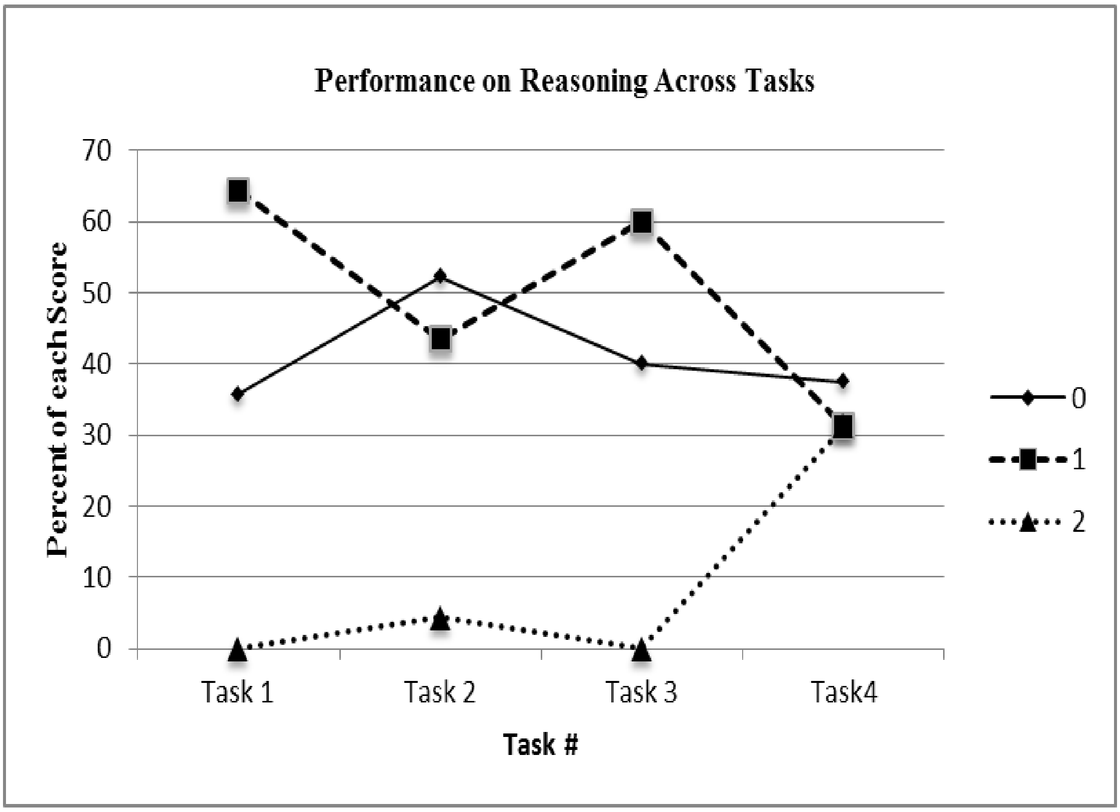

Figure 3. Performance on reasoning across tasks

Discussion and Conclusion

There is a large body of research demonstrating that teachers of science often teach science through lectures, exclusively focus on scientific facts and memorization (Driver, Newton, & Osborne, 2000; Jimenez-Aleixandre & Erduran, 2008; Larrain, 2014; Osborne et al., 2013). Similarly there is a consistent and growing concern among science educators about this trend in science classrooms. Science education researchers argue that science includes more than just facts discovered through observations and investigations, but also includes scientific ways of thinking and reasoning, and engagement in such practices as modeling and argumentation (Duschl & Osborne, 2002; Kuhn, 1993; McNeill, 2011). Consequently, they argue that in addition to developing an understanding about scientific facts, students should also be able to effectively engage in scientific practices such as argumentation during their formal education.

As Osborne (2010) states the production of new knowledge about the natural world through objective argument and critique is one of the hallmarks of science (Driver et al., 2000; Osborne, 2010). Moreover, argumentation scholars argue that activities where students assess alternatives, weigh evidence, interpret texts, and evaluate the viability of scientific claims are essential components of constructing scientific knowledge (Driver et al., 2000; Sampson et al., 2013; Simon, Erduran & Osborne, 2005). However, as the results of this case study indicate young students have difficulty in developing quality scientific arguments.

Consistent with the results of previous research related to student learning in the context of argumentation, our results suggest that students especially struggle with the reasoning component of the argument (Bell & Linn, 2000; McNeill, Lizotte, Krajcik, & Marx, 2006). The reasoning component measures the ways in which students justify how and why their evidence supports their claims (Berland & McNeill, 2010; Sandoval & Millwood, 2005). In other words, it deals with how successfully students use evidence to justify their claims to knowledge. Students struggle with this component of argument construction for two reasons: 1) lack of adequate disciplinary knowledge (Cross, Taasoobshirazi, Hendricks, & Hickey, 2008) and 2) perception of task goal that has been shaped by their prior experiences with assessments (Berland, 2011; Mila, Gilabert, Erduran & Felton, 2013). When students lack adequate disciplinary knowledge they cannot identify and use evidence to justify their claims. Because they are not directly involved in forming and pursuing their own questions, designing and collecting evidence through systematic investigations, their only source of evidence is what they can remember from the lecture, the textbook or homework assignments.

Second, in spite of our sustained effort to help the students to provide more elaborate arguments, the quality of their arguments fell short of that expectation. One possible explanation for this failure is that the teacher had to strictly follow the standardized curriculum, moved from one topic to another every other day, which did not provide the students with enough time to comprehend and reflect on the topic. As a result, students did not develop sufficient disciplinary knowledge to reason with and elaborate on. This lack of disciplinary knowledge subsequently might have impacted both their ability to identify and use evidence as well as to understand the complex relationships between different components of the concepts under investigation.

Several implications can be drawn from these findings. First, while the idea of the assumption that the teacher can facilitate students' learning progression in argumentation (Berland & McNeill, 2010) may be possible, context plays an important role in the success and failure of such progression. For instance, if the teacher had ample time to elaborate on each topic beyond one lecture and one argumentation activity, students could have developed more sophisticated arguments. In fact, the success of progression has been reported in Ryu & Sandoval, 2012 and Sampson et al., 2013. Recent work by Katchevich, Hofstein and Namlok-Naaman (2013) points to the importance of context in the quality of arguments produced by high school students. Katchevich et al (2013) conducted a study with 116 11th and 12th grade advanced placement chemistry students in five different high schools in Israel. The purpose of the study was to explore the quality of students' arguments in two types of laboratories: confirmatory-type laboratories and inquiry-type laboratories. The results of their study showed that the number of arguments generated in inquiry-type laboratories were greater than the number of arguments generated in confirmatory-type laboratories. While the students in laboratories where confirmatory-type experiments took place were able to generate 1.9 arguments in 11 observations (21 in total), the students in laboratories where open-ended type experiments took place developed 6 arguments in 11 observations (66 in total). In addition to the greater number of arguments observed in inquiry type laboratories, students also generated arguments of higher quality in inquiry-type laboratories. For instance, the mean of quality of arguments developed by the students in laboratories where confirmatory-type experiments took place was 1.48. On the other hand, the mean of the quality of arguments developed by the students in classrooms where open-ended type experiments took place was 2.41. These results imply that contexts that allow students to conduct systematic inquiry where they collect evidence can make positive impacts on the quality of arguments produced by students.

Second, changing the culture of learning may not be as easy as it sounds in six weeks. In spite of all the scaffolding that we provided, students were not able to develop arguments of high quality. This may be, at least partly, related to students' expectations from assessments. The testing culture dominates Turkish schools, so the culture of assessment may have influenced students' expectations from the assignments and thus formed their answers accordingly. However, based on our analyses of students written arguments, we conclude that lack of disciplinary knowledge is the main limitation to students' progress in forming sophisticated arguments over time. In fact, Ryu and Sandoval's (2012) recent work may provide an explanation for our observations. Ryu and Sandoval's work showed that when students (mixed-age class of 8–10-year-old children) engaged in sustained argumentation around a core idea (i.e. electric circuits) for a long time, they do make progress in forming arguments of higher quality. We used a different and un-related topic each week in our argumentation tasks to keep up with the curriculum-pacing guide. This speedy change of topics may explain the limited progress achieved by our participants. Had they been exposed to argumentation around the same concepts over time; we might have observed a different pattern in students' progress on constructing scientific arguments. Finally, we want to emphasize the role of teacher in these reported results. While the teacher was knowledgeable about argumentation as an instructional approach, she did not successfully frame learning tasks when presenting the task, so the students would deliberately and persuasively engage in justification of their knowledge. As a result, students invested limited effort in elaborating on their justifications. The importance of teacher framing has been shown to greatly influence the quality of arguments produced by students (Berland & Hammer, 2012; Kelly & Chen, 1999; McNeill & Krajcik, 2008; Songer, & Wenk Gotwals, 2012). For instance, McNeill and Krajcik (2008) found that students construct high quality arguments when their teachers provide an explicit rationale for the importance of argumentation and provide the necessary guidance and scaffolding for them to construct scientific arguments. However, this claim needs to be further verified through systematic studies of teacher framing in the context of argumentation. Our future efforts will focus on exploring the effect of teacher framing on the quality of students' arguments.

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Use of Biographical Recount of Famous Scientists to Enhance Scientific Literacy for New Pre-Service Primary Science Teachers at the Lebanese University

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Abstract

The preparation of scientifically literate citizens able to use science in their daily life is becoming a major goal in science education. In light of this, Boujaoude (2002) developed a framework to investigate the balance of scientific literacy themes within the Lebanese school science curriculum. He reported the neglect of "science as a way of knowing" in the Lebanese science curriculum and national textbooks. The purpose was determining the perception of pre-service primary science teachers, at the Lebanese University- Faculty of Education, of science and scientists, and examining their scientific literacy according to BouJauode (2002) framework. In addition, the study investigated whether the use of biographical recounts of famous scientists would enhance scientific literacy, and promote science as "a way of knowing" in classrooms. It was found that participants perceived science mainly as a body of knowledge, and that the implementation of the biographical recount activity exposed them to other aspects of science, and helped them enhance their scientific literacy.

Key words: Scientific literacy, Perception of scientists, Pre-service primary science teachers, Biographical recount of famous scientists

Introduction

Science educators around the world are currently trying to switch the emphasis of science education from the focus on academic scientific education within schools to the application of science in everyday life. Therefore, the preparation of scientifically literate citizens able to use science in their daily life and to take related decisions is becoming a major goal in teaching and learning science (BouJauode, 2002). The call for the reforms has led to an international effort aiming to promote scientific literacy as a major goal and outcome of science education in various countries around the world (Bybee, 2008).

Scientific Literacy

The term "scientific literacy" includes a wide variety of different definitions in the literature. It was first introduced in science education by Hurd (1958), who expressed a deep concern of how fast the world was changing and the urgent need of a new approach to education. The author emphasized on the quick change and developments in science and technology. The necessity to educate children adequately to enable them to meet the challenge and become good citizens living in a society full of scientific and technological advancements, by providing them with the necessary knowledge and skills. Hurd (1958) addressed the gap between scientific achievement and scientific literacy. He reported that the problem lies within the fact that scientific achievement was high, but scientific literacy was poor among students. Although Hurd introduced the concept of scientific literacy, he did not provide a clear definition for it.

Since the 1960s, the main focus of science education has become to educate people to be aware of scientific and technological developments. Many efforts have been exerted, to cite only, "Science for All Americans" (American Association for the Advancement of Science [AAAS], 1989) and "Benchmarks for Science Literacy" (AAAS, 1993) that were the products of one of the most important projects in USA, known as Project 206. They considered scientific literacy as a main goal for science education and initiated reform in science education. In addition, The National Science Education Standards (National Research Council [NRC], 1996) contributed to the reform in science education by setting the standards for achieving scientific literacy.

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During the 1970s and early 1980s, scientific literacy came to be even more strongly identified with science in its social context (DeBoer, 2000). In his historical review about scientific literacy, DeBoer (2000) concluded that there are many ways to reach scientifiy literacy; and the main outcome of scientific literacy is to lead students to find something interesting in science, and continue to study science both formally and informally in the future. The author added that scientific literacy changes and grows over time, and it primarily exists in the adult population. He stated that "few if any students can be said to be "scientifically literate" upon graduation from high school in any meaningful sense of the word. At best, students have been introduced to science and the issues that science raises in society, and they like science and care enough about it to stay informed as adults"(p. 597-598).

The science education community has no consensus about the definition of scientific literacy (Laugksch, 2000). Roberts (2007) discusses that although scientific literacy has been defined as a goal of science education, there is no agreement about its meaning and implication. He outlined two visions of scientific literacy: the first emphasizes on students' understanding of human affairs like a scientist does, and the second includes citizen understanding of science and the scientific investigation.

Nowadays researchers and science educators consider scientific literacy as multidimensional concept including science concepts and ideas, the nature of science, and the interaction of science and society (Laugksch, 2000). Dani (2009) considered that a scientifically literate person can identify scientific issues underlying national and local decisions, and express positions that are scientifically and technologically informed, while being able to evaluate the quality of scientific information on the basis of their source and the methods used to generate them. Holbrook and Rannikmae (2009) have examined the concept of scientific literacy within two major camps: the first one focusses on the knowledge of science, and builds on the notion that the content of science is a crucial and essential component of scientific literacy. This view is very common among science teachers today. Whereas the second point of view among researchers focusses on the longer term view; as it sees scientific literacy as a requirement for any individual in the society to be able to adapt to the challenges of a rapidly changing world. This view of scientific literacy aligns with the development of life skills.

The Program for International Student Assessment PISA (2015) targeted scientific literacy, and assessed how well 15 year-old students from over 80 countries were prepared for life beyond the classroom. PISA defines Scientific Literacy as the ability to engage in science-related issues, and in the ideas and concepts of science, as thoughtful and reflective citizens. Therefore, a scientifically literate person is someone who is willing to engage in the world of science and technology, which requires the development of three competencies: "Explain phenomena scientifically" **(**recognize, offer and evaluate explanations for a range of natural and technological phenomena); "Evaluate and design scientific enquiry" (describe and appraise scientific investigations and propose ways of addressing questions scientifically) and "Interpret data and evidence scientifically" (analyze and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions).

Chiapetta, Sethna, and Fillman (1993) proposed four dimensions or themes for scientific literacy: Science as a way of thinking, science as a way of investigation, science as a body of knowledge, and science and its interaction with technology and society. Based on these four dimensions, BouJauode (2002) developed a framework that includes four characteristics or aspects of science literacy: aspect 1 the knowledge of science, Aspect 2 the investigative nature of science, Aspect 3 science as a way of knowing, and Aspect 4 the interaction of science, technology and society.

Scientific literacy in the Lebanese educational system

The general objectives of the Lebanese science curriculum highlight the importance of conceptual and procedural components of science. It stresses on the understanding of scientific concepts and their implications to everyday life (National Center for Educational Research and Development, 1995). BouJaoude (2002) conducted an analysis of the Lebanese science curriculum to investigate the balance of scientific literacy themes within it, as well as its potential to prepare scientifically literate citizens. He used the four aspect framework he developed and found great emphasis in the Lebanese curriculum on the knowledge of science" (Aspect 1), "the investigative nature of science" (Aspect 2), and the "interactions of science technology, and society" (Aspect 4), and a neglect to the third aspect of the framework, which is "science as a way of knowing" (2002, p. 153). The author claims that the curriculum's emphasis on the "interaction of science, technology, and society" holds a potential for the development of decision-making citizens who use scientific knowledge meaningfully in their lives. However, he cautions, "Teaching, assessment, and the quality of textbooks used are also important factors that need to be considered if students' experience with science is to be complete and fulfilling" (BouJaoude, 2002, p. 154).

Dani (2009) examined Lebanese teachers' purposes for teaching science against the backdrop of BouJaoude's (2002) framework of scientific literacy. The author interviewed eight intermediate and secondary Lebanese science teachers, five males and three females, conducted classroom observations, and collected various artifacts such as lesson plans and classroom handouts. The results of his study showed that participants' purposes for teaching science corresponded with the aspects of "the knowledge of science," "the interaction of science, technology, and society," and "the investigative nature of science" aspects of scientific literacy described by BouJaoude. In addition, all participants considered that the national textbooks and exams facilitate the operationalization of their "knowledge of science," and "investigative nature of science" goals since these documents emphasize on these two aspects of scientific literacy. These results reflect the aspects of scientific literacy emphasized in the Lebanese science curriculum as reported by BouJoaude (2002).

In an unpublished thesis, Miski (2013) measured the scientific literacy of Lebanese grade 10 students on the basis of PISA framework. The study included 14 students from public and private high schools in Beirut. Miski reported that students were able to "explain phenomena scientifically" and to "interpret data and evidence scientifically", however the competence of "evaluate and design scientific enquiry" was not developed.

Research Problem

Being an Assistant Professor at the Lebanese University, Faculty of Education, in the Science Education Department, the research conductor of the current study has noticed over years of instruction that pre-service teachers in science department perceived science as mainly being a body of knowledge, ignoring the procedural aspect of science. It is well believed that teachers are one of the most important factors that play a key role in promoting scientific literacy. Therefore, they must be well prepared in both science subjects and science teaching education. Thus, they must have a thorough understanding of the implication of science in society and of the current technological advances affecting society every day. In this vein, Shulman (1987) stated that the role of teachers is crucial in promoting science literacy in both schools and society, and therefore research on teachers' education suggests that both teachers' subject matter knowledge and teachers' pedagogical knowledge are crucial to good science teaching and student understanding.

Consequently, scientific literacy requires, to be achieved, more than teaching and learning science as a body of knowledge. In fact, developing it requires a wider view of science where three principal components are included: the knowledge of science, the methods of science, and the nature of science (Lederman, 1998). Unfortunately, candidates entering the pre-service science teaching program at the faculty of Education at the Lebanese University are mainly exposed to science as body of knowledge during their academic journey, and this is mainly due to the lack of an epistemological view in the Lebanese Science curriculum (BouJauode, 2000). For these reasons, the purpose of this study was first to determine the scientific literacy of new candidates of pre-service science teaching program at the Lebanese University, Faculty of Education, according to BouJauode's (2002) framework, and also to investigate possible ways of promoting science as "a way of knowing" in classrooms. This aspect of scientific literacy was featured by the framework as being where the emphasis is on thinking, reasoning, and reflection in the construction of scientific knowledge and the work of scientists which includes all the mental and experimental activities of "doing Science" (see table 1).

Biographical recounts of famous scientists were chosen as a way to promote "science as a way of knowing". The main reason behind the use of the biographical recounts activity, was that searching the life and main achievement of scientists will allow the exploration of the main components of "science as a way of knowing". Through biographical recounts, students would be exposed to the work of scientists, how they detect problems, use assumptions, test their ideas and find evidence; and thus students will be able to explore the empirical nature of science. The following specific research questions were addressed:

1- How do pre-service science teachers, namely first year students' of primary science teaching program at the Lebanese University, Faculty of Education perceive "Science" and "Scientists"?
2- Does their "science" perception correspond with the four aspects of scientific literacy presented in BouJauode (2002) framework?
3- Does the use of biographical recount of famous scientists promote the development of scientific literacy, and mainly the development of "science as a way of knowing" aspect of scientific literacy?

It is assumed that through the "Biographical recounts of famous scientists" activity, scientific literacy would be enhanced, especially the aspect of "science as a way of knowing". It is also suggested that this sort of activity does not develop the skills of science as "way of knowing", but rather promotes awareness among students regarding this aspect of scientific literacy, since it is completely denied and neglected in the curriculum and the practice.

Method

The framework developed by BouJauode (2002), presented in table 1, was used to find out the degree of congruence between the participating pre-service science teachers' perception of science, and aspects of scientific literacy, as well as to investigate the effect of the use of biographical recounts of famous scientists in promoting scientific literacy i.e. mainly the "science as a way of knowing" aspect, which was reported as neglected in previous studies.

Table 1. BouJaoude (2002) framework of scientific literacy

Aspects of scientific literacy	Components
Aspect 1: The knowledge of science	• Facts, concepts, principles, laws, hypotheses, theories, and models of science.
Aspect 2: The investigative nature of science	• Using methods and processes of science such as observation, measuring, classifying, inferring, recording and analyzing data; • Communicating using a variety of means such as, writing, speaking, using graphs, tables, and charts; • Making calculations; • Experimenting.
Aspect 3: Science as a way of knowing	• Emphasis on thinking, reasoning, and reflection in the construction of scientific knowledge and the work of scientists; • Empirical nature of science Ensuring objectivity in science; • Use of assumptions in science Inductive and deductive reasoning; • Cause and effect relationships; • Relationships between evidence and proof; • Role of self-examination in science; • Describes how scientists experiment.
Aspect 4: Interaction of science, technology, and society	• Impact of science on society; • Inter-relationships between science, society, and technology; • Careers Science-related social issues; • Personal use of science to make everyday decisions, solve every- day problems, and improve one's life Science related moral and ethical issues.

The framework was used by Lebanese researchers to investigate scientific literacy such as Dani (2009) and by international researchers such as Cansiz and Turker (2011), who investigated the Turkish science and technology curriculum for the balance of scientific literacy (SL) aspects, and its potential to educate scientifically literate citizens.

Sample

Participants consisted of a convenient sample of 25 first year students of pre-service primary science teaching program at the Lebanese University Faculty of education, where English and French are the languages of instruction. They all hold Lebanese baccalaureate degrees in "Life Science" or "General Science", coming from both private and public high schools in Lebanon. The primary science teaching program at the Lebanese University Faculty of Education consists of a three years full time course, equivalent to six semesters. The study was conducted during the first semester of the first year; so all students were still new to the educational program provided by the Faculty of Education, and therefore their perceptions of science were not yet influenced by the content of the program offered by the teacher training program.

Data Collection and Analysis

In order to explore the perceptions of science and scientists, and before the intervention of biographical recounts of scientists, participants were interviewed, in writing, about their perceptions of

- "Science" by answering the question "what is science?"
- "Scientists" by drawing a scientist of their choice, and answering questions about that scientist, specifying his/her gender, social status, family life, social life and work.

In addition, they were also asked

- Do you think you can be a scientist? Explain why.
- Do you like to become scientists? Explain why.
- Where did you get your information about scientists?

Then, participants were asked to research the biography of famous scientists (scientists who have made major contributions in biology e.g. Claude Bernard, Gregor Mendel, Louis Pasteur and many others) by following a detailed biographical recount template provided by the researcher, focusing on the personal life of the scientist (childhood, teenage, social status), education, major events that affected the scientist's career, and major achievements with all the details provided throughout their work.

Students worked in teams and presented their work in class. After around two weeks of presentations and discussions, they were asked to reflect on their work and answer the following questions:

- Being a pre-service science teacher, what did you learn from this experience about Science and scientists?
- Participants' perceptions about science before and after the intervention were analyzed and classified as belonging to Aspect 1, Aspect 2, Aspect 3, and Aspect 4, then the frequencies and percentages of each aspect of scientific literacy were computed.

Results and Discussion

Before the Intervention

Participants' Perceptions of Scientists

80% of participants perceived the scientist as male, not married, not ready to have a family life, and not engaging in any social or political activities; they drew male scientists, wearing goggles and white coats in labs; 84% of them believed that scientists spent all their life in their laboratories. Figure 1 represents a sample of the participants' drawings of a scientist.

Figure1. Sample of participants' drawings

All participants considered it is very hard to be a scientist. Some of them attributed it to the fact that scientists are born with special talents

> I can't be a scientist…a scientist is a very talented person

others believed that they can't, because they don't have the skills and competencies that enable them to be scientists

> I can't be a scientist… scientist have special skills and competencies

another reason stated by the participants was the scientist's imagination

> it is impossible to become a scientist, he has a wide imagination.

As for the question about whether they would like to become scientists, 10 participants out of 25 (40%) didn't like to be scientists and considered that a scientific career would affect their social and marital life, e.g.

> I wouldn't like to ignore myself or my social life"; "I want to have a normal life"; "I love my life and my family, I don't want to be isolated in lab.

4 participants (16 %) liked to become scientists

> I like to become a scientist and work on new inventions, the work of a scientist does not affect his life"; " I like to be a scientist..";" I think it is not hard to be a scientist if I have specific conditions like knowledge and expertise and I should love to be a scientist.

11 participants (44 %) were hesitant about this questions and their answers varied between "not sure" and "don't know". All participants agreed that the main source of information about scientists was media and science textbook.

Participants' Perceptions of Science

In this study, the perceptions of participants were classified as belonging to Aspect 1, Aspect 2, Aspect 3, and Aspect 4, and then the frequencies and percentages of the each aspect of scientific literacy were tabulated. The overall distribution of percentages of participants' perception about science with regards to the four aspects of scientific literacy is shown in Table 2.

Table 2. Distribution of percentages of participants' perceptions about science with regards to the four aspects of scientific literacy

Perception of Science			
Aspect 1 Knowledge of science	Aspect 2 Investigative nature of science	Aspect 3 Science as a way of knowing	Aspect 4 Interaction of science, technology and society
72%	20%	16%	12%

It was found that the knowledge of science (Aspect1) is overemphasized when compared to the other three aspects. The Investigative nature of science (Aspect 2) is fairly emphasized, while science as a way of knowing (Aspect 3) and "interaction of science, technology and society" (Aspect 4) were underestimated.
The distribution of percentages of participants' perceptions about science in regards to single or combined aspects, as well as samples of the participants' answers are shown in table 3.

Table 3. Distribution of percentages of participants' perceptions, and answers samples about science in regards to single or combined aspects.

Aspects	Percentage	Samples of Participants answers
1	56%	- "Laws and theories that deals with physics, chemistry and biology." - "Study of animal, plants and human." - "Knowledge of anything surrounding us."
1 + 2	4%	- "Study and observation of living things surrounding us."
1+3	8%	- "Study to explain and understand what is going on around us." - "Study to understand"
1+4	4%	- "Knowledge and study of the interaction between organism and its surrounding"
2	12%	- "Experiment." - "Validation of hypothesis and observation."
2+3	4%	- "Experimentation and Discovery"
2+4	0%	
3	4%	- "Study of relationships/cause and effect"
3+4	0%	
4	8%	- "Respond to our needs"
2+3+4	0%	
1+2+3+4	0%	

The table above shows that the majority of participants' answers displayed a single aspect of science, with a predominant percentage, 56%, of Aspect 1 representing "knowledge of science, whereas the percentages of Aspect 2 "Investigative nature of science", Aspect 3 "Science as a way of knowing" and Aspect 4 "Interaction of science, technology and society" were respectively 12%, 4% and 8%. However, for answers displaying more than one aspect of scientific literacy, they all included only two aspects, with predominance of Aspect 1: answers including Aspect 1 with Aspect 2 make 4%, 8 % for Aspect 1 and Aspect 3 and 4% for Aspect 1 with Aspect 4. Only 4 % of answers included two aspects different from Aspect 1 which are Aspect 2 and Aspect 3. None of the answers included three aspects or the four aspects combined together. These findings indicate that the participants perceived science in a single dimension, so they were not aware of the multi-dimensional feature of science.

After the Intervention

Participants' Perceptions of Scientists

Interviews were conducted with all the participants about whether they can and like to be scientists.
17 out of 25 (68%) considered that scientific skills and competencies are learned:

> I think that I can be a scientist but I just need to work more on myself, learn more and get support"; "I can be a scientist, since a scientist's first character is to ask questions… and answering them by experimenting.

20 out 25 (80%) reported that they would like to become scientists, and considered that a scientist is a person that can have a normal life:

> I would like to be a scientist since I love to discover new things… distribute my time or manage it for everything… working and being motivated to reach my scientific goals and having a normal life, getting married, having children and all luxury conditions"; "Scientists may have a social life and a family, divide their time between family and work.

Participants' perceptions of science

After the intervention of biographical recounts of famous scientists, participants were asked to reflect on their work, and describe what they have learned about science, apart from the fact that it is a body of knowledge. Table 4 shows the percentages of the three aspects of scientific literacy, apart from Aspect 1, identified in their answers.

Table 4. Percentages of aspects 2, 3 and 4 of scientific literacy identified in participants perception of science after the usage of biographical recount

Perception of Science			
Aspect 1 Knowledge of science	Aspect 2 Investigative nature of science	Aspect 3 Science as a way of knowing	Aspect 4 Interaction of science, technology and society
-	32%	80%	36%

It was found that the Investigative nature of science (Aspect 2) and interaction of science, technology and society (Aspect 4) increased fairly to 32% and 36% respectively. This biggest difference was with science as a way of knowing (Aspect 3) which increased from 16% to 80%.

The distribution of percentages of participants' perceptions about science after the intervention of the biographical recount of a scientists, in regards of single or combined aspects, as well as samples from participants' answers are presented in table 5.

Table 5. Distribution of percentages of participants' perceptions, and answers samples about science in regards to single or combined aspects after the usage of biographical recount of scientists

Aspects	Percentage	Samples of participants' answers
2	0%	
2+3	12%	- "Through biographical recount we discover many things about science and scientists: how they think, their reasoning, inductive or deductive reasoning, analyzing, how they used differences and similarity." - "Discover the methods they (scientists) applied and lead them to their discoveries. They have applied the scientific method, in a deductive or inductive approach, experiments, and the observations that triggered the first torch of their investigation."
2+4	0%	
3	36%	- "Science is not stable." - "Scientific thinking includes curiosity, creativity and objectivity" - "The great work and contribution of these scientists is the results of hard work…it helped us know how does the scientific thinking go, how does a theory evolve …and good scientist is the scientist that use the other scientists work and build on it in order to reach his goals."
3+4	16%	- "Scientists are ordinary people, their discoveries are result of hard work. Science includes thinking, interaction within scientific community".
2+3+4	20%	- "Scientists formulate hypothesis, interact with their environment. Science includes curiosity, and scientific work results in making laws". - "Scientists react with their surroundings, they use scientific investigations to discover things, and they use skills."

What is interesting in the findings above, that the answers combining the three aspects 2, 3 and 4 increased from null before the intervention to 20%. This finding suggests that the participants were exposed to different aspects of science through the activity of biographical recount.

Conclusion

The first purpose of this study was to explore participants' perceptions about scientists and investigate ways to improve their views about scientists. The results show that participants relied mainly on information presented by media and in science textbooks, where mostly male scientists are presented. At first participants considered it to be very hard to be a scientist, as they perceived scientists to be naturally skilled and talented. After the introduction of the biographical recount project, participants changed their perceptions, as they discovered that scientific skills and abilities are acquired through education and experimentation. They also learned that scientists lead normal lives. The findings of the study are parallel to the findings of Erten, Kiray and Sen-Gumus (2013) in that certain treatments may change students' views of science and scientists.

Another purpose of this study was to investigate the degree of congruence between the participants' (primary science teaching program first year students) perceptions of science with aspects of scientific literacy as per BouJaoude's (2002) framework. The results of this study show that participants' perceptions of science were mostly focused on "the knowledge of science" (Aspect 1), that reflect scientific knowledge such laws and facts, whereas the other views of science represented in "Investigative nature of science" (Aspect 2) that focalize on the science process skills, and those presented in "science as a way of knowing" (Aspect 3) and "interaction of science, technology and society" (Aspect 4) vary from fair representation for Aspect 2, to almost missing for aspect 4. Those findings are by large in line with BouJaoude's (2002) and Dani's (2009) findings about the Lebanese curriculum, teachers and textbooks literacy in science. However, it is found in this study that the participants underestimate the aspect of "interaction with science, technology and society"; a finding not reported in previous studies.

In addition, the study highlighted that most participants hold a unidimensional view of science, as they were not able to perceive the multidimensional identity of science. However, the usage of biographical recounts of famous scientists has helped participants to shift their perceptions from a unidimensional view of science to a more comprehensive one that includes more than one dimension of scientific literacy.

Recommendations

Regarding the intervention proposed in this paper about the use of the biographical recounts to enhance scientific literacy, the results suggest that this activity is beneficial to promote scientific literacy among students, mainly "science as a way of knowing"- the missing aspect in the Lebanese curriculum. The activity allows them to discover how scientists think, reason, and reflect in the construction of scientific knowledge. In addition, it highlights the empirical nature of science by ensuring the objectivity in science. Moreover, thorough biographical recounts of scientists, students would discover careers in sciences, and how science is related to everyday life. It is recommended that this activity would be used by science teachers, where students may research the biography of scientists related to the studied topic. It is also advisable that teachers choose Lebanese scientists, when available, to highlight the impact of science in society. However, this activity is not enough to develop scientific literacy, it helps to give an insight to the "investigative nature of science", "science as a way of knowing" and "interaction of science, technology and society". It may be one of many instructional processes used by teachers. As Abd-El- Khalick and Lederman (2000) reported that science teachers should use explicit and reflective instructional processes to promote "the nature of science" perspectives that lead to the development of scientific literacy.

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Children's Conceptual Development: A Long-Run Investigation

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Abstract

The study sought to investigate conceptual change process. It is specifically aimed to probe children's initial ideas and how or to what way those ideas alter in the long run. A total of 18 children volunteered and participated in the study. Individual interviews were conducted. The children were asked to define the concept of evaporation, explain how this phenomenon occurs, and picturize this natural occurrence. A total of five consecutive interviews were conducted. All interviews were recorded and later transcribed. The results indicated the children's initial ideas got enriched in time. In this course of enrichment, instead of replacing radically their former conception with the novel one, the children seemed to have reinterpreted the new idea within the framework of their prior knowledge. The novel conception further is mixed up with the elements from both old and new beliefs leading intermediate structures to emerge. The data further indicated the children seemed to have been unable to recognize the discrepancies between their personal knowledge system to that of the scientific. They seemed lacking meta-conceptual awareness preventing them to compare and contrast their personal views to that of scientifically accepted one.

Key words: Conceptual change, Radical change, Enrichment process, Children conception

Introduction

Investigating how children's conceptual change or development occurs has been and is still one of the topics of concern in education. There is a good reason for this concern. Figuring out and knowing what initiates conceptual change, how it occurs, and what is the end product of it make us get a better understanding of this process and be aware of the limitations and allowances of our instructional strategies. In the literature, how one's conceptual change occurs is mostly affected by the ideas of Jean Piaget (1977). To him, as interacting with his/her surrounding, one either assimilates it or accommodates a novel mental structure in order to get adapted to it. According to this latter view, one, therefore, needs to construct a mental structure in order to perceive or cope with novel situations. This course of constructing action was seen as a radical or revolutionary change (Stafylidou & Vosniadou, 2004; Vosniadou, 1994; Vosniadou, Ionnides, Dimitrakopoulou Papademetriou, 2001), hard core change (Lakatos, 1970), or strong restructuring (Carey, 1985). To illustrate, abandoning the idea that the earth is a flat object with no motion and supported by ground or water and adopting the idea that the earth is a sphere object rotating around its axis and moving with no support (Vosniadou & Brewer, 1992) is viewed as a radical change. The important question that we ask to ourselves is now whether this sort of change could possibly happen, how it could be searched out and what others have done so far.

A number of empirical studies (Samarapungavan, Vosniadou, & Brewer, 1996; Samarapungavan & Wiers, 1997; Stafylidou & Vosniadou, 2004; Vosniadou & Brewer, 1992; Vosniadou, Skopeliti, Ikospentaki, 2004) investigated knowledge acquisition process or conceptual change through probing children's thoughts on astronomy, origin of species, fractions, shape of the earth, and day/night cycle respectively. In gathering data, these studies utilized an identical method. They probed the children's beliefs once through interviews or questionnaire and the development of children's understanding was determined by comparing beliefs held by different age groups. This comparison allowed the researchers to appreciate how children's conception alters from one grade to another. In other studies (Alvermann & Hague, 1989; Beerenwinkel, Parchmann, & Gr¨asel, 2011; Mikkilä-Erdmann, 2001), in an experimental (pre- and post-test) condition, the impact of a variable (refutation text or conceptual change text) on improving children's understanding was investigated. These studies indicated that the text involving or discussing alternative ideas is effective in initiating conceptual change process. However, none provided a qualitative analysis and seemed being short in offering a comprehensive account for the change process.

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The present study, unlike others cited above, aimed to investigate the change process through a different method. Rather than examining the ideas of different age groups or employing quantitative methods in gathering data, a qualitative and prolonged method was preferred to monitor the change process. In other words, in this paper, the change process is probed through a long-term follow-up. The questions such as 'What is the make-up of the initial idea?' 'What happens to it after an intervention?' And 'what happens to it in the long run?' became the focus of our concern.

The Aim of the Study

The aim of the present paper is to explore the development of children conceptual understanding for the concept of evaporation. It is specifically aimed to probe children's initial ideas on the concept of evaporation, how those ideas evolve when they get exposed by a scientifically accepted view, and what happens, in this transition, to alternative ideas. Therefore, the following research questions are the focus of our concern.

1. How do children's initial ideas about evaporation evolve?
2. What happens to alternative ideas if instruction solely focuses on the concept of evaporation?

Theoretical Framework

In order to comprehend how the learner grasps, modifies or shifts novel ideas, we primarily need to identify the notion of theoretical knowledge. According to Davydov (1990), theoretical and empirical thoughts possess discrete contents. Theoretical thought involves a system of interaction, an organized whole, which is the realm of objectively interconnected phenomena. This interconnection or essential relationship cannot be observed readily through the senses and it brings together things that are dissimilar, different, multifaceted, and not coincident. In contrast to empirical thought, a theoretical one does not find identical in every particular object in a class. Rather, it traces the interconnection of particular objects within the whole. To illustrate, recognizing the interconnection amongst sunrise, day, sunset, night, the Sun and the Earth's shape and rotation around its axis points to a theoretical understanding explaining the cycle of day and night. This notion, which is not readily observable, brings together the things (sunrise, day, sunset, night, the Sun, the Earth's shape, rotation around its axis) that are indeed dissimilar, different, multifaceted, and not coincident. How does such a theory grow in one's mind? Or How does one grasp a theoretical idea?

As studying semiotics, specifically language and interpreting the ideas of Ferdinand de Saussure, a linguist and semiotician, Chandler (2007) alleged that meaning is a structural and relational entity rather than a referential one. To him, within the system of the language, no sign makes sense on its own, but it gets meaning only in relation to other signs. In other words, the value of a sign depends on its relations with other signs within the system as a whole. Meaning of a sign hence refers to a specific position within a particular system and represents dissimilarities. It involves negative oppositional differences amongst signs. The growth of a sign therefore depends on other signs within a whole. Similarly, according to Davydov (1990), in the growth of theoretical ideas, the former idea is replaced by its own other retaining everything positive in it. In other words, because the conceptual growth happens through the differentiation of former ideas, new ideas exist with its relation to the former ones. For instance, after learning to draw the letter a , a child builds a mental structure for it. Thereafter, as learning to draw the letter g , the child might think, 'In order to draw the letter g, I just need to draw the letter a and add a tale to it'. The value of drawing the letter g therefore depends on its relation with another sign, the letter a, within the system of handwritten alphabet as a whole. Meaning of building the letter g hence refers to a particular position within the alphabetic system and represents the dissimilarity (the short tale in this specific case) from the letter a. The novel conception for the letter g hence depends on and grow from the differentiation of the former concept of a. The value of drawing the letter g could only exist with its relation to the letter a.

Further to that, similarly, to van Oers (2001), an abstract is not a recognition of a general characteristic of objects; rather, it is an attribute added to the objects in our thinking. In abstraction (in the growth of a theoretical idea), there is a process of enrichment rather than that of impoverishment. For instance, a child might initially think that every living that flies is a bird. The concept of bird thus brings together things (pigeons, crows, eagles, sparrows, flies, grasshoppers, bees, and the like) that are dissimilar, different, multifaceted, and not coincident. The flying property is therefore a dissimilarity of the concept of bird from the related concept of land animal. However, he/she later learns that the small featherless ones are indeed insects. Meaning of ‘bird’ within the system of signs for flying livings is differentiated once more and now represents both flying and feathered ones, which are two negative oppositional differences from the signs for the land animals and insects respectively. In other words, the feathered property is added to the meaning of the bird. This act of addition is therefore an enrichment process. The concept of bird is enriched by differentiating it from the insects and land animals.

Method

The Sample and the Study Context

The study was carried out at a rural elementary school located in Gaziantep, Turkey. A total of six third graders, of whom one was female and five were male, and twelve fourth graders, of whom nine were female and three were male volunteered and participated in the study. The concept of evaporation was first introduced to children at third grade under the unit of water cycle and, in order to reveal the children's initial ideas on evaporation, individual interviews were conducted. In the interviews, the children were particularly asked to define the concept of evaporation and explain how this phenomenon occurs. They were next asked to picturize this occurrence. They were further asked to describe and interpret their drawings. In this way, it is aimed to get a comprehensive view on their initial understanding of evaporation. All the interviews were video taped and carried out by the second author. Each interview lasted about 10-15 minutes. After these initial interviews, the second author met the children in their spare time at the school and had an instructional discussion on evaporation.

The discussion started with having a conversation on the meaning of the concept of evaporation. One child pointed that evaporation occurs when the water boils in a kettle. Another one stated that if there is water in a lake, when the Sun touches it, it evaporates. Still another stated if we pour some cologne on to our hands, it evaporates. The teacher repeated the child's explanation and also told that when we pour cologne on our hands, it takes heat from us as it evaporates. A different child restated the teacher's utterance. Another one stated that because of the Sun, water in pools runs out in time. The discussion next continued with an experiment where one child, in front of the class, dipped a piece of wipe in a glass of water and wiped his face with it. The child was afterward asked what she might have felt. After she said she had felt cool, the teacher asked the class to offer an explanation for why she has felt that way. The children provided various explanations. For instance, one child stated, 'when cold water touches our face, it takes its temperature; it cools our face. Another child stated, 'because water is cold, she felt cool', and another one stated, 'her face was initially hot. Later, when she wet her face, the water evaporated and water is formed, because of that, she felt cold'. The dialogue continued with a discussion. They discussed what happens if hot water was used instead and why one feels cool after having a shower. Then, the teacher showed a photo of a lake taken in winter, in which there is thick fog formed on its surface and asked the children what they see in the photo. The children jointly indicated that there is evaporation on the surface of the lake. They further indicated that heat or temperature is responsible for this occurrence and the source of heat ought to be the Sun. The dialogue later continued with a discussion on whether evaporation causes a decrease or no change in the amount of water in the lake. Then, the teacher showed a picture very similar to the one (Figure 1) depicted below.

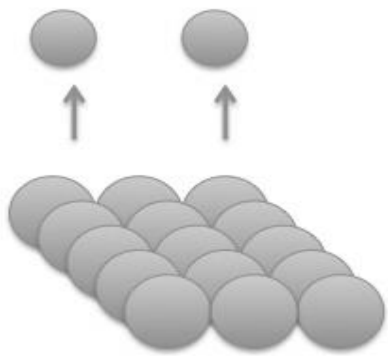


Figure 1. The water particles leaving the surface layer

The teacher thereafter provided an explanation for evaporation process and pointed to such details: (1) in water are tiny particles (pointing to Figure 1), (2) these tiny particles could not be seen by naked eye, (3) the particles tightly hold one another from below and sides, (4) when the particles get heat, they start to move and begin to move farther away form each other, (5) particles with high energy get their energy from other particles, (6) particles possessing higher energy get into the space above the liquid, (7) the remaining particles have a lower energy, and (8) evaporation is hence a cooling process. The teacher did this explanation two times. Thereafter, the children played a game. The teacher first drew a big circle in front of the class and asked for volunteers. Six children volunteered and got into the circle. Then, the teacher asked them to imagine themselves as being water particles in a cup. The children standing up then started to move in their place. After the teacher said that they are getting heat energy, the children began to move faster and bump into one another. The bumping eventually resulted in two children jumping out of the circle. The remaining ones however sustained their motion. Right after, the teacher intervened the play and stated that there happened an energy transfer and the particles with higher energy got out of the liquid. This is called evaporation. The teacher therefore fulfilled the activity with an emphasis on evaporation process without mentioning or discussing any alternative conceptions that children had or could possibly hold. Afterward, individual interviews were again conducted with the children. In the mean time, no child had further instruction on evaporation. The first interview was conducted right after the above discussion on the same day, the second one is done one week later, the third one was done two weeks later and, the fourth one was done nine months later. Together with the interview done at the beginning of the study, a total of five interviews were conducted with each pupil. All the interviews were recorded and, consequently, a total of 90 videos were taped.

Data Analysis

The videotapes were first transcribed. The transcriptions were next read several times and inductively analyzed (Patton, 2001). In this course of analysis, numerous patterns (codes) were discovered and the emerging codes were later defined. Operational definitions for the codes are depicted in Table 1

Table 1. Operational definitions for emergent codes

Codes	Definitions	Exemplary Children's Explanations
1. Cycle	The statements that indicate that the formation of snow, cloud or rain is part of evaporation process; or drawing a cloud(s) without declaring it in the interview.	*When we put the fire under water, it evaporates. Water then rises into the air. Then it becomes cloud.*
2. Particle	The statements that indicate evaporation happen as tiny particles (micro particles that could not be seen by naked eye) of water get into air or drawing small circles as a representation of water particles without declaring them in the interview.	*For instance, if we put some water in a glass. There are small particles that we could not see. Under the Sun, those particles fly into air.*
3. Boiling	The statements that indicate evaporation happen as a result of boiling or cooking of water in a pot.	*If you put some water in a pot, it evaporates by boiling.*
4. Melting	The statements that indicate evaporation happen as a result of melting of water.	*Put some water in a deep cup. If you put it under the Sun, it melts, evaporates.*
5. Warmth	The statements that indicate temperature, energy, the Sun, or heat causes evaporation to begin or drawing the picture of the Sun without declaring it in the interview.	*Let's say there is water. We put it under the Sun. As the Sun delivers its heat to it, it evaporates.*
6. Smoke	The statements that indicate evaporation happen as a result of burning something.	*Like this, you will burn bushes, smoke occurs.*
7. Fog	The statements that indicate evaporation happen as a result of formation of fog on the window.	*When you look at the window, if evaporates, you could not see outside. This happens when inside is hot.*

Based on operational definitions in Table 1, the video-transcripts were coded. Two additional coders also used the table and coded randomly selected transcriptions independently. Over ninety percent of the codes showed consistency, which indicated strong inter-coder reliability (Miles & Huberman, 1994).

The Results

Based on the operational definitions displayed in Table 1, the children's utterances were then analyzed. For instance, the following explanations are taken from the interviews with Pupil 16. In the interviews, she is repeatedly asked to explain evaporation process. She is also asked to draw a picture of the process and describe it in detail. Below are her explanations, drawings and descriptions of her drawings.

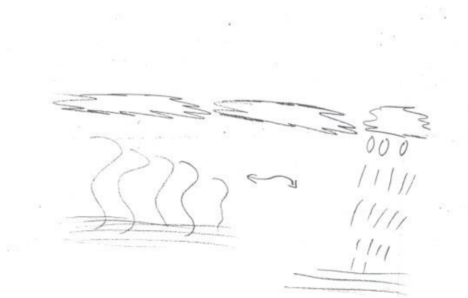
An Example

Former Interview

Pupil's (Pupil 16) Explanation:

In this process, the vapor moves from sea to clouds and moves from clouds to sea too. In the clouds, it turns into rain and falls into sea.

Pupil's Drawing and Description:

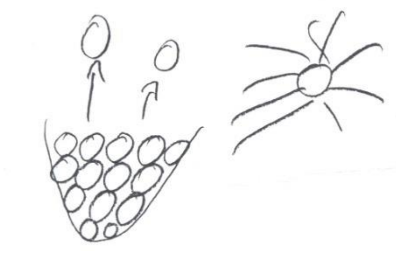


This is the sea. It is evaporating and going to the clouds. It is coming back from the cloud as rain.

First Interview

Pupil's Explanation:

It evaporates as delivering heat. The buds (particles) in the water jump into air when they get heat. They are attached to one another. When they get heat, they get separated from each other. Some that take a lot of energy jump up.



The heat from the Sun reaches to the buds. The buds that have high energy jump into air.

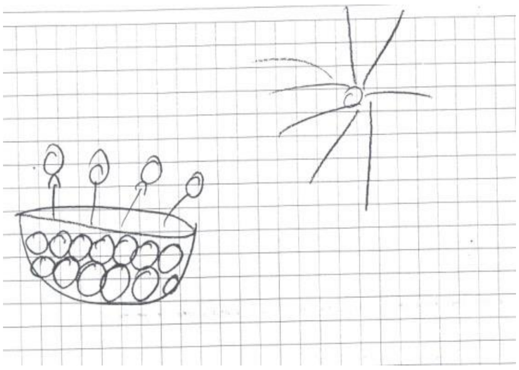
Pupil's Drawing and Description:

Second Interview

Pupil's Explanation:

There are buds in the cup. After they get heat, since they are attached, they get separated. Those they get more energy from the others jump into air. As heat reaches, water evaporates.

Pupil's Drawing and Description:



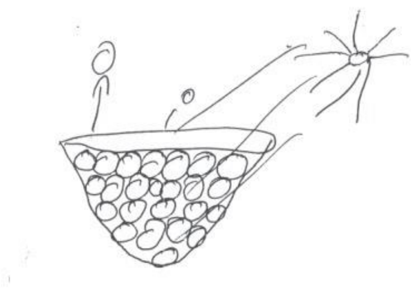
The Sun offers its heat, the buds that gets high energy separate from one another, some taken high energy jump up.

Third Interview

Pupil's Explanation:

Some water in a glass and there are buds in it that we could not see. When the Sun touches that water, the buds get separated from one another. Those getting a lot of energy jump into air.

Pupil's Drawing and Description:



As the Sun touches the water in the cup, the buds get separated from one another and those getting a lot of energy jumps into air.

Fourth Interview

Pupil's Explanation:

For instance, there is a lake, when the Sun gives heat to it, it goes to clouds. The clouds could not hold it and falls back to the earth as rain. Somewhere, there is a lake or sea. As the Sun gives heat, it evaporates and the clouds, in time, could not hold it. It comes down to the earth as rain.

Pupil's Drawing and Description:

In the former interview, she associated the evaporation process with the formation of cloud and rain. She, later, in the first, second and third interviews, associated evaporation process with small unobservable particles moving and escaping into air. She also pinpointed the important role of heat in this course. In the last interview, however, she again associated it with the formation of clouds and rain, and highlighted the role of the Sun as a heat source. In our analysis, her accounts are compared to the operational definitions depicted in Table 1 and assigned to such codes as Cycle, Particle-Warmth, Particle-Warmth, Particle-Warmth and Cycle-Warmth respectively. In a similar fashion, the remaining children's accounts are analyzed. Table 2 displays the emergent codes.

Here is a lake. Here as the Sun gives its heat, this water evaporates and goes to the clouds. Below, the clouds, in time, could not hold it, it comes down to the lake as rain.

Analysis of Children's Accounts for the Concept of Evaporation

In order to compare and see the trends in children's accounts depicted in Table 2, five figures were created. The figures allowed us to reduce and visualize data and, therefore, to perceive likely pattern(s) in the codes. Figure 2 depicts the initial codes emerging from the former interviews. In the following and subsequent figures, the capital letter C stands for Cycle, the letter B for Boiling, W for Warmth, P for Particle, F for Fog, S for Smoke and the letter M stands for Melting. To illustrate, the letters C-B-W signify the codes of Cycle, Boiling, and Warmth respectively.

Table 2. Analysis of children's accounts for the concept of evaporation

Children	Former Interview *(Before Intervention)*	First Interview *(After Intervention)*	Second Interview *(One week later)*	Third Interview *(Two weeks later)*	Fourth Interview *(Nine months later)*
	Codes				
Pupil 1 *(Male, third grade)*	Cycle Warmth	Cycle Particle Warmth	Particle Warmth	Cycle Particle Warmth	Cycle Particle Boiling Warmth
Pupil 2 *(Male, third grade)*	Smoke	Cycle	Melting Particle Warmth	Cycle Particle Boiling	Cycle Particle Boiling Warmth

Pupil 3 *(Male, third grade)*	Cycle Warmth	Cycle Particle Warmth	Particle Warmth	Particle Warmth	Cycle Particle Warmth
Pupil 4 *(Male, third grade)*	Cycle Warmth	Cycle Particle Warmth	Cycle Particle Warmth	Cycle Particle Warmth	Cycle Particle Warmth
Pupil 5 *(Male, third grade)*	Cycle Warmth	Cycle Particle Warmth	Particle Warmth	Particle Warmth	Cycle Particle Warmth
Pupil 6 *(Female, third grade)*	Boiling Warmth	Boiling Warmth	Particle Boiling Warmth	Melting Particle Warmth	Melting Particle Warmth
Pupil 7 *(Male, fourth grade)*	Fog	Boiling Warmth	Particle Warmth	Particle Warmth	Cycle Warmth
Pupil 8 *(Female, fourth grade)*	Boiling Warmth	Particle Boiling Warmth	Particle Boiling Warmth	Warmth	Cycle Boiling Warmth
Pupil 9 *(Female, fourth grade)*	Boiling Warmth	Particle Warmth	Particle Warmth	Particle Warmth	Warmth
Pupil 10 *(Female, fourth grade)*	Cycle Warmth	Cycle Particle Warmth	Particle Warmth	Particle Warmth	Cycle Particle Warmth
Pupil 11 *(Female, fourth grade)*	Melting Warmth	Particle Warmth	Particle Warmth	Particle Warmth	Cycle Boiling Warmth
Pupil 12 *(Male, fourth grade)*	Warmth	Boiling Warmth	Particle Warmth	Warmth	Cycle Particle Boiling Warmth
Pupil 13 *(Female, fourth grade)*	Cycle Boiling Warmth	Particle Warmth	Particle Warmth	Particle Warmth	Cycle Particle Warmth
Pupil 14 *(Male, fourth grade)*	Cycle Warmth	Particle Warmth	Particle Warmth	Particle Warmth	Cycle Warmth
Pupil 15 *(Female, fourth grade)*	Boiling Warmth	Particle Warmth	Particle Warmth	Particle Warmth	Particle Boiling Warmth
Pupil 16 *(Female, fourth grade)*	Cycle	Particle Warmth	Particle Warmth	Particle Warmth	Cycle Warmth
Pupil 17 *(Female, fourth grade)*	Cycle Warmth	Particle Warmth	Particle Warmth	Particle Warmth	Cycle Particle Boiling Warmth
Pupil 18 *(Female, fourth grade)*	Boiling Warmth	Particle Warmth	Particle Warmth	Particle Warmth	Particle Boiling Warmth

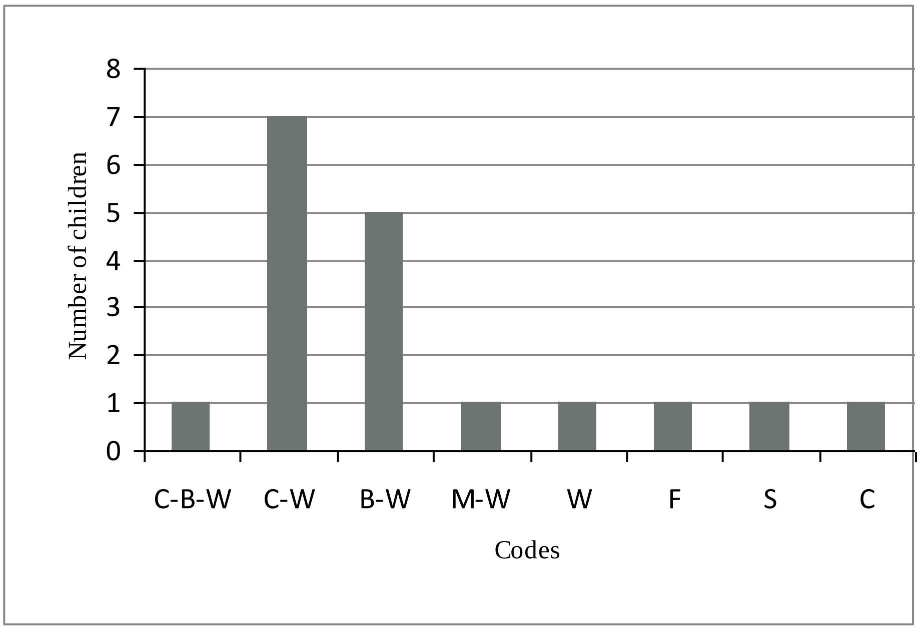


Figure 2. The codes emerging from the former interview

Figure 2 indicates that a total of seven children associated evaporation with the concept of Cycle and Warmth and generally stated that the Sun heats up the water causing water to evaporate and going to the cloud that eventually results in the formation of rain. Five children, associated it with the concept of Boiling and Warmth. They generally claimed that evaporation occurs as a result of boiling of the heated water. One child associated it with the concepts of Cycle, Boiling and Warmth, another one associated with Warmth, another one with Fog, another with Smoke and still another associated with Cycle. A total of nine children associated evaporation with cycling and fourteen children associated it with heating. The former interview further indicated that no child mentioned the particle nature of evaporation process. Moreover, the children's accounts fell into 8 different codes (CBW, CW, BW, MW, Warmth, Fog, Smoke, and Cycle). One code (CBW) involved three concepts (Cycle, Boiling and Warmth), three codes (CW, BW and MW) involved two concepts and four codes involved only one concept.

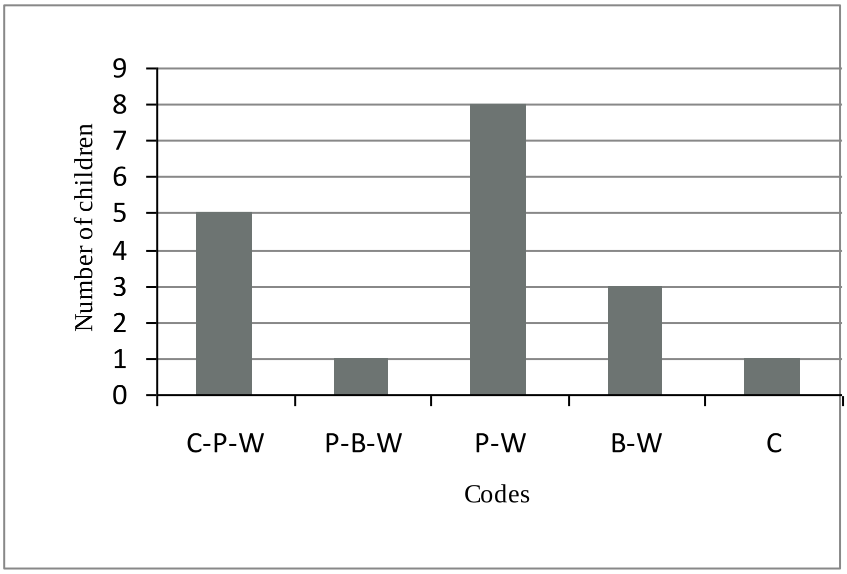


Figure 3. The codes emerging from the first interview

The first interview (Figure 3) indicates that eight children associated evaporation with the concept of Particle and Warmth and generally stated water consists of small unobservable particles and when they get heated, some of them with high energy escape into air. Five children associated it with the concept of Cycle, Particle, and

Warmth. One child associated it with the concepts of Particle, Boiling, and Warmth, and another one associated it with Cycle. The interview further indicated that 14 children were able to associate evaporation process with particle motion. Moreover, the children's accounts fell into 5 different codes. A total of six codes involved three concepts, eleven codes involved two concepts and one code involved only one concept.

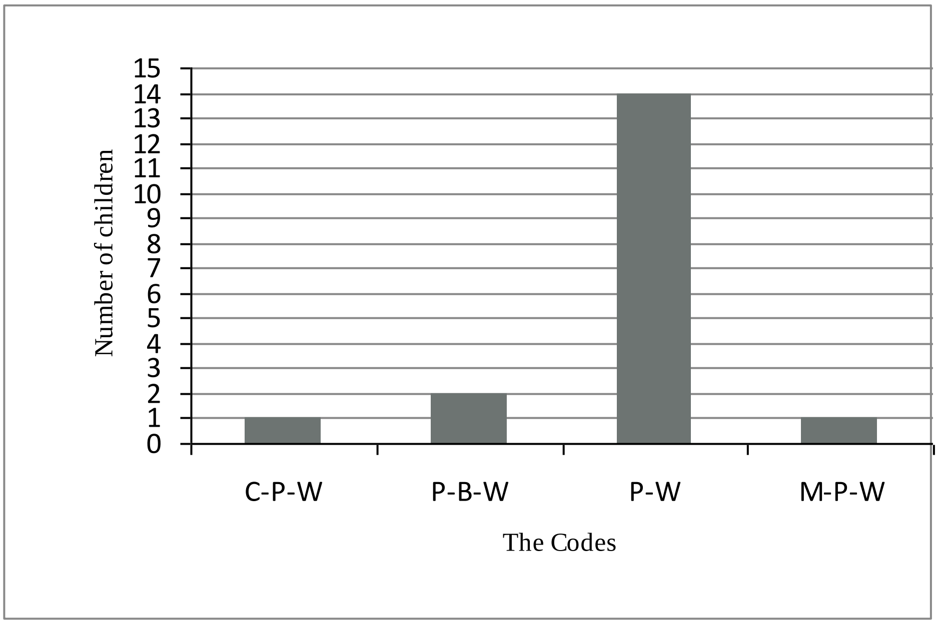


Figure 4. The codes emerging from the second interview

The second interview (Figure 4) indicates that all the children successfully demonstrated particle motion view of evaporation process. Fourteen children associated it merely with Particle and Warmth. Two children associated it with the concepts of Particle, Boiling and Warmth. One child associated it with the concepts of Cycle, Particle, and Warmth, and another one associated it with Melting, Particle and Warmth. The second interview further indicated that all the children (18 children) were able to associate evaporation process with particle motion. Moreover, the children' accounts fell into 4 different codes. A total of four codes involved two concepts, fourteen codes involved two concepts and no code involved one concept.

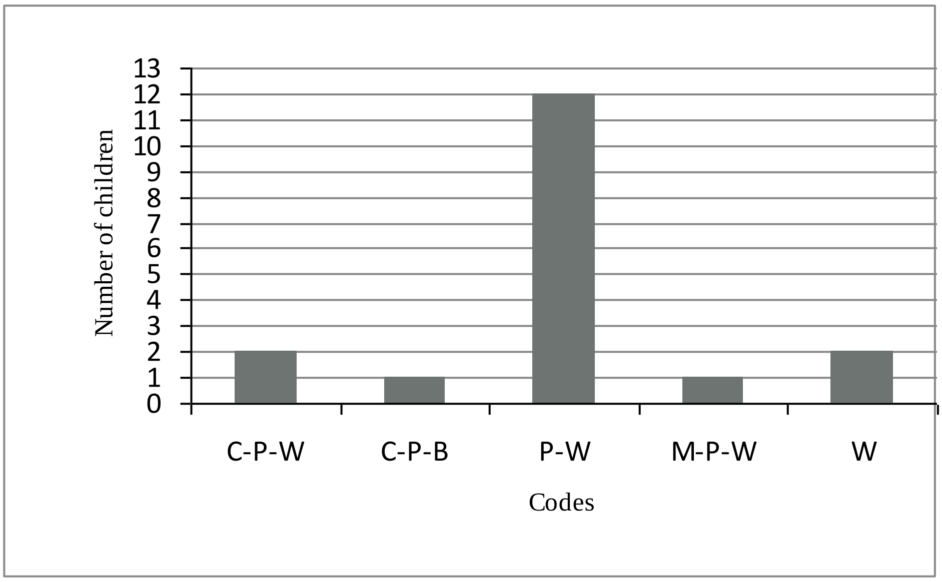


Figure 5. The codes emerging from the third interview

The third interview (Figure 5) indicates that 12 children associated evaporation with the concepts of Particle and Warmth. Two children associated it with the concepts of Cycle, Particle, and Warmth and another two associated with Warmth. One child associated it with the concepts of Cycle, Particle, and Boiling, and another one associated it with Melting, Particle and Warmth. The third interview further indicated that a total of 16 children were able to associate evaporation process with particle motion. Moreover, the accounts fell into 5 different codes. A total of four codes involved three concepts, twelve codes involved two concepts and two codes involved only one concept.

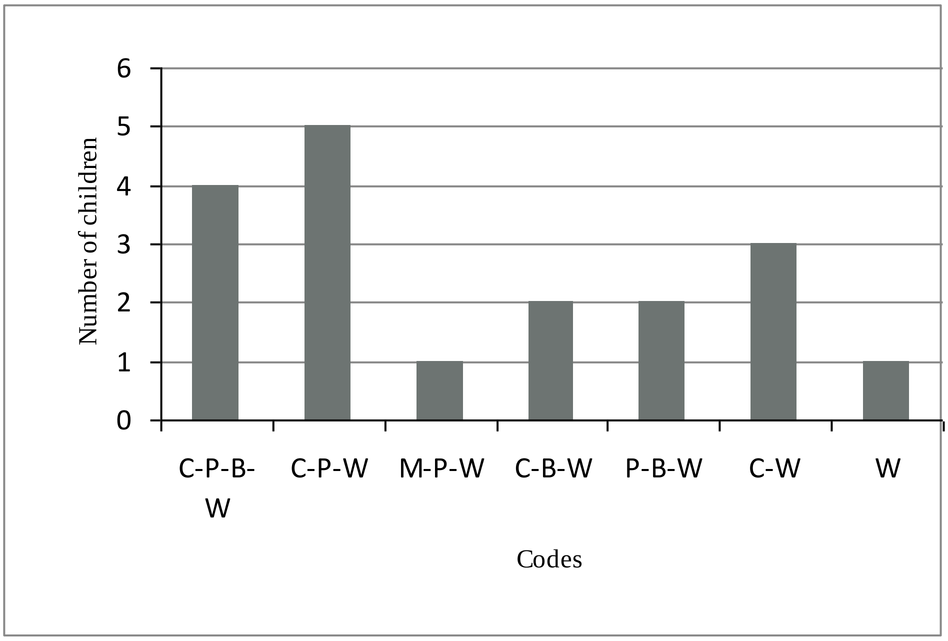


Figure 6. The codes emerging from the fourth interview

The fourth interview (Figure 6) indicates that four children associated evaporation with the concepts of Cycle, Particle, Boiling and Warmth. Five children associated it with the concepts of Cycle, Particle, and Warmth. Three children associated evaporation with the concepts of Cycle and Warmth. Two associated it with Cycle, Boiling and Warmth and another two associated with Particle, Boiling and Warmth. One child associated it with the concepts of Melting, Particle, and Warmth and another one associated it with solely Warmth. The final interview further indicated that 12 children were able to associate evaporation process with particle motion. However, this association not only involved particle motion but also included other notions such as Cycle, Boiling and Melting. Moreover, the children's accounts fell into 7 different codes. A total of four codes involved four concepts, ten codes involved three concepts, three codes involved two concepts and one code involved only one concept.

The Quality of Children's Explanations Uttered in the Last Interview

In order to examine the quality of children's explanations, their (Pupil 1, 2, 3, 4, 5, 6, 10, 12, 13, 15, 17, and 18) utterances indicating particle understandings in the fourth interview were singled out. Table 3 depicts those utterances taken from the last interview. Comparing the children's accounts to those having emerged from the discussion, a number of differences were observed. First of all, the children used some terms that were indeed not pointed out in the teaching discussion. The words such as jammed, small balloons (P1), blow up (P2, 5), buds (P4, 15, 18), move up and down (P6), bubbles (P10), and rolling over (P12) that have not been brought out by the teacher. Second, even though the teacher provided a detailed explanation (causatively linked statements in the form of a complete story regarding the process of evaporation), no child was able to do so. Their explanations involved missing parts or inappropriate links. To illustrate, Pupil 3 invoked that when the Sun gives heat, when they get heat, they jump into air. This explanation excluded the vital connection between heat and motion. The student seemed to have failed in establishing the linkage between heat provided by the Sun and the kinetic energy of the particles. Finally, their (P1, 2, 4, 5, 6, 10, 12, 15, 17, and 18) explanations were mostly off base or inaccurate indicating important deviations or divergence from the scientific meaning for the concept of evaporation. The Pupil 2, for instance, stated that there are small particles in water. When they blow up, some are very close to one another, when they blow up, they evaporate. The child seemed to believe that the water particles blow up in order to evaporate.

Table 3. Children's utterances on the concept of particle motion

Children	The Children's Explanations Fourth Interviews *(Nine months later)*
Pupil 1 *(Male, third grade)*	...When it provides heat, water gets heat, heat gives itself over and jump into air. It squeezes itself. They get ***jammed***. They jump into air. There are ***small balloons*** that we could not see. They evaporate fast into air. Being in gas form like steam they go into air...
Pupil 2 *(Male, third grade)*	...There are small particles in water. When they ***blow up***, some are very close to one another, when they blow up, they evaporate...
Pupil 3 *(Male, third grade)*	...There are small particles that we could not see. When the Sun gives heat, when they get heat, they jump into air...
Pupil 4 *(Male, third grade)*	...In water are tiny tiny particles. They are connected. They never get detached. When the heat from the Sun touches them, those having large amount of heat get into air. The remaining ones take heat from those to the right and left. When some water is put into a kettle and when we put it on a heater or something else, when it gets hot, ***buds*** get formed and water begins to splash. Evaporation, there is smoke rising from under the kettle. Those are evaporation...
Pupil 5 *(Male, third grade)*	... The water becomes hotter and hotter and is, in time, becoming lesser and lesser in amount. Since it evaporates, small things get formed. The molecules are formed and later when it ***blows up***, when they stick together, they do not blow up, they hold each other tightly. When they get separated, they turn into rain in the air...
Pupil 6 *(Female, third grade)*	...There was a lake and there was small particles in it. Those particles melted and ***moved up and down*** and there happened evaporation...
Pupil 10 *(Female, fourth grade)*	...There are combined ***bubbles*** in the water. Every time when the heat of the Sun touches, they get detached and rise, evaporate...
Pupil 12 *(Male, fourth grade)*	...There is a cup and water in it on a heater. The water boils, then it goes up by ***rolling over.*** The rounds mean that it is boiled...
Pupil 13 *(Female, fourth grade)*	...Initially, the liquids take heat. Then, because they get heat, the molecules on the surface, because they get more heat, they evaporate.
Pupil 15 *(Female, fourth grade)*	Let's assume we have boiling water in a kettle. Because the heater gives heat, it evaporates. The little little particles ***buds*** go into air. Because they could not hold each other, they go into air. Up on getting heat from the Sun, water evaporates. There is some boiling in water. Then, buds get formed. They go into air as steam...The heater gives heat to it and it turns into steam. The buds get larger and becomes steam.
Pupil 17 *(Female, fourth grade)*	...For example, in order to cook a meal, we put some water in a cup. When that cup becomes hot, molecules get formed on it. They indicate that the water is boiling. Then, when water boils well, steam gets formed over it and goes into air...
Pupil 18 *(Female, fourth grade)*	There is some water in a cup. Those particles, when they boil, evaporate. When the Sun gives heat to water, the water takes heat, there happens smoke going up, buds going up. In order for the Sun to touch the water, ***buds*** get formed. When the Sun gives its heat to the water, it rises to air.

Discussion and Conclusion

Children's Initial Ideas Enriched in Time

The children initially could not display a particle motion understanding of evaporation process and seemed to have a variety of alternative conceptions. First of all, some (Pupil 1, 3, 4, 5, 10, 13, 14, 16, and 17) viewed evaporation as the transition of water from liquid to gas and related it to the phenomenon of water cycle. They seemed to possess an alternative conception that formation of cloud, rain or snow is also part of evaporation. Some other (Pupil 6, 8, 9, 13, 15, and 18) seemed to believe that evaporation occurs as water boils. These children seemed to possess an alternative conception that evaporation starts when only water reaches at boiling temperature. One student further inaccurately viewed it as the formation of fog and another as the formation of smoke and still another as melting. Later, in the teaching discussion, the teacher pointed out that evaporation is the result of interplay between heat and water particles (without addressing those alternative ideas). The teacher stressed on the concept of evaporation and its meaning (particle, heat, and motion relationship). This notion, in the initial weeks (in the first, second and third interviews), was grasped by 8, 14 and 12 children respectively. A radical change in their thoughts seemed to have happened. However, nine months later, the children (Pupil 1, 2, 3, 4, 5, 6, 10, 12, 13, 15, 17, and 18) demonstrating particle motion understanding began to involve the elements from the concepts of Cycle, Boiling, or Melting in their elucidations. Former beliefs seemed not being lost and the particle motion property was added to those beliefs. Therefore, the concept of evaporation seemed to get enriched. This result indicated that, in conceptual development, rather than replacing the former idea with the novel one or completely abandoning the former one, the children differentiated their former beliefs. This finding corresponds to the claims that peripheral theory change (Chinn & Brewer, 1998) or evolutionary constant development (Saglam, 2010) happens in the course of conceptual change.

To illustrate, the Pupil 15 initially thought that evaporation occurs when water boils in a kettle upon exposed to heat. She hence seemed to have established a linkage amongst heat, boiling and the transition of water (from liquid to gas phase). The concept of evaporation thus brought together heat, boiling and the transition of water that are in fact dissimilar, different, multifaceted, and not coincident. She, later on (in the first, second and third interview), however began to think that this process occurs when small particles get into air. At this point, one could think that there is a replacement or radical change in her knowledge structures. Yet, she, in the final interview, started to believe again that in the course of evaporation, when water boils in a kettle, the water particles get into air. She seemed to have established a linkage amongst heat, boiling, particle motion, and transition of water. Her initial understanding of evaporation has not been therefore completely lost. The linkage amongst heat, boiling and the transition of water is not lost and the particle motion property is added to the meaning for evaporation. The concept of evaporation is thus enriched by adding particle motion understanding into the former explanatory framework.

Intermediate Structures Emerging

The final interview indicated that 12 children were able to associate evaporation process with particle motion. However, this association not only involved particle motion but also included former notions such as Cycle, Boiling and Melting. Further to that, the quality of the children's explanations indicated that the pupils carried forward their personal views. To illustrate, their utterances involved such terms as jammed, small balloons (P1), blow up (P2, 5), buds (P4, 15, 18), move up and down (P6), bubbles (P10), and rolling over (P12). This therefore seem to indicate that the novel structures did not surface or exist independent from the former beliefs. In other words, the novel ideas existed with its relation to the former ones. The explanations hence involved the elements from both the former and new beliefs leading unique intermediate structures to emerge. The children seemed modifying their initial structures to make them more consistent with the scientifically accepted one by gradually reinterpreting their presuppositions (Vosniadou & Brewer, 1992). In another saying, the children seemed trying to reconcile their prior conceptions with the scientific one (Stafylidou & Vosniadou, 2004). This intermediate structure is both mixed up with the elements of personal and those of scientific view. This finding corresponds to the claims that intermediate synthetic (Samarapungavan, Vosniadou, & Brewer, 1996; Vosniadou, 1994) or hybrid (Jung, 1993 as cited Duit & Treagust, 2003) structures emerge in children beliefs in the course of conceptual change.

Even though those structures were not fully accurate from a scientific viewpoint, the children used them in a consistent manner. This finding is, however, in conflict with the idea of 'knowledge in pieces' proposed by diSessa (1988). He claimed that intuitive physics is a fragmented collection of ideas that are loosely connected and reinforcing and have none of the commitment and systematicity that could be attributed to theories. Unlike this claim, the present data indicated inversely that the children's former ideas involved theory like beliefs. Theories are essential relationships that bring together things that are dissimilar, different, multifaceted, and not coincident (Davydov, 1990, p. 255). In the present study, the children established relationships, even not scientifically fully accurate, amongst water particles, warmth, and boiling, cycle, or melting. Those beliefs helped them explain observations they faced in every day life in the past, are still helpful in the present, and will continue being helpful in their future observations.

Some Alternative Ideas Disappearing but Some Retained

The results indicated that solely focusing on meaning of evaporation without probing and discussing the children's alternative conceptions is almost useless in getting rid of those alternative conceptions. The children's alternative ideas such as 'formation of cloud, rain or snow is also part of evaporation'(P1, 2, 3, 4, 5, 7, 8, 10, 11, 12, 13, 14, 16, and 17), 'evaporation starts when only water reaches at boiling temperature'(P1, 2, 8, 11, 12, 15, 17, and 18), and 'evaporation happens as a result of melting of water' (P6) were retained while others such as 'evaporation occurs as a result of formation of fog on a window' (P7) and 'evaporation occurs as a result of burning something' (P2) disappeared. The children seemed to have kept their former alternative ideas that they found related to the evaporation process, but abandoned those they believed irrelevant. They, unlike scientists, seemed not being fully aware of or lacking metacognitive awareness of their possession of alternative ideas. This finding corresponds to the claim put forward by Vosniadou and Ioannides (1998) that the children seem to be not aware of the explanatory frameworks they hold or have constructed. To them, this lack of metaconceptual awareness prevents children from questioning their prior knowledge structure and encourages the assimilation of new information into this existing structure. This assimilatory activity however seems to form the basis for the creation of synthetic models, misconceptions or inconsistencies in children's reasoning.

This finding hence supports the idea of the importance of making children aware of their implicit representations, beliefs, or presuppositions and of providing meaningful experiences in instructional activities to motivate children to understand the limitations of their explanations and be motivated to change them (*ibid.*). In order to do this, according to Vosniaedou and Ioannides (*ibid.*), it is necessary to create learning environments where children could freely express their thoughts, participate in discussions, verbally express their own ideas. This will eventually cause the internal ideas to surface, be discussed, and compared to those of others. This activity, even seems being time consuming, is important for children to get aware of their own alternative conceptions. In the present study, to illustrate, the alternative conception that *evaporation starts when only water reaches at boiling temperature* could be discussed in the class. Such steps could be taken as, discussing whether clothes could get dried or not on winter days; probing children's ideas and comparing and contrasting them to that of others; designing and conducting related experiments; investigating for instance what will happen if a wet towel is left in the classroom for one day; and evaluating and making comments on the result of this inquiry.

Concluding Remarks

In summary, the findings of the present study have not supported the radical change view. In other words, abandoning the old concept and adopting that of the novel unmistakably and independently from former beliefs did not happen in actuality. The children, rather than grasping all properties of evaporation process or building a perfect understanding as it is presented by the teacher, reinterpreted the novel information within the framework of their former knowledge system. That is, the novel conception for evaporation depended on and grew from the differentiation of the former conceptions. Moreover, the novel conception was both mixed up with the elements of personal and those of scientific view leading intermediate structures to emerge in children's mind. The data further indicated that the children seemed to have been unable to recognize the discrepancies between their personal knowledge system and that of the scientific. It could, therefore, be speculated that children lack meta-conceptual awareness preventing them to compare and contrast their personal view to that of scientifically accepted one.

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How Does Air Pollution Threaten Basic Human Rights? The Case Study of Bulgaria

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Abstract

The main purpose of this article is to analyze the relationship between air pollution and human rights. It investigates whether air pollution threatens basic human rights such as the right to health, life, and the environment. Air pollution represents a major threat both to health and to the environment. Despite the adoption of numerous international, national and regional norms, air pollution still continues to be one of the major environmental issues of concern. The human rights to life, health, and a clean environment are powerful tools available for citizens to strengthen the enforcement of existing laws and regulations and combat air pollution. This study examines the case of air pollution in Bulgaria and how it can be related to human rights threat. Findings of the study are prerequisite to conclude that air pollution threatens some of the fundamental human rights such as the right to life, health, and the environment.

Key words: Air pollution, Human rights, Human rights threat, Air pollution in Bulgaria

Introduction

Air pollution over the past decades is a worldwide problem. With the increase of the population, globalization, and industrialization, air pollution has become one of the major environmental issues of concern (Fenghua et. al., 2015), (Zhang et. al., 2011), (Cramer, 2002). Millions of premature deaths occur each year as a result of exposure to air pollutants. A wide range of adverse effects of air pollution on health has been well documented by studies conducted in various parts of the world (Jonathan et. al., 2012), (Solomon, 2011), (Clark et. al., 2010), (Goldsmith, 1964). The latest assessment by WHO's International Agency for Research on Cancer (IARC) concluded that worldwide seven million premature deaths annually is linked to air pollution (Jasarevic et. al., 2014). In addition to the impacts on human health, air pollution also causes environmental degradation such as acid rain, eutrophication, haze, ozone depletion, crop and forest damage, and global climate change (UNEP, 2011), (EEA, 2014).

Clean air is considered to be a basic requirement of human health and well-being (WHO, 2000). However, air pollution continues to pose a significant threat to health and environment worldwide. All human beings depend on the environment in which we live. A safe, clean, healthy, and sustainable environment is integral to the full enjoyment of a wide range of human rights, including the right to life, health, food, water and safe environment (UNHRC, 2012). Without a healthy environment, we are unable to fulfill our aspirations or even live at a level commensurate with minimum standards of human dignity (Bank, 2014).

In recent years, the recognition of the links between environment and human rights has greatly increased. Human rights and environmental norms are powerful tools to combat air pollution and its impact on health and the environment. The dependence of human rights on environmental quality has been recognised in international texts and by human rights treaty bodies (Guillerm and Cezari, 2013). The number and scope of international and domestic laws, judicial decisions, and academic studies on the relationship between the environment and human rights have grown rapidly. The records of the United Nation Human Rights Council on Human Rights and Environment, The Rio Declaration on Human Environment, and Stockholm Declaration on Environment and Development, and others give basic guidelines for understanding the relationship between human rights and the environment. Many studies have concluded that environmental degradation threatens basic human rights (Akyuz, 2015), (Boyd, 2012), (Amechi, 2009), (Fitzmaurice et. al., 2007).

The main objective of this study is to analyze the relationship between air pollution and human rights and to outline how air pollution can be related to threat to basic human rights such as the right to life, health, and

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environment. This objective is achieved through two main steps. First, looking at the concept of human rights and finding the linkage with air pollution. Second, looking at the air pollution in Bulgaria as a case study, and discussing how it threatens basic human rights.

Human Rights Concept and the Linkage with Air Pollution

Human rights are set of essential and fundamental rights inherent to all human beings, regardless their nationality, place of residence, national or ethnic origin, colour, religion, language, or any other status. These rights are all interrelated, interdependent and indivisible. Universal human rights are often expressed and guaranteed by law, in the forms of treaties, customary international law, general principles and other sources of international law. International human rights law lays down obligations of Governments to act in certain ways or to refrain from certain acts, in order to promote and protect human rights and fundamental freedoms of individuals or groups (UN, 2008). The international doctrine of human rights is one of the most ambitious parts of the settlement of World War II. These rights were first recognised internationally under the Universal Declaration of Human Rights, and specified by the United Nations in 1948 to provide a global understanding of how the individuals should be treated (Sachs, 2004 and Clemson, 2012). Since then, the language of human rights has become a common language of practice of human rights for guidance in understanding the central idea. Only recently, during the second half of the 20th century, the right of the third generation has started to be recognized where the right for a clean environment has become more prominent.

Due to the increase of environmental degradation and deterioration in many parts of the world, environmental issues have become a topic of vigorous debate. As a consequence, many international treaties, national laws and regulations for environmental protection have been introduced and adopted. In 1976, Portugal became the first country to adopt a constitutional *"right to a healthy and ecologically balanced human environment".* Since then, more States have adopted similar rights in their national constitutions (Boyd, 2011). Most of the constitutional rights refer to health; alternative formulations include rights to a clean, safe, favourable or wholesome environment (Knox, 2012). In general, the environment and human rights are inherently interlinked.

A clean environment is a basic condition for the enjoyment of a full range of human rights. Everyone needs access to clean air, safe water, fertile soil, and nutritious food in order to survive. Nothing is more basic to life than having access to clean air to breathe. In recent years, there has been more of an awareness of the links between human rights and clean air. There has been recognition that a clean and healthy environment is essential to the realization of fundamental human rights. Can this recognition be used as a tool to fight air pollution and achieve better air quality, which is an essential part of the clean environment? Human rights are grounded in respect for fundamental human attributes such as dignity, equality, and liberty. The realization of these attributes depends on an environment that allows them to flourish. Health as a human right cannot be imagined without clean air. United Nations Human Resource Council states: "Atmospheric - related environmental impacts are becoming more predominant as a result of increasing human activity, population growth and continued economic growth. These activities exacerbate atmospheric emissions, leading to air pollution, climate change and ozone-layer depletion which are major environmental threats to human rights" (UNHRC, 2011). Air pollution threat to human rights is going to be discussed looking at the case study of Bulgaria.

Air Pollution in Bulgaria and Human Rights Threat

According to the latest released data by the European Environment Agency (2013), Bulgaria is one of the worst air polluted countries among all EU Member States (EEA, 2015). It also has one of the highest rates of premature deaths due to air pollution (UNEP, 2015). Air pollutants - sulphur dioxide, nitrogen dioxide, particulate matter (PM_{10}, $PM_{2.5}$), and carbon monoxide, cause respiratory, cardiovascular, and heart related diseases. As a result, thousands of people die prematurely. The Environmental burden of disease calculations of the WHO show that 3,400 Bulgarians die annually because of air pollution (WHO, 2009).

The latest assessment made by the European Environment Agency for air quality in the European Union showed that air quality in Bulgaria was a big concern. According to the realized data, citizens all over the country breathed in air that is considered harmful to health. For example, concentrations of PM_{10} (particulate matter) were much higher than what the EU and the World Health Organization have set to protect health. This can be seen from the following figure, published by European Environment Agency.

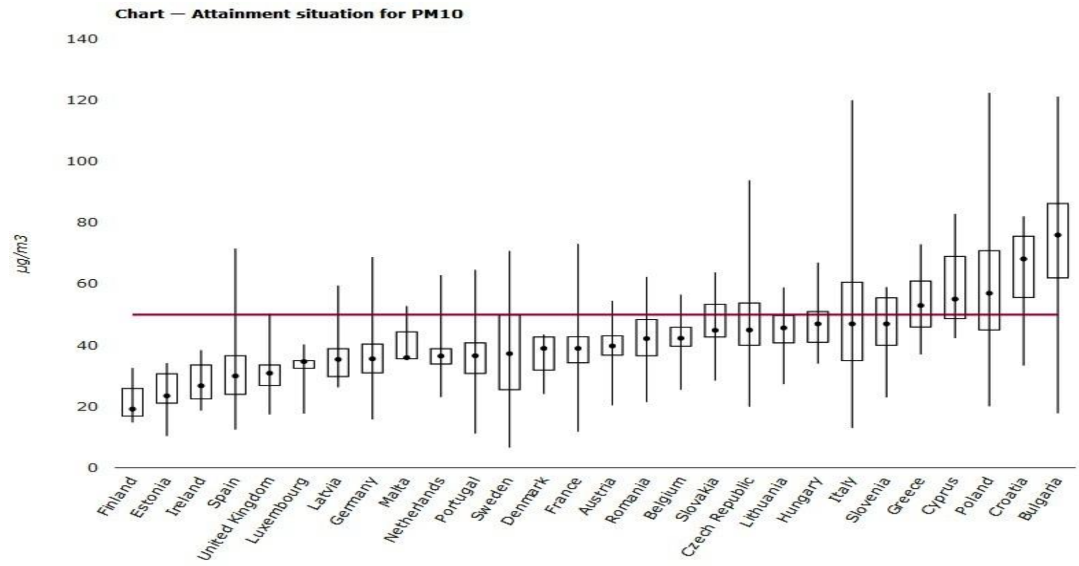

Figure 1. Attainment situation for Partuculate Matter $_{10}$ (PM_{10}) in different EU countries

Source: European Environment Agency, air quality e-reporting database. Data for 2011 - 2013
Note: The graph is based, for each Member State, on the 90.4 percentile of daily mean concentration values corresponding to the 36^{th} highest daily mean. For each country, the lowest, highest and median percentile 90.4 values (in µg/m^3) at the stations are given. The rectangles mark the 25 and 75 percentiles. At 25% of the stations, levels are below the lower percentile; at 25% of the stations, concentrations are above the upper percentile. The daily limit value set by EU legislation is marked by the red line.

Data provided by Executive Environment Agency (2016) of Bulgaria about the levels of certain key parameters, characterizing air quality, in accordance with the national and European legislation, shows exceedance of PM_{10} to present date in 2016. Bulgarian citizens still breathe in air that is not matching the air quality standards set by the European Union.

Table 1. Exceedance of Air Qiality (AQ) limit values in Bulgaria

Exceedances of AQ limit values (LV) for sulphur dioxide, nitrogen dioxide, particulate matter (PM10), ozone and carbon monoxide in ambient air within the period from 00:00 to 24:00, 29.02.2016 /Bulgaria

Settlement / Station	**SO_2**		**NO_2**	**PM_{10}**	**CO**	**O_3**
	1h LV 350.0 µg/m^3	**24h LV 125.0 µg/m^3**	**1h LV 200.0 µg/m^3**	**24h LV 50.0 µg/m^3**	**LV (8h) 10.0 mg/m^3**	**Information threshold 180.0 µg/m^3**
Nesebar				1.35		
Vidin				1.33		
Pleven				1.25		
Plovdiv - Kamenitsa				1.05		
Plovdiv - zh.k. Trakia				1.34		
Stara Zagora - Zelen Klin				1.17		

Source: Executive Environment Agency Bulgaria, National System for Air Quality Control

Is breathing clean air a human right? In order to understand the relationship between air pollution and human rights threat, three basic human rights are going to be discussed – the right to life, health, and the environment.

The Right to Life and Health

Thousands of people die each year from air pollution in Bulgaria. Is the right to life a basic human right? In this regard the Universal Declaration of Human Rights, Article 3 states that *"Everyone has the right to life, liberty and security of person".* Furthermore, the International Covenant on Civil and Political Rights, adopted in December 1966 protects the right to life in Article 6. (1), which is stated as follows: *"Every human being has the inherent right to life".* The right to life is at the core of all other types of rights and it is constantly interpreted to include environmental distresses. The European Commission on Human Rights has adopted an approach where its member states are required to take positive measures to ensure that right to life is sufficiently respected and guaranteed (Leib, 2011). Therefore, the right to life which is described in Article 2 of the European Convention states *"Everyone's right to life shall be protected by law".*

The right to health is also a fundamental part of our human rights and of our understanding of a life in dignity. The right to enjoyment of the highest attainable standard of health is not new. Internationally, it was first articulated in the 1946 Constitution of the World Health Organization, where states that *"The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition".* The 1948 Universal Declaration of Human Rights also mentioned health as part of the right to an adequate standard of living in Article 25.(1) - *"Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, ...".* The right to health was again recognized as a human right in the 1966 International Covenant on Economic, Social and Cultural Rights where Article 12 states *"The right of everyone to the enjoyment of the highest attainable standard of physical and mental health".* The right to health is furthermore recognized in several regional instruments, such as the African Charter on Human and Peoples' Rights (1981), the Additional Protocol to the American Convention on Human Rights in the Area of Economic, Social and Cultural Rights, known as the Protocol of San Salvador (1988), and the European Social Charter (1961, revised in 1996). The American Convention on Human Rights (1969) and the European Convention for the Promotion of Human Rights and Fundamental Freedoms (1950) contain provisions related to health, such as the right to life. The right to health is relevant to all States. Every State has ratified at least one international human rights treaty recognizing the right to health. Moreover, States have committed themselves to protecting this right through international declarations, domestic legislation and policies, and at international conferences. Air pollution in Bulgaria causes health related illnesses which lead to premature death and this way threatens the above mentioned two fundamental human rights – the right to life and health.

The Right to a Clean Environment

Air pollution causes not only health related problems but also environmental degradation such as acid rain, eutrophication, haze, ozone depletion, crop and forest damage, and global climate change (UNEP, 2011), (EEA, 2014). Is healthy environment (which includes clean air) a human right? The relationship between the environment and human rights are mentioned for the first time in the 1970s. The first UN Conference on the Human Environment, which took place in Stockholm, shed light on the relationship between human rights and the environment. Indeed, the preamble to the Stockholm Declaration proclaims that:

> Both aspects of man's environment, the natural and manmade, are essential to his well-being and to the enjoyment of basic human rights – even the right to life itself.

Further on, Principle 1 of the Stockholm Declaration established a foundation for linking human rights, health, and environmental, declaring that:

> Man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being …

Furthermore, the 1992 Rio de Janeiro Conference on Environment and Development (UNCED) focused on the link that exists between human rights and the environment in terms of procedural rights. Despite the fact that the 1992 Rio Declaration does not grant the right to a clean environment directly, it places emphasis on the importance of nature. It states that ''*human beings . . . . . are entitled to a healthy life in harmony with nature''.*

As a matter of fundamental human right, the importance of adequate environment was also enunciated in the 1987 Brundtland Commission Report ("Our Common Future"). The Brundtland Commission included a set of General Principles, Rights and Responsibilities for achieving environmental protection and sustainable development. Its broad first principle of human rights was presented as follows:

> All human beings have the fundamental right to an environment adequate for their health and well-being.

The importance of the environment as a human right is outlined not only by international bodies but also the right to a healthy environment is included in some national constitution. For example, the Bulgarian Constitution provides a right to a healthy and favourable environment. Article 55 of this constitution states that:

> Citizens shall have the right to a healthy and favourable environment in accordance with the established standards and norms.

The above given information is prerequisite to say that clean environment is one of the fundamental human rights. Everyone has the right to demand environment that is adequate to their well-being. Since clean air is a major part of a clean environment, it can be said that air pollution threatens this basic human right – the right to a clean environment.

Conclusion

Air pollution represents a major threat both to health and to the environment. Despite the adoption of numerous international, national and regional norms, air pollution still continues to be one of the major environmental issues of concern. The human rights to life, health, and a clean environment are powerful tools available for citizens to strengthen the enforcement of existing laws and regulations and combat air pollution. Despite the air quality regulations in Bulgaria, measurements show exceedance of the major air quality parameters such as PM_{10}. The air pollution in Bulgaria which causes health related illnesses and premature death can be said that threatens basic human rights such as the right to life, health, and the environment.

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Turkish Mathematics and Science Teachers' Technology Use in Their Classroom Instruction: Findings from TIMSS 2011

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Abstract

The goal of this study was to describe Turkish mathematics and science teachers' use of computer in their classroom instruction by utilizing TIMSS 2011 data. Analyses results revealed that teachers most frequently used computers for preparation purpose and least frequently used computers for administration. There was no difference in teachers' technology usage ways in regard to gender. Although teachers had ready access to computer staff in their schools for technical problems and received adequate support for integrating computers in their teaching activities, teachers used computer software rarely as basis for instruction. Textbook was the most commonly used resource as the basis for instruction. In 69.6% of the mathematics classes and in 41.5% of the science classes, students had computer(s) available to use during lessons and in computer available classes, computers were generally connected to internet. Students rarely engaged in computer activities, such as exploring principles and concepts, practicing skills and procedures, looking up ideas and information, doing experiments, processing and analyzing data. Suggestions were made in order to improve technology usage in mathematics and science instruction.

Key words: Technology use, Teacher education, Mathematics teacher, Science teacher, TIMSS 2011

Introduction

For the last twenty-five years, technological tools have become commonplace in many aspects of professional and personal lives of individuals. Despite widespread usage of technology across many disciplines in 21st century, it is rarely used in education. Rapid changes and remarkable advances in technology forced to drive educational institutions to adapt technology into their activities (Campbell et al. 1987; Gülbahar 2008). In the present study, we aim to investigate Turkish mathematics and science teachers' educational technology use at school.

Before 1983, there was almost no literature about using educational technologies in the educational environment (Kaput and Thompson 1994). Up to the year 2000, existing technologies were not very specific to the teaching area and there was lack of research evidence justifying that technology helps teachers to teach concepts effectively. Research studies and large-scale meta-analyses of educational technology studies (e.g. Bernard et al. 2004; Dillon and Gabbard 1998; Fabos and Young 1999) clearly confirmed that educational technology had not reached its full potential back in the early 2000's. In recent years, a number of studies were conducted to investigate effectiveness of educational technology in teaching. Recent studies demonstrated that teachers' teaching practices could be developed if there is adequate technology, administrative support, and a substantial curriculum (Johnson and Maddux 2008).

Today's teachers should employ educational technology to develop a deep understanding of mathematics and sciences both for themselves and for their students (Drier 2001; Leigh 2003). In addition to having subject matter knowledge, pedagogical content knowledge, and the skills to apply the curriculum, teachers also need to be proficient in educational technology in order to perform pedagogical content knowledge (Pierson 2001). Teacher training programs should provide pre-service teachers with a rich technological environment to facilitate techno-pedagogical knowledge and skill development. This perspective suggests that teacher preparation program must provide numerous experiences to engage pre-service teachers in investigating, thinking, planning, practicing, and reflecting (Niess 2005).

According to the National Council for Accreditation of Teacher Education standards (NCATE 2002), the new professional teacher who graduates from a department of education should be able to integrate technology into

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instruction to effectively enhance student learning. In order to be an effective teacher, pre-service teachers need to know fundamental concepts, knowledge, skills, and attitudes for applying technology in educational settings (NETS•T 2008 p.1). To achieve the technological goals stated by NCATE, teachers should be prepared for their new roles in a technological environment (Thompson and Kersaint 2002).

In their study, Johnson and Maddux (2008) determined four conditions for technology integration into education:

1. Capacity–the hardware, software, and connectivity must be of a sufficient quality.
2. Accessibility–both students and teachers must have sufficient access to technology.
3. Implementation–effective teaching and learning strategies for capitalizing on the technology must be implemented in the classroom.
4. Support-policy makers must encourage and support the wise use of technology.

As difficult as it is to satisfy the capacity, accessibility, and implementation aspects of full integration, we have seen examples where even with all other conditions being present, policymakers can stifle integration efforts (Johnson and Maddux 2008 p.2). In consistent with these four conditions, the current elementary mathematics and science curricula developed by Ministry of National Education (MONE) in Turkey also emphasize using technology in teaching and learning process to provide students with the opportunity for expressive mathematics and science teaching. In 2008, Turkish General Directorate of Teacher Training and Education (ÖYEGM) declared educational technology as a required competency to be qualified mathematics and science teachers. According to their standards, professional mathematics teacher should become aware of the importance of using educational technology in teaching for effective learning. Teachers should have the technical skills to use subject specific educational technologies and use this knowledge in teaching actively. In addition, teachers should share their technical knowledge and experiences with their colleagues (ÖYEGM 2008a).

In order to provide educational technology facilities to teachers and learners, MONE established Directorate General for Innovation and Educational Technology (YEĞİTEK) in 1998 (YEĞİTEK 2010). YEĞİTEK prepares learning environments for efficient technological applications and develop projects such as FATIH [Movement for Increasing Opportunities and Improving Technology] Project, Intel Teacher, Intel Students to encourage the use of technology for teaching and learning activities. The FATIH Project, which includes strong support for technology- assisted learning, is expected to show some positive results that are demonstrated with research evidence. FATIH Project compensates the need for technologically literate teacher who can use new technologies effectively to enhance students' learning by in-service training. Teachers were expected to use educational technology consistent with the curriculum. For doing this, MONE created technology modules to be taught in the seminars. To make in-service training available for all teachers, MONE trained formatter teachers. The availability of appropriate technologies were provided by MONE to public schools. These technologies included a variety of modern hardware and software, student tablet pc, classroom smart board, etc. There were networked computers in each classroom, enough to provide one-to-one computer access for the students. The technical support for the use of technology at the district level was also provided by MONE. In a number of schools, district policies encouraged teachers to use the educational technology in their schools. This project also aims to provide each and every student with a tablet PC (Karal et al. 2013).

In recent years, technological tools such as graphing calculators, electronic white boards, spreadsheets, applets, interactive online learning systems, simulations, web pages, and dynamic geometry software have been emerging in educational studies to improve the mathematics teaching and learning environment (Kim and Baylor 2008). National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards (1989), recommended that teachers need to promote use of calculators to enhance mathematics instruction from kindergarten through high school. Calculator enables children to concentrate on understanding the mathematical concepts and develop number sense (Kieran and Guzman 2005). Before doing the calculation via calculator, students learn how to estimate the result to develop number sense, which should be considered by the teachers. Furthermore, students should criticize the results if it is reasonable for that question (Kieran and Guzman 2005). It is believed that when students do not have a concern about computation mistakes, they can focus on reasoning more (Reys and Arbaugh 2001). Dynamic technology-supported instruction presents an opportunity to enhance mathematical reasoning and explore various conjectures of science and mathematics teachers. Graphing calculators and dynamic software packages - such as GeoGebra, Geometer's Sketchpad, and Tinker plots are vital in raising student awareness, challenging their conceptual understanding and motivating the synthesis of mathematical notions (Hollebrands 2007; Kaput and Thompson 1994; Peressini and Knuth 2005). Construction of mathematical objects, creating models, and conducting interactive explorations are available via GeoGebra by dragging objects tracing points, changing parameters, and measuring objects. Technology also can be used to improve teaching and learning of science concepts and its processes to make scientific concepts more available for students through conducting a simulation experiment in virtual labs, doing hands-on science activities, exploring interactive web resources (Flick and Bell 2000).

In the present study, we aim to investigate Turkish mathematics and science teachers' usage of educational technology at school by utilizing teachers' responses to Trends in International Mathematics and Science Study (TIMSS) 2011 questionnaire. We focused on technology use relevant items in the questionnaire such as teachers' usage of computers for preparation, for their classroom instruction, and for administration; teachers' usage of computers comfortably and technical support they have in their school. Additionally, since many studies have revealed that there may be gender differences in teachers' technology use (e.g. van Braak et al. 2004), we will examine whether there are differences between male and female teachers in regard to technology use. Following research questions were asked:

1. For which ways (for preparation, for classroom instruction, and for administration) mathematics and science teachers use computer in their teaching?
2. Is there any difference between male and female teachers in terms of the ways they use technology?
3. Do mathematics and science teachers feel comfortable when using computers in their classroom instruction?
4. Do mathematics and science teachers have ready access to technical support staff when they have technical problems and receive support for integrating computers in their teaching activities?
5. Do mathematics and science teachers use resources, such as textbooks, workbooks, concrete objects, and computer software, as basis and as supplement for mathematics instruction?
6. Do mathematics teachers allow their students to use calculators during mathematics lessons?
a. For which activities do students use calculators?
7. Do students in mathematics and science class have computer(s) and internet available to use?
8. How often do mathematics teachers have students use computers to explore mathematics concepts, practice skills, look up ideas, and process data?
9. How often do science teachers have students use computers to practice skills and procedures, look up ideas and information, do scientific procedures or experiments, study natural phenomena through simulations, and process and analyze data?

The significance of this study arises from providing detailed information about the Turkish mathematics and science teachers' technology use in their teaching. By utilizing TIMSS 2011 data for Turkey, we attempt to describe mathematics and science teachers' technology use in their schools. As mentioned earlier, technology usage in teaching is highly recommended by MONE in Turkey (ÖYEGM 2008a; ÖYEGM 2008b) and previous studies suggest positive effects of technology use in the school (e.g. Lee et al. 2013). Thus, it seems important to explore mathematics and science teachers' technology use in their teaching.

Method

The data was taken from TIMSS database (http://timss.bc.edu/timss2011/index.html). TIMSS is a system of international assessment, which provides background information on teachers' demographics to benchmark performance. It is conducted every four years. From the questionnaire, in addition to teachers' demographic information, we were interested in teachers' responses to following items: Whether teachers feel comfortable using computers in their teaching; if there is any technical problems, whether they have ready access to computer support staff in their school; whether they received adequate support for integrating computers in their teaching activities; what kind of teaching resources they use to teach mathematics and sciences; and which activities students do using computers in the class, such as practicing skills and procedures. There was a special question for mathematics teachers about for what reason they permit students use calculators; to check answers, do routine computations, solve complex problems, or explore number concepts. Frequency analyses were conducted to describe mathematics and science teachers' technology use. Additionally, chi-square tests were run in order to examine whether teachers' computer usage ways change in terms of their gender.

Participants

239 mathematics teachers from 239 schools around Turkey participated in TIMSS 2011. There were 106 (44.4%) females and 133 (55.6%) males. 18 (7.6%) of the participants were under 25 years old; 95 (39.9%) of the teachers were between 25 and 29 years; 90 (37.8%) of the teachers were between 30 and 39; 12 (5%) of the

teachers were between 40 and 49; 22 (9.2%) of the teachers were between 50 and 59, and there was one teacher with an age of 60 or more. Participants' experience in teaching profession ranged from 1 to 35 years, with a mean of 9.28 (7.79) years.

238 science teachers from 237 schools around Turkey participated in TIMSS 2011. There were 117 (49.2%) females, 119 (50.0%) males, and 2 teachers (0.8%) did not report gender. 15 (6.3%) of the participating teachers were under 25 years old; 86 (36.3%) of the teachers were between 25 and 29 years; 81 (34.2%) of the teachers were between 30 and 39; 29 (12.2%) of the teachers were between 40 and 49; 25 (10.5%) of the teachers were between 50 and 59, and there was one (0.4%) teacher with an age of 60 or more. Participants' experience in the profession ranged from 1 to 34 years, with a mean of 10.37 (*SD*= 8.50) years.

Results

Technology Use

Teachers were asked whether they use computers in their teaching for preparation, for their classroom instruction, and for administration (See Table 1). Most of the mathematics teachers (82.4%) and science teachers (84.7%) reported to use computers for preparation. While 64.9% of the mathematics teachers used computers for classroom instruction, a higher percentage of science teachers (81.1%) used computers for classroom instruction. In both groups, teachers less frequently preferred to use computers for administration; 20.1% of the mathematics teachers and 29.8% of the science teachers used computers for administration.

Table 1 Computer usage ways

	Mathematics Teachers		Science Teachers	
	Yes	No	Yes	No
For preparation	196 82.4%	42 17.6%	200 84.7%	36 15.3%
For classroom instruction	155 64.9%	84 35.1%	193 81.1%	45 18.9%
For administration	48 20.1%	192 79.9%	71 29.8%	167 70.2%

In order to investigate whether male and female teachers differ in terms of the ways they use technology, chi-square tests for independence (with Yates Continuity Correction) were conducted. Among mathematics teachers, no significant association was found between gender and computer use for preparation [χ^2 (1, *n*= 238)= .07, *p*= .79, phi= -.03)]; gender and computer use for classroom instruction [χ^2 (1, *n*= 239)= .38, *p*= .54, phi= -.05)]; and gender and computer use for administration [χ^2 (1, *n*= 239)= 2.42, *p*= .12, phi= -.11)]. Similarly, among science teachers, no significant association was found between gender and computer use for preparation [χ^2 (1, *n*= 234)= 1.99, *p*= .16, phi= .10)]; gender and computer use for classroom instruction [χ^2 (1, *n*= 236)= .53, *p*= .47, phi= -.06)]; and gender and computer use for administration [χ^2 (1, *n*= 236)= 1.10, *p*= .29, phi= -.08)].

Teachers who reported to use computers for their classroom instruction were further asked about their usage of computers comfortably and technical support they have in their school. Most of the mathematics teachers (90.2%) and science teachers (94.8%) reported to feel comfortable when using computers in their teaching. Most of the mathematics teachers (74.7%) and science teachers (80.7%) had ready access to computer staff in their school when they had technical problems. 77.8% of the mathematics teachers and 85.9% of the science teachers received adequate support for integrating computers in their teaching activities.

Resources used

Mathematics teachers were asked about resources they use in their mathematics class (See Table 2). Among the resources (i.e., textbooks, workbooks or worksheets, concrete objects, and computer software), textbooks were the most commonly used resource as basis for instruction (80.8%), which was followed by workbooks or worksheets (36.6%), concrete objects (24.8%), and computer software (9.2%). About half of the participants (%54.8) used computer software for mathematics instruction as supplement while 36.0% of the teachers did not use computer software for mathematics instruction.

Table 2 Resources used by mathematics teachers

	Basis for instruction	Supplement	Not used
Textbooks	193 80.8%	40 %16.7	6 %2.5
Workbooks or worksheets	87 36.6%	147 %61.8	4 1.7%
Concrete objects or materials that help student understand quantities or procedures	59 (24.8%)	169 71.0%	10 4.2%
Computer software for mathematics instruction	22 9.2%	131 54.8%	86 36.0%

Science teachers were also asked about resources they use in their science class (See Table 3). Among textbooks, workbooks or worksheets, science equipment and materials, computer software for science instruction, and reference materials (e.g., encyclopedia, dictionary), textbooks emerged as the most commonly used resource as basis for instruction (88.2%). Computer software was the most used supplement resource for science instruction (71.9%), which was followed by reference materials (69.2%), science equipment (61.9%), and worksheets (56.5%).

Table 3 Resources used by science teachers

	Basis for instruction	Supplement	Not used
Textbooks	209 88.2%	27 11.4%	1 0.4%
Workbooks or worksheets	103 43.5%	134 56.5%	-
Science equipment and materials	83 35.2%	146 61.9%	7 3.0%
Computer software for science instruction	38 16.2%	169 71.9%	28 11.9%
Reference materials (e.g., encyclopedia, dictionary)	9 3.8%	164 69.2%	64 27.0%

Mathematics teachers were asked whether they permit students in their class use calculators during mathematics lessons. 23.2% of the teachers reported that students were permitted to use calculators with unrestricted use; 49.1% reported that students were permitted to use calculators with restricted use; and 27.6% reported that students were not permitted to use calculators. Additionally, mathematics teachers who allowed students to use calculators were asked how often students used calculators to check answer, to do routine computations, to solve complex problems, and to explore number concepts (See Table 4).

According to Table 4, 15.6 % of students never used calculator to check the answers, 42.7 % of students never used calculator to do routine computations, 14.4 % of students never used calculator to solve complex problems and 33.1 % of students never used calculator to explore number concepts. In a similar manner, 70.1 % of students used calculator in some lessons to check the answers, 46.2 % of students used calculator in some lessons to do routine computations, 61.0 % of students used calculator in some lessons to solve complex problems and 54.5 % of students used calculator in some lessons to explore number concepts. The rest of the students used calculators in mathematics lessons at least about half of the mathematics lessons to check the answers, to do routine computations, to solve complex problems, and to explore number concepts.

Table 4 Activities using calculator in mathematics class

	Every or almost every lesson	About half the lessons	Some lessons	Never
Check answers	9 6.1%	12 8.2%	103 70.1%	23 15.6%
Do routine computations	6 4.2%	10 7.0%	66 46.2%	61 42.7%
Solve complex problems	16 11.0%	20 13.7%	89 61.0%	21 14.4%
Explore number concepts	7 4.8%	11 7.6%	79 54.5%	48 33.1%

Computer Availability and Activities using Computers

In 69.6% of the mathematics classes, students had computer(s) available to use during mathematics lessons while in 30.4% of the classes, students did not have such an opportunity. In most of the computer available classes (84.1%), computers had access to the internet. In classes, where students had computer(s) available to use, students' usage of computers to explore mathematics principles and concepts, to practice skills and procedures, to look up ideas and information, and to process and analyze data were presented in Table 5. Accordingly, teachers rarely had the students do the aforementioned activities. Students general did these activities one or four times in a month.

Table 5 Activities using computers in mathematics classes

	Every or almost every lesson	Once or twice a week	Once or twice a month	Never or almost never
Explore mathematics principles and concepts	4 5.8%	22 31.9%	29 42.0%	14 20.3%
Practice skills and procedures	9 13.0%	21 30.4%	18 26.1%	21 30.4%
Look up ideas and information	8 11.8%	22 32.4%	29 42.6%	9 13.2%
Process and analyze data	5 7.4%	22 32.4%	24 35.3%	17 25.0%

In 41.5% of the science classes, students had computer(s) available to use during science lessons while in more than half of the classes (58.5%) students did not have such an opportunity. In most of the computer available classes (92.7%), computers were connected to the internet. In classes, where students had computer(s) available to use, students' usage of computers to practice skills and procedures, to look up ideas and information, to do scientific procedures or experiments, to study natural phenomena through simulations, and to process and analyze data were presented in Table 6.

Table 6 Activities using computers in science classes

	Every or almost every lesson	Once or twice a week	Once or twice a month	Never or almost never
Practice skills and procedures	7 7.4%	39 41.5%	32 34.0%	16 17.0%
Look up ideas and information	11 11.8%	47 50.5%	30 32.3%	5 5.4%
Do scientific procedures or experiments	4 4.3%	41 44.1%	40 43.0%	8 8.6%
Study natural phenomena through simulations	10 10.6%	43 45.7%	30 31.9%	11 11.7%
Process and analyze data	7 7.5%	35 37.6%	32 34.4%	19 20.4%

Discussion

This study aimed to explore Turkish mathematics and science teachers' technology use at school by utilizing teachers' responses to TIMSS 2011 questionnaire. MONE in Turkey highly emphasizes technology integration in instruction (ÖYEGM 2008a; ÖYEGM 2008b) and research reveals positive effects of technology usage in schools (e.g. Lee et al. 2013). Therefore, this study attempted to describe mathematics and science teachers' technology use in Turkey.

When mathematics and science teachers' ways of using computers were examined, they used computers for preparation more often than they used computers for classroom instruction. Computers were used least for administration purposes. Teachers who used computers for classroom instruction generally felt comfortable when using computers in their teaching. Furthermore, when they had technical problems, they reported to have ready access to computer staff in their school and receive adequate support for integrating computers in their teaching activities. Thus, it seems that teachers' integration of computers in their instruction were well supported by the technical staff in their school. Johnson and Maddux (2008) suggested that adequate technology and administrative support contribute to teachers' teaching practices. Therefore, we see developments in Turkish school as encouraging but there is still need for improvement. Results showed that in 30.4% of the mathematics classes and 58.5% of the science classes, students do not have computers available to use during lessons. Therefore, there are many classes in Turkey where computers are absent for students' usage. According to Johnson and Maddux (2008), sufficient quality hardware, software, and connectivity (i.e. capacity) is a prerequisite for technology integration into education and, both students' and teachers' access to technology (i.e. accessibility) is important. We suggest that in Turkey more classes may be equipped with computers so that more students may access to technology in class.

Computer software was rarely used for mathematics and science instruction; 9.2% of the mathematics teachers and 16.2% of the science teachers used computer software as basis for instruction; 54.8% of the mathematics teachers and 71.9% of the science teachers used computer software as supplement for instruction; and 36.0% of the mathematics teachers and 11.9% of the science teachers did not use computer software for instruction. Textbooks were the most preferred resource used for instruction; 80.8% of the mathematics teachers and 88.2% of the science teachers used textbooks as basis for instruction. Therefore, it seems that textbooks are still major resources used by teachers in class and computer software is not utilized as a basis for instruction. Though, if teachers use computer software for instruction, they may find activities, videos, simulations, and pictures, which may be interesting for students, attract their attention, and visualize concepts for student. This may in turn increase students' engagement in the lesson. The reason for not using computers as a resource in their instruction may be due to receiving inadequate training about how to use it effectively, thus they may rely mostly on textbook resources. Teachers may be given training about advantages of using computers for instruction and effectiveness of using computers as a resource. Niess (2005) suggested that teacher-training programs should be enriched with technological environment and pre-service teachers should have opportunity to practice in these environments to develop techno-pedagogical knowledge and skills.

When we examine activities done using computer, in mathematics classes, where students had computers available to use, students rarely used computers to explore mathematics principles and concepts, to practice skills and procedures, to look up ideas and information, and to process and analyze data. Similarly, in science classes, where students had computers available to use, students used computers rarely to practice skills and procedures, to look up ideas and information, to do scientific procedures or experiments, to study natural phenomena through simulations, and to process and analyze data (See Table 5 and 6). However, it is important that students' usage of computers for different activities in the class may contribute their learning. For instance, computer games were found to improve students' achievement (e.g. Cameron and Dwyer 2005; Kebritchi Hirumi, and Bai 2010); computer-assisted learning was associated with deep learning outcomes (Zimitat and McAlpine 2003); and computers supported classroom conversation in science and mathematics lessons (Wegerif 2004). At the end of their meta-analysis about effects of teaching and learning with technology, Lee et al. (2013) pointed out the importance of students' collaboration in groups with computers and developing students' skills through projects. Results revealed that in Turkey, students engage in very limited computer activities and they should be given more opportunity to use computers for different activities, such as exploring principles and concepts, practicing skills and procedures, looking up ideas and information, doing experiments, processing and analyzing data, which may improve students' mathematics and science learning.

Additionally, mathematics teachers were asked whether students were permitted to use calculators in class and for which purposes calculators were used. In mathematics classes, half of the students were permitted to use calculators with restricted use, however, from these students 33.1% of students never used calculators to explore number concepts (See Table 4). NCTM Curriculum and Evaluation Standards (1989), recommended that to enhance mathematics instruction, teachers need to promote use of calculators just because, calculator enables children to concentrate on understanding the mathematical concepts and develop number sense (Kieran and Guzman, 2005) without any concern about computation mistakes. However, 27.6% of the mathematics teachers reported that students were not permitted to use calculators. Therefore, we suggest mathematics teachers allow their student use calculators in lessons more frequently to check answers, do routine computations, solve complex problems, and especially to explore number concepts.

Another finding of the study was that teachers' ways of using technology did not differ in regard to gender. However, previous studies generally found that male teachers use technology more than female teachers (e.g. Hakverdi et al. 2011; van Braak et al. 2004). For instance, in a study with primary school teachers (n= 468), teachers' computer use was assessed through items such as "using the computer as a tool for demonstration" and "encourage pupils to search for information on the Internet" (van Braak et al. 2004 p. 410). Path analysis results showed that males used computers more than females. Similarly, in another study with science teachers (n= 63), males reported to integrate computers as an instruction tool more than females (Ocak and Akdemir 2008). Tough low in number, there are some studies which revealed no gender difference for teachers' technology use. Gorder (2008), studying with K-12 teachers (n= 174), found no difference between male and female teachers in terms of their technology integration in classroom teaching and learning. In the present study, we also found that females and males did not differ from each other in regard to their computer use for preparation, for classroom instruction, and for administration.

Conclusion

This study attempted to reveal Turkish mathematics and science teachers' technology use in their instruction. Although teachers had ready access to computer staff in their school when they had technical problems and received adequate support for integrating computers in their teaching activities, teachers used computers rarely as basis for instruction. Textbooks continued to be the major resource for teachers. In Turkey, in some classes there was no computer available to use during lessons. In computer available classes, students seldom engaged in activities done using computers. We suggest that computers should be available in more classes, teachers should use computer for instructional purposes more effectively, and students should be given more opportunity to involve in various activities by using computers like exploring concepts and practicing skills. Pre-service and in-service teacher education programs in Turkey should give training in order to encourage teachers' active technology usage at schools and thus enhance their instruction through technology. These programs may emphasize usefulness and ease of computer use, so that teachers' intention to use computers may increase (Yuen and Ma 2002). Teachers' competence and ability to organize technology related activities are important factors for effective technology integrated instruction (Gorder 2008). Therefore, it is important for teacher education programs to train teachers about how to use technology effectively as an instructional tool and provide teachers opportunities to get experience in technology use.

Limitations of the Study

The data of the study were provided from TIMSS database and measures of teachers' technology use were based on self-reports.

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STEM Applications in Turkish Science High Schools

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Abstract

The idea of establishing Science High Schools in Turkey was discussed in a multilateral project at the beginning of 1963. The Ministry of National Education (MoNE), Ford Foundation, Middle East Technical University (METU), Ankara University, and International Development Agency (AID) participated in this project to establish these schools. In Ankara, Science High School project was a US funded and technically supported project, carried out jointly by the Florida State University, METU, and Ankara University. Science High Schools' organizational goals were: (1) to improve students' ability and increase their intelligence in science (2) to increase the number of qualified personnel in higher education and industry, and (3) to develop more laboratories by increasing students' scientific knowledge in order to be the center of research and development. MoNE created the "Science High School Project Advisory Board" with six members from Ankara University and four members from METU to contribute to the scientific and curriculum aspects of the project. The Advisory Board selected 30 teachers from Mathematics, Chemistry, Physics and Biology disciplines by written and oral exams from the existing high schools of MoNE from all over the Turkey. Selected science teachers received special training for the development regarding the assessments of subjects and provided with opportunities to study on the curriculum at some universities in the United States (U.S.). To train teachers in Turkey, a modern building was constructed at METU campus and the education at Ankara Science High School started in 1964. After the success of the Ankara Science High School, the MoNE started the Science High School Projects in Istanbul and Izmir. Today, there are 238 Science High Schools serving as public schools and the same amount of schools serving as private schools. In the U. S., the training of 100K STEM teachers started in 2012. In this article, Science High Schools' development and their innovation activities, the STEM projects and the vision for increasing the STEM education in Turkey and other developed countries were discussed.

Key words: Science high schools, STEM education, MoNE

Introduction

The launch of Russia's first satellite on October 4, 1957 had an important impact on the U.S. education policies. The tension of the Cold War increased by the launch of Sputnik-1 (Bybee, 2010). This was a shock for the U.S. and created an awareness of the need for improving science. The development of physics education in the American educational system was the first work in this direction (Daeschner, 1965). Then, chemistry, mathematics and biology education were reviewed (McInerney, 1986; Saritha, 2014; School Mathematics Study Group, 1958-1977). In these areas, Massachusetts Institute of Technology (MIT) and other well-known universities, non-governmental organizations, public and private institutions and organizations involved in forming a working group including teachers to review all publications and studies to develop the curriculum and prepare new school books. These studies were transferred to Turkey in the 1960s called as the modernization of physics, chemistry and mathematics education. The system was pre-tested at Bahçelievler High School, Gazi High School and Ankara Atatürk High School. The Ankara Science High School began training in 1964 with the technical and financial support of Ford Foundation at METU campus with allocated 120 acres of land (Regulation on Science High School, 1975; Zabun, 2007).
The objective of science high schools was defined in Secondary Education Institutions Regulation of MoNE published in the Official Gazette on September 7, 2013, no: 28758 as following:

- To graduate students with bodily, mental, moral, spiritual, social and cultural characteristics in the direction of development of democracy and respect for human rights, equipping them with the knowledge and skills required to prepare for the future,
- To prepare students at the secondary level for life and higher education by providing a common public culture and profession,

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- To construct a healthy, balanced, and a dynamic school and education structure in accordance with the principles and policies of the MoNE and the employment relationship,
- To rise students' self-confidence, self-control and develop their sense of responsibility,
- To improve students' working habits and teamwork skills
- To improve students' creative and critical thinking skills,
- To follow the developments and changes to teach foreign languages
- To support students to develop projects to use their information to produce new knowledge and skills,
- To take advantage of technology to increase the quality of the education,
- To promote lifelong learning for all individuals,
- To encourage education and training services and certification to ensure compliance with international standards,
- To enhance students' vision in a scientific way.

These objectives of Science High Schools indicate today's Science, Technology, Engineering and Mathematics (STEM) education (Erdogan & Stuessy, 2015a; Erdogan & Stuessy, 2015b). The following teams and councils were established to ensure the efficiency of government activities in order to develop STEM education with; the realization of the importance of school and environment cooperation, the support of local authorities and civil society organizations, and the development of cooperation with all types of institutions:

- Teachers Council
- Teacher's Board for a specific course and subject
- Group of Teachers Council
- School Student Council
- School Student Awards and Disciplinary Committee
- Honorary Board
- Social Activities Committee
- Science Consulting Art Design Boards

It would be inevitable to say that the Science High Schools were successful to carry out the objectives so that along fifty years, hundreds of highly qualified graduates were attended to METU and other high-ranking universities in Turkey as well as abroad. Thus, the MoNE started initiating more than 200 science high schools between 1964-2014 in Turkey. Since 2010s, the private science high schools were started using the same curriculum as a model.

Table 1. Weekly hours for science high school curriculum in the 1964-1965 school year

Courses	First Year	Second Year	Third Year		
			Physics Branch	Chemistry Branch	Biology Branch
Basic Math	4	4	4	4	4
Geometry	3	2	2	2	2
Science	6 (lst term)	0	0	0	0
Physics	3 (2nd term)	4	6	0	0
Chemistry	3 (2nd term)	4	0	6	0
Biology	4	4	0	0	4
Literature	4	4	4	4	4
History	0	3	0	0	0
Geography	3	0	0	0	0
Social Science	0	0	3	3	3
2nd Language	5	5	5	5	5
Sport	1	1	1	1	1
National Security	1	1	1	1	1
Elective Courses	5	4	7	7	7
Total	36	36	36	36	36

(Source: Ankara Science High School Project, 1964)

Method

Our work in this monograph was initiated by examining Ankara Science High School project and the protocols at the establishment phase and the legislation in different ways. The numbers of high school graduates placed to STEM education in the university were reviewed.

Table 2.Comparison of weekly hours for three different high school curricula

	Anatolian High School					Science High School					Social Science High School					
	Grade					Grade					Grade					
Course Name	9	10	11	12	Total	9	10	11	12	Total	Hz	9	10	11	12	Total
Turkish	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4
Language and expression	2	2	2	2	8	2	2	2	2	8	0	2	4	4	4	14
Turkish literature	3	3	3	3	12	3	3	3	3	12	0	3	4	4	4	15
Religious culture and moral knowledge	1	1	1	1	4	1	1	1	1	4	0	1	1	1	1	4
History	2	2	0	0	4	2	2	0	0	4	0	2	4	3	0	9
Turkey revolution history and Kemalism	0	0	2	0	2	0	0	2	0	2	0	0	0	2	0	2
Contemporary Turkish and world history	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
Geography	2	2	0	0	4	2	2	0	0	4	0	3	2	4	4	13
Mathematics	6	6	0	0	12	6	6	6	6	24	3	6	6	6	6	27
Physics	2	2	0	0	4	2	2	4	4	12	0	2	2	0	0	4
Chemistry	2	2	0	0	4	2	2	4	4	12	0	2	2	0	0	4
Biology	3	3	0	0	6	3	3	3	3	12	0	3	3	0	0	6
Health information	1	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1
Philosophy	0	0	2	0	2	0	0	2	0	2	0	0	0	2	0	2
First foreign language	6	4	4	4	18	7	3	3	3	16	20	6	3	3	3	35
Second foreign language	2	2	2	2	8	2	2	2	2	8	4	2	2	2	2	12
Physical education	2	2	2	2	8	2	2	2	2	8	2	0	0	0	0	2
Visual arts	1	1	1	1	4						0	2	2	0	0	4
Traffic and first aid	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1	1
Counseling and guidance	1	1	1	1	4	1	1	1	1	0	1	1	1	1	1	5
Social science studies	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	6
Psychology	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Sociology	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4
Logic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Ottoman Turkish	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	6
Applications of mathematics	0	0	0	0	0	0	2	2	2	0	0	0	0	0	0	0
Science applications	0	0	0	0	0	0	3	3	3	0	0	0	0	0	0	0
Total main course hours	36	33	20	17	106	36	36	40	37	130	34	36	40	40	38	188
Weekly total hours	40	40	40	40	160	40	40	40	40	160	34	40	40	40	40	194

In this study several doctoral dissertations, MoNE e-school database, and yearly reports were examined and related statistics were collected. The archive scanning was performed. The latest activities and capacity of Bronx High School in the U.S., which was visited later in 1964 as a successful model for the Ankara Science High School, were observed to compare the development by the years (The Bronx High School of Science, 2016). Interviews were conducted with Ankara Science High School graduates, students, and teachers.

Results and Discussion

Different curricula with minor changes have been implemented over the years at Ankara Science High School. The first curriculum at 1964-1965 is given in Table 1. The decisive point in the preparation of the curriculum had been the weight of science courses. Share of class hours for science high schools except foreign language and sport was more than 65% of the total weekly hours. Later, this ratio was revised as %60 in 1993 (MoNE, 1993). More lectures have been taken place in accordance with the objectives of science high school on cultural and social sciences. In the 1999 regulations, while maintaining the weight of in-class education, more importance was given to the laboratory practices. The program, which is currently being implemented, is given in Table 2 that compares the high school curriculum with standard curriculum of other high schools. When the weekly hours for mathematics was compared between Science High School and Anatolian High Schools, the weekly hours for mathematics was twice more in Science High School than Anatolian High Schools. This occasion was similar for biology subject for three types of schools. The weekly hours for physics and chemistry subjects were three times more in Science High School than other two types of schools.

In Science High Schools, total weekly course time is double in mathematics and biology, and triple in physics and chemistry. The first Science High School started to serve students in 1964-1965 academic year and had been serving as the first and only Science High School for 18 years until the second one was opened in 1982. Until 2009, the maximum number of operating schools was eight. In 2009-10 and the following three years, the number of schools increased much more than previous years. In 2014-2015 Teachers High Schools were converted to Science High School and 81 new science high schools started their new training preparation**.**

Table 3.Number of science high schools by year

Start of Education Year	Number of Schools	Start of Education Year (Continued)	Number of Schools (Continued)
1964-1965	1	1999-2000	5
1982-1983	1	2000-2001	2
1983-1984	1	2001-2002	6
1984-1985	1	2002-2003	4
1985-1986	1	2003-2004	3
1986-1987	1	2004-2005	7
1987-1988	1	2005-2006	2
1988-1989	1	2006-2007	7
1989-1990	5	2007-2008	4
1991-1992	1	2008-2009	3
1992-1993	3	2009-2010	12
1993-1994	3	2010-2011	20
1994-1995	6	2011-2012	26
1996-1997	8	2012-2013	4
1997-1998	3	2013-2014	6
1998-1999	3	2014-2015	81
Total			232

(Source: MONE E-School, 2015)

There are 159 high schools serving with 3735 teachers. The standard capacity of these schools in terms of permanent staff is 3957. The average number of students per school is 350. The percentages for female and male for overall students are 67.5 and 32.5, respectively. In 2015, 15 Science High Schools from various provinces were selected as “STEM Project School” to develop new and innovative training programs. The list of them is given in Table 4.

Table 4. MoNE STEM Project for science high schools

City	County	Name of School
Adana	Seyhan	Adana Science High School
Ankara	Çankaya	Ankara Science High School
Antalya	Döşemealtı	Yusuf Ziya Öner Science High School
Bursa	Nilüfer	Tofaş Science High School
Diyarbakır	Yenişehir	Rekabet Kurumu Cumhuriyet Science High School
Erzurum	Palandöken	Erzurum İbrahim Hakkı Science High School
Gaziantep	Şehitkâmil	Vehbi Dinçerler Science High School
İstanbul	Kadıköy	İstanbul Atatürk Science High School
İstanbul	Fatih	Çapa Science High School
İzmir	Bornova	İzmir Science High School
Kayseri	Melikgazi	Kayseri Science High School
Malatya	Yeşilyurt	Malatya Science High School
Mersin	Yenişehir	Eyüp Aygar Science High School
Şanlıurfa	Karaköprü	Şanlıurfa Science High School
Van	Edremit	Türk Telekom Science High School

(Source: MoNE E-Okul, 2015)

The development of private sector in K-12 education is an important factor to analyze the change in Turkey. From 2006 to 2014, more than 30% of public science high school students were graduated from the private middle schools (seeTable 5).

Table 5.Student source of public science high schools from different type of middle schools

Year of Education	Private Middle School	Public Middle School	Total
2006-2007	2,463	5,087	7,550
2007-2008	2,644	5,129	7,773
2008-2009	2,918	5,961	8,879
2009-2010	3,570	7,723	11,293
2010-2011	4,128	9,249	13,377
2011-2012	5,390	10,422	15,812
2012-2013	6,148	14,399	20,547
2013-2014	9,003	22,735	31,738
Total (%)	36,264 (31)	80,705 (69)	116,969 (100)

(Source: MoNE E-School, 2015)

Private Science High Schools

There are 58 private science high schools in Istanbul, 30 in Ankara, 18 in İzmir, and 231 in total. Their capacity is 35,593 students; however, currently 19,251 students are enrolled. Accordingly, the occupancy rate is 54% as of April 6, 2015. MoNE decided to allocate 3,500 Turkish Liras per student per year according to the law no 6528 in 2014-15 if parents have their child register to the private schools. Totally 168,310 students were supported and 33,749 of them registered to private schools. Out of 33,749, 2,069 students registered to the private science high schools. Accordingly, the capacity usage in private science high schools was increased by 6%. MoNE expects that the capacity usage of these schools will increase more in the next years up to 90% and also new private high schools will begin to serve students. The numbers of public and private science high schools are nearly the same, but the quota and capacity utilization is normally higher in public schools. However, the number of students per classroom is lower at the private science high schools.

When the distribution of public and private science high schools by the region is taken into consideration, there are eight private science high schools separately in Ankara and Antalya. Both cities have the highest number of science high schools in comparison to other cities whereas Şanlıurfa has the second highest number of private science high schools. During the period of 1990-2011, the ratio of male students had continuously decreased and the ratio is nowadays around 50%. The percentage of female and male public science high school graduates attended to STEM related majors at higher education is given in Table 6. The Faculty of Engineering is ranked as first with 45.5% and Faculty of Medicine with 25.3% is ranked as the second. It is observed that 70% of science high school graduates attended to STEM related majors after the high school. There are 5.881

permanent teacher positions in public science high schools. This corresponds to approximately 26 teachers in each school.

Table 6. The distribution of MoNE science high school graduates to faculties

Faculty	Female (%)	Male (%)	Total (%)
School of Medicine	10.5	14.8	25.3
Faculty of Engineering and Architecture	10.1	33.5	45.5
Faculty of Dentistry	1.7	1.5	3.2
Faculty of Law	0.2	0.3	0.5
Faculty of Economics and Administrative Sciences	1.7	6.3	8.1
Faculty of Arts and Sciences	3.4	3.6	7.0
Faculty of Education	1.7	1.6	3.3
School of Pharmacy	1.3	1.2	2.5
Faculty of Agriculture	0.3	0.4	0.7
Faculty of Veterinary Medicine	0.4	1.0	1.4
School for Open Learning	0.4	0.7	1.1
Vocational Schools	0.1	0.2	0.3
Health Vocational Schools	0.5	0.3	0.7
Others	1.5	1.0	2.5
Total	33.7	66.3	100.0

(Source: MoNE E-School 1990-2011)

As the number of private schools had been increasing, the number of students graduating from private science high schools has been increasing since 2008. The fund given by MoNE is one of the dominant factors in this increase. In 2013, the number of graduates from public science high schools dramatically increased.

Table 7. Number of graduates from science high schools

Year of Education	Private School	Public School	Total
2008-2009	2,393	4,490	6,883
2009-2010	2,097	4,735	6,832
2010-2011	2,295	5,276	7,571
2011-2012	2,327	5,442	7,769
2012-2013	2,639	6,252	8,891
2013-2014	2,919	8,380	11,299
Total	14,670	34,575	49,245

(Source: MONE E-School, 2014)

As shown in Table 8, from 1967 to 2014, 4300 students graduated from Ankara Science High School in total. Over the years, all students got acceptance from universities but three. The distribution of placement according to the faculties is 43.3% to Medical Faculties and 49% Engineering Faculties.

STEM Applications in the US

On October 4, 1957 the USSR sent the Sputnik-1 satellite from the Baikonur Cosmodrome in Kazakhstan to the orbit of 250 km. The success of Russia had a significant impact on the U.S. government and citizens. Shortly after the Sputnik satellite, the U.S. had concerns because of not sending the very first satellite (Bybee, 2010). The Cold War and the Space Fair triggered the revision of the system, so the rocket science and space science brought to the attention and financial resources allocated to projects increased. Success of Japan in the 1980s constituted the second most important influence for the U.S. education system. It was observed that a similar success, which was a threat to the U.S., was achieved by China, India and Brazil during 2000-2010. Therefore, the U.S. has started several reform initiatives and the very well known of these initiatives was the one in 1996. National Science Education Standards were published within the scope of the science curriculum to give direction to schools on how to teach (National Research Council, 1996). This program was the basis for both the development of the U.S. and STEM program (Erdogan & Stuessy, 2015a). In 2012, the scope of the Next

Generation Science Standards was established in accordance with the basic standards established in the 1996 (Achieve, 2013; National Science Teachers Association, 2014); thus, the standards of 15 laboratories in STEM disciplines have been published. No Child Left Behind Act (2001) and The Every Student Succeeds Act (2015) were the important developments for Turkey as well. Therefore, the Education Faculties of all universities in Turkey accelerated their research studies on STEM, many scientific projects started and thesis published, and many articles being published at scientific journals.

Table 8. The faculties selected by Ankara Science High School Graduates as student numbers

Year	Number of Graduates	Medical Faculty	Eng. Faculty	Others	Total
1967	96	24	60	12	96
1968	96	19	60	17	96
1969	96	7	75	14	96
1970	96	14	71	11	96
1971	95	23	67	3	95
1972	95	26	69	0	95
1973	96	28	66	2	96
1974	96	45	48	3	96
1975	96	65	31	0	96
1976	96	75	18	3	96
1977	89	60	26	3	96
1978	85	51	30	4	96
1979	84	58	20	6	96
1980	73	70	13	0	96
1981	96	87	8	1	96
1982	90	70	20	0	90
1983	85	70	15	0	85
1984	88	62	20	6	88
1985	96	30	57	9	96
1986	89	25	60	4	89
1987	94	17	72	5	94
1988	92	49	39	4	92
1989	94	29	64	1	94
1990	95	13	45	37	95
1991	94	26	52	13	94
1992	88	35	44	4	88
1993	95	33	45	17	95
1994	23	9	10	4	23
1995	58	25	25	8	58
1996	24	9	10	5	24
1997	93	18	72	5	93
1998	94	27	66	1	94
1999	90	26	60	4	90
2000	89	25	60	4	89
2001	94	30	50	4	94
2002	92	49	39	4	92
2003	90	30	56	4	90
2004	91	27	52	12	91
2005	89	35	44	10	89
2006	94	38	46	10	94
2007	93	48	36	9	93
2008	92	52	30	10	92
2009	92	39	48	7	92
2010	90	44	35	9	90
2011	94	48	37	9	94
2012	92	52	30	10	92
2013	90	46	38	6	90
2014	98	52	40	6	98
Total	4,247	1,840	2,079	339	4,300

(Source: Ankara Science High School, 1967-2014)

The main subject of the national and international conferences organized in Turkey is how to develop the STEM education in Turkey and how to adapt it to our school-curriculum (Akgündüz et al., 2015). The private sector is much more flexible and faster to adapt STEM education. MoNE also works hard on STEM education by conducting pilot studies in selected the Ankara Science High School and others, which were listed in Table 4.

STEM education is an interdisciplinary concept (Corlu, Capraro, & Capraro, 2014; see Figure 1). The selection of different faculties by science high schools graduates reflects this concept. A resistant STEM pipeline also needs some scientific and financial support. Turkey currently does not have STEM program at the national level, but STEM education related organizations and their increasing activities would be a base for a national STEM Program. The EU supported projects also raise the capacity and develop the network between the stakeholders in Turkey. In addition, TUBITAK announced funds for STEM programs running in science high schools.

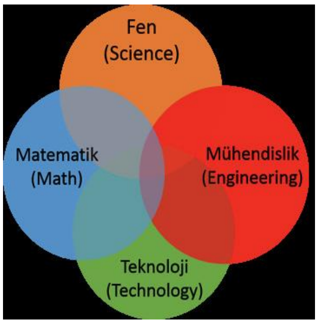

Figure 1. STEM Education

Some STEM applications done by Virginia Thomas Jefferson Science and Technology High School (2015) graduates in the research labs are presented in the following list:

- Astronomy and Astrophysics
- Automation and Robotics
- Biotechnology and Life Sciences
- Chemical Analysis and Nano Chemistry
- Communication Systems
- Computer Aided Design
- Computer Systems
- Energy Systems
- Multidisciplinary Research
- Microelectronics
- Mobile and Web Application Development
- Neuroscience
- Oceanography and Geophysics Systems
- Quantum Physics and Optics
- Prototyping and Engineering Materials

Supports by TUBITAK for STEM Education

The projects supported under TUBITAK Science and Society program was for to use STEM approach in the projects that are useful to the community in an understandable format where the information is supported by visual tools and interactive applications (The Scientific and Technological Research Council Of Turkey, 2015). In this project, the main goal is to trigger the participants' curiosity, for research and learning by making them to realize simple scientific facts, not by transferring the knowledge.

TUBITAK 4003 Program of Science and Technology Centers

This program was designed to bring people from different ages and different backgrounds together around science by providing information resources and to trigger their interest in experimental and applied sciences

(The Scientific and Technological Research Council Of Turkey, 2015). The purpose of the program is also to increase participants' interest in and attention to science. These centers are expected to increase creativity. Along with their contribution to the science, these centers also have exhibited the history and culture of the regions in which they are located. They present a combination of art and science because the submission of scientific knowledge requires creativity and an artistic perspective.

Science centers can help participants to broaden their horizon by using scientific approaches for explanation of daily events. Everyone can demonstrate creative thinking because creative thinking is a skill that can be improved. In particular, visitors can decide on their own whether to contribute to young or adults. Science centers are the center of attraction not only because of their content but also because of the structure within a diversity of green space. Large entrance and waiting room with high ceilings offer a comfortable environment for guests. The entrance with interactive outdoor science center exhibits invites them to the mysterious world of science.

TUBITAK aims to develop scientific thinking, to spread the scientific knowledge, to create a culture among the society, to promote asking questions, to raise pioneering individuals, to provide a new vision for society, and to take the leap in science that Turkey has needed by generalizing science centers in Turkey. Science and Technology Committee 23 meeting was arranged to increase the interest and curiosity of every individual, especially children and youth, in science and technology in all metropolitan cities as of 2016. Outcomes of the science centers will be more accurate in 2023. Policy makers decided to cooperate with local governments to establish these centers in all provinces.

TUBITAK 4004 Nature Education and Science High Schools Program

The aim of this program is to transfer the knowledge to the society in a comprehensive manner while using visualization tools and interactive applications. The main goal in this program is to trigger the participants' curiosity and ambition for the research, query, and learning by making them to realize simple scientific facts, not by transferring the knowledge (The Scientific and Technological Research Council Of Turkey, 2015). 289 projects were carried out between 2007-2012. The aim of this program is:

- To popularize the science and scientists,
- To emphasize the entertaining part of science,
- To overcome prejudices, negative concerns about science and scientists in society and student concerns,
- To build bridges between the school and research organizations
- To develop scientific process skills,
- To provide an understanding of the nature of science,
- To understand the interaction among science technology, society, and individuals,
- To provide sources from outside of the school according to the call to ensure the use of objective,
- To use original methods and techniques to promote the effective use of materials,
- To share scientific expertise to promote activities for the development of new content,
- To develop higher-order thinking skills,
- To enable the delivery of meaningful answers to questions regarding everyday life
- To ensure understanding of the technological activities and their relationship to the welfare of the society
- To improve environmental awareness and sensitivity with a scientific standpoint,
- To promote science literacy,
- To transfer best practices and to adapt issues related to the call,
- To promote activities in the framework of the concept for "citizen science",
- To use Web 3.0 (the Semantic Web) technology for their activities and to improve the formation of call to spread.

TUBITAK 4005 Science and Society Innovative Activities and Practices Program

This program was related to the topics about teachers' training. The program aims to arouse teachers' interest, to teach the content knowledge and improve skills to increase their motivation, to develop positive attitudes, to gain innovative approaches through interactive methods and techniques in science related subjects, and to raise the awareness of teachers in innovative approaches outside the traditional teaching methods, strategies, and techniques for implementation in their teaching environment (The Scientific and Technological Research Council Of Turkey, 2015). With all these intentions 11 projects were supported in 2014. Some examples to achieve the objectives under this program are presented in the following paragraphs.

Quantum Physics and Optics Laboratory offer exciting opportunities for computerized monitoring of research and applied physics. Students in applied research frequently learn theoretically and experimentally with new devices in optical, electromagnetic, acoustic, nanotechnology, photonics and systems. In optical projects, imaging systems, vision sensors, color, human perception, image processing, holography, laser interferometry and other applications are located. Students in Modern Physics Laboratory were engaged in research on metamaterials, holographic data storage, atoms, quantum, nuclear, solid state, and elementary particle physics. The main target of the laboratory followed by professionals in the field of contemporary research topics is to attract the attention of students in cooperation with schools.

Optics and some projects are carried out in the Modern Physics Laboratory:

- 3D Visualization for "Augmented Reality" Design Glass,
- Dissimilar Metals between Quantum Tunneling,
- Generated Using Holographic Data Storage Computer,
- Microwave Metamaterial with Q-Factor Improvement,
- Noise Analysis with pentacene transistors.

Modern Physics Laboratory has the following devices:

- Newport vibration-isolated optical breadboards,
- Helium-neon, argon-ion and Solid-State Lasers,
- Scintillation Detector Multi-Channel Scalar/Analysis,
- Computer Controlled X-Ray System,
- Easy scan Scanning Tunneling Microscope,
- Microwave Generation and Measurement Apparatus.

CAD Laboratory with a complex mechanism such as a heart pumping device simulation engages in technological design and engineering studies. Engineering software packages, including Autodesk products, mainly used in architectural design, which makes it possible for laboratories to use them. Some of the projects carried out in the Computer Aided Design Laboratory are:

- Underwater Life Design (Ocean Life of materials, pressure and toxicity studies),
- Multipurpose Design and Installation,
- Solar Tools,
- DNA Modeling,
- Flight Simulation Test,
- Artificial Body Parts and Body Design and Simulation,
- Clean slate of innovative mounting the Screen Auto Car Lift Robot.

The following equipment and software are used in the laboratory:

- The HP Compaq dc5100 Micro-tower,
- Intel Pentium 4 HT/2.8 GHz, 1 GB RAM,
- NVIDIA Quadro NVS 280 Graphics Adapter,
- Blaster Audigy X-Fi Audio Midi Interface,
- Design Jet 500 plotters,
- Z 310 3-D prototyping plotter machine,
- Inventor, AutoCAD Mechanical, Civil, Land, Revit, VIZ, and 3ds Max Solid Works CAD Software.

TUBITAK 4006 Science Fair Support Program

In accordance with the protocol signed between the MoNE and TUBITAK, the program was established to develop the scientific culture of our country (The Scientific and Technological Research Council Of Turkey, 2015). Within the framework of the school curriculum, students have been studying courses and making research on the issues that they have identified by their own interests, so that they can share the results of their research. Therefore, the program needs to include following items to create an environment where the learning is fun for all:

- Encourage the adoption of science and scientific work by the new generations,
- To link the science to everyday life,
- To develop research techniques and scientific reporting as well as to distribute the scientific presentations in order to improve young people’s skills,
- To provide an opportunity for every child in different science projects and cognitive developmental level,
- To create new environments and opportunities for students to do research projects and sharing,
- To introduce entertaining and interesting part of the science to students to eliminate the pressure of competition on students,
- To ensure equal access for scientific projects to school districts in different socioeconomic levels,
- To teach how to adapt the science and solutions to real-life problems.

Science Fair will be held in the year 2015 in 3,300 schools.

4007 TUBITAK Science Fair Support Program

The aim of this program was to provide science communication, to spread scientific knowledge to a broader community, to raise the interaction of science and technology for public, and to comprehend exhibitions, stage shows, performances, workshops/laboratory work, thematic science games, contests, interviews and so on (The Scientific and Technological Research Council Of Turkey, 2015). Providing the participants the fundamental scientific facts through these events, it was aimed to trigger curiosity and desire to learn, research, and inquiry. In 2014, TUBITAK decided to support 25 projects with an upper limit of 100,000 Turkish Liras as grant per project.

TUBITAK 5000 Open Source Digital Content Support Program

The overall objective of the program is to accelerate the creation of high quality e-books and e-courses for K-12, so that equal opportunities for all students can be provided (The Scientific and Technological Research Council Of Turkey, 2015).

Conclusion

In Turkey, public and private science high schools contribute to the actualization of 2023 targets by submitting qualified students to universities. For a better quality, the following suggestions should be considered. Curriculum needs to be changed to accelerate the transition from industrial society to the information society, so individuals should be trained for future technologies and professions. Laboratories in STEM High Schools should be updated. Physical conditions of high schools should be improved to the best level. Cooperation between alumni, students, parents, and schools should be strengthened.

There should be cooperation between universities and schools for K-12 such as METU and Ankara Science High School. Freedom in decision-making and implementation should be provided to the science high schools. Science high school teacher selection should be rearranged according to much more objective principles (McKinsey & McKinsey, 2007). Master of philosophy and doctorate in teacher appointments and knowledge of foreign languages should be set as prerequisites. In-service training for teachers should be permanent, teachers' knowledge and experience should be enhanced, and teachers should go to abroad, so that they can be up to date about new developments in the world. Alumni’s opinions should be obtained to understand whether their education was sufficient for the university that they attended. More resources and new programs must be devoted to public and private science high schools.

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