

## Pre-Service Science Teachers' Views towards the Process of Associating Science Concepts with Everyday Life\*

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### ABSTRACT

For students to be educated as science-literate individuals; It is expected that they will be able to know the basic knowledge of science, transfer these knowledge to everyday life, and use them to solve issues / problems they encounter. At this point, there are great duties for prospective teachers, who are teachers of the future, to raise science-literate individuals. It is aimed to take the opinions of prospective science teachers about the process of associating science subjects with everyday life in this study. 106 prospective science teachers participated in the research carried out as a case study. Opinion form and semi-structured interview were used as data collection tools while descriptive and content analysis methods were preferred in analysis. According to the theme created from the findings, the prospective teachers defined association with daily life as the use of information in everyday life, the connection of information with everyday life, giving examples from everyday life. As a result, in the study, it was found that, in associating with daily life, prospective teachers focused on transfer of knowledge to everyday life whereas they emphasized less about feeling, seeing or understanding science in events or situations that they encounter in everyday life.

**Keywords:** Association with everyday life, opinion, prospective teacher, science.

### INTRODUCTION

Parallel to the increase in knowledge, individuals who know the necessary information and in addition to this, can access the information that they need whenever necessary are required instead of individuals who memorize all information. Parallel to this situation, the educational programs of the countries have begun to be changed (Schudel, Le Roux, Lotz-Sisitka, Loubser, O'Donoghue and Shallcross, 2008) and some changes have been made in the teaching programs in Turkey over the years. This change has a background which is an international concept, for ex. PISA's contextual learning (OECD, 2015). Associating science with daily life is a key factor for PISA which OECD countries become more and more interested in (Carvalho & Costa, 2015). Because we believe it is an indicator that shows us students from all over the world are becoming scientific literate individuals (OECD, 2015). As Eryilmaz and Kaya (2011) stated; Students in science programs are expected to explain the



problems they encounter in their lives and use the information they have acquired in their solution. As a matter of fact, the vision of the science curriculum is defined as; "To educate all students as science literate individuals" [Ministry of National Education (MEB), 2013:1]. As a result, in the science program; It is expected that instead of memorizing knowledge, they should be science literate individuals who are active in the process and have high-level thinking skills. One of the most basic features of being science literate individuals, besides knowing the concepts of science, is to understand the place of these concepts in daily life and to be able to use concepts effectively in everyday life. Science education aims to make students aware of how science concepts can be used in everyday life (Çepni, Taş & Köse, 2006; İlkörücü, Göçmençelesi & Özkan, 2009). In this context, it can be said that associating science programs with daily life has a prominent place.

Association with daily life is to be able to perceive that science in the nature exists in every field of human life, to understand what events can be made up of which causes and to be able to comprehend what field of science these causes belong to (Yılmaz 2008). In this context, the association with daily life provides a meaningful learning of science concepts and the use of this knowledge in situations or problems where they are encountered in life. As stated by Ay (2008); giving examples from daily life during the course presentations and establishing the necessary relationships in this area will also minimize the misconceptions that arise from the daily misguided observations of the students. In addition, the association with daily life increases the interest and attitudes of the individuals towards science and provides the permanence of the learned information (Hürcan & Önder, 2012). As it can be understood, the association with daily life has an important place in the development of cognitive, affective aspects and skills of students.

While the association with daily life is important in science lessons, it can be said that, the association with daily life is not done completely in science lessons and the level of students' association with daily life is low. In the studies conducted in field literature, it has been concluded that the students are not in a sufficient level to associate the concepts of science with the events in everyday life (Akgün, Tokur & Duruk, 2016; Deder, Şen, Sarı & Çelik, 2013; Doğan, Kırvak & Baran, 2004; Emrahoğlu & Mengi, 2012). Similarly, parallel results were obtained from the studies conducted with prospective teachers and it was understood that their levels of association with daily life were low or moderate (Özmen, 2003, Yadigaroglu, Demircioğlu, Azizoglu, Topal, Ağalar, Crespo & Pozo, 2004) also point out that, most of the studies done on teaching science indicate that students have difficulty establishing relationships between daily (intuitive) and scientific knowledge taught to them. In this context, it is thought that it is important in terms of field literature to dwell on the subject on association of science concepts with everyday life, on how to make association with everyday life and to go over the shortcomings made in the process.

For science lessons to be associated with daily life, it can be said that it is necessary to continue the lessons with examples and connections from the daily life in the process of discussing the topics. Likewise, Yildirim and First (2014) concluded that students can more easily explain situations which resemble the events that they encountered in textbooks or teaching process, but they cannot explain adequately in face of different examples. In parallel with this situation, it can be said that the more place is given in the lessons to association with daily life, the more effective it is on the students. Malan, Ndlovu and Engelbrecht (2014) concluded that using realistic activities during lessons, cognitive processing became more concrete and realistically oriented and the students reported greater motivation to learn. In this context, several factors such as course books, teacher, and teaching process influence the process of association with daily life. It is stated in field literature that teacher, curriculum, textbook, laboratory, learning attitudes and socio-economic factors (Koçak Kösece, 2013; Yılmaz, 2008) are affective in association of science with everyday life. In this context, it is

thought that taking the views of the participants on the process of association with daily life and determining the expectations and deficiencies in these points will be important in terms of field literature. When the literature is examined, we met very few studies which have identified the views of the participants on associating science with everyday life. Kamaraj (2009) examined the opinions of teachers and secondary school students on how they relate science and technology curriculum to daily life. Tanuğur, Ogan-Bekiroğlu, Gürel and Süzük (2012) evaluated the associations of secondary school physics program with everyday life according to teacher's opinions. In some studies conducted in the field, the views of science teachers on the effects of misconceptions on the daily life regarding heat and temperature (Türkoğuz & Yankayı, 2015) and the solar system and space (Yılmaz, Türkoğuz & Şahin, 2015) were examined. Ürek and Dolu (2016), on the other hand, determined the views of university students on the subject of elements and compounds in everyday life. Yildirim, Köklükaya & Selvi (2015) have taken prospective science teachers' views on the use of science in daily life in 3-Idiot film and the role of the public education in the education process. In this context, it is understood that the opinions on the association with daily life are usually based on the reflection of a science theme in daily life. However, there was no study in which the views of teachers or teacher candidates regarding the theoretical structure of association with daily life were taken. In this regard, in this study, it is aimed to determine the views of prospective teachers on matters such as what they understand from association with daily life, what are the factors that are effective in association with daily life, the level of usage of association with daily life in their lessons and how effective it is on students.

## METHODS

A holistic single case design was used in the study in which the prospective science teachers' views on the process of associating science concepts to everyday life were determined. A case study was deemed appropriate because of the presence of a single analytical unit in a holistic one-case study and an investigation of its unique situation in the process (Çepni, 2014) and because, in the study done, status of the students in one faculty regarding association with daily life was aimed to be determined.

The study done was conducted in the education faculty of Uludağ University in 2015-2016 academic years. 106 prospective science teachers, including 39 fourth grade, 36 third grade and 31 second grade, participated in the study. First class students were not included in the study because training courses and field courses were differentiated in the questions in the study and they had not yet taken the training courses. For this reason, the participation of second, third and fourth grade prospective teachers were deemed appropriate. 87 of the prospective teachers in the study are female and 19 are male.

Opinion form and semi-structured interviews were used as data collection tools in the study. When the opinion form was prepared, firstly the field literature was searched and important points related to the association process with daily life were determined. Parallel to this point, open-ended questions are drafted. The questions were sent to two people who are experts about association with daily life and one person who is an expert about qualitative researches. Some inquiries were issued according to the feedbacks received, and some of the questions were edited. For example; It was proposed by the expert to add sub-dimensions to the questions written on what the factors that are effective in association with daily life are, and the question was structured from scratch by adding sub-dimensions. Parallel to this situation, the opinion form consists of 5 open-ended questions. In addition, open-ended questions were added to the form on demographic features and association with daily life, and the final form was given. The interview form was prepared in parallel with the open-ended questions on the opinion form and probe questions were added to the form. The response form was answered within a total of 30 minutes with 106 prospective teachers at different grade

levels. The interviews were selected among the participants who completed the opinion form. Participants were selected from among the students who were in good, intermediate and low level in their elective courses, and care was taken to include students with knowledge about association to everyday life. Interviews were done with the participation of a total of 21 students, with six of them in the fourth grade, eight of them in the third grade and seven of them in the second grade.

Content and descriptive analysis was used in the analysis of the data. From the data analysis, the data obtained from the opinion form was analyzed first. For this purpose, codes were extracted in the analysis process, and then categories were created by combining these codes. Frequency and percentage values for these have been established. The data obtained from the interviews were then transcribed and used to support findings from the opinion form. Here, notations such as Ö24 have been used in the representation of prospective teachers. Here, Ö indicates prospective teacher, 2 indicates that he/she is in second grade and 4 indicates that he/she is the fourth prospective teacher.

## FINDINGS

Findings regarding prospective science teachers' views on the process of associating science concepts with everyday life are included. In Table 1, there are findings about the opinions of prospective teachers about the importance of association to daily life.

**Table 1.** Findings regarding importance of association with daily life

	Very Important		Important		Undecided		Insignificant		Very Insignificant	
	f	%	f	%	f	%	f	%	f	%
The importance of association with daily life in learning a subject	58	55.2	43	40.9	4	3.8	-	-	-	-
Biology's place in your daily work in your life	20	19.1	64	60.9	20	19.1	1	0.9	-	-

It is seen that prospective teachers are aware that transfer of scientific concepts to daily life is very important but that they give less space to this subject in their lives. They pointed out that transfer to daily life is important in the context of students' learning at school. They considered that concepts such as persistent learning and concretization were effective in learning, and stated that this problem could be solved by transfer. This condition can have different causes. As a result of the individual interviews with the students, the views on the importance of transfer to daily life can be seen in more detail with the following examples.

Ö44: *I do not think I use it enough, of course, I need to get more information on this subject. I also think that the lessons in the school are sufficient.*

Ö25: *I use it. For example, even when I buy detergent, I look at it and it says with bleach additive. I check exactly what it does and doesn't have. Milk, for instance has everything such as pasteurization method and such written on its back. I pay attention to those kinds of things. Even when I get a hand cream, I look at its content chemically, I do it in this way. Or I give you the smallest example; Here we are working on chemical substances in our laboratory lessons. Let's just say, how do we clean it when something splashes on our hand? You cannot wash everything under water.*

Ö34: *as one will consider it alive knowing that it is related to life and in this way, he will establish a connection with his life, I think that he will never forget, as a matter*

*of fact, I don't forget the knowledge I learned in this fashion but I usually forget it when I memorize.*

Ö41: *When we give examples of daily life to the students, we see that it is much more lasting and interesting. In this school, I think that these laboratories, training courses are useful in this regard.*

In table 2, there are findings related to the process of giving place to association with daily life of prospective teachers.

**Table 2.** Findings related to the process of association with daily life

	Always		Frequently		Occasionally		Rarely		Never	
	f	%	f	%	f	%	f	%	f	%
The status of giving place to association with daily life in your lessons when you are a teacher	37	35.2	66	62.9	1	0.9	1	0.9	-	-
The status of giving place to association with daily life in your lessons at university	1	0.9	13	12.4	63	60.0	26	24.8	3	2.9

In table 2, the degree to how much transfer to daily life is used in the lessons students take at university and their answers related to giving place to transfer to daily life in their lessons when they become a teacher are given. Accordingly, they clearly show that when they are teachers, they will use transfer to daily life in their lessons. However, transfer to daily life in the lessons they have taken at university, although included, is not widely used. Students have answered this question with rarely or occasionally (84.8%). The rate of the answer frequently is 12.4%. In the individual interviews carried out with students, they have stated that daily life is not generally given a place except for some particularly some lessons. They have stated that in other lessons an occasional place is given. Therefore, it can be said that these lessons are not taught in the context of transfer to daily life. It is important for the students to indicate that there is not much room for transfer and that it is a deficiency and that it is difficult for them to understand the course subjects. Below are the opinions of the students about the situation; as a result of the individual interviews.

Ö32: *frankly speaking, they were all taught theoretically. Yes, of course there were examples in them from daily life, in genetics course for instance, mostly in genetics, but because it was mostly taught theoretically, it was never related to daily life.*

Ö42: *there was no place given to it in biology lessons until now. Because we only took information from books. We learned them but we never encountered them, but it was happening in other lessons, teachers were instructing us to do it.*

Ö21: *if I cannot give this to a student when I am a teacher, there wouldn't already be any meaning for me to give that information. Of course, my job is to deliver knowledge but I should also be able to teach him how to use that knowledge.*

**Table 3.** Findings of prospective teachers' understanding from transfer to daily life

Category	Code	f	%	f	%
From knowledge to daily life	Usage/practice of knowledge in daily life	46	34.1	108	80.0
	Association of knowledge with daily life	22	16.2		
	Giving examples related to daily life	10	7.4		
	Practice of knowledge in problems encountered in daily life	9	6.7		
	Turning knowledge into practical methods	7	5.2		
	Transferring knowledge to daily life	6	4.4		
	Explaining knowledge with examples from daily life	5	3.7		
	Experiencing knowledge by way of life	2	1.5		
	Preferring events from daily life in lessons	1	0.8		
From daily life to knowledge	Showing that lesson is a part of daily life	5	3.7	15	11.1
	Becoming aware of the subject in daily life	4	2.9		
	Seeing where knowledge is in daily life	3	2.2		
	Combining daily life with the subject of the lesson	3	2.2		
Its effect on learning	Increasing permanence	4	2.9	12	8.9
	Grasping the subject better	3	2.2		
	Concretization of teaching	2	1.5		
	Learning by doing and living	1	0.8		
	Knowledge creating differences in our behavior	1	0.8		
	Knowledge making life easier	1	0.8		
Total		135	100.0	135	100.0

When table 3 is evaluated, students mostly (80%) perceive transfer to daily life or association as applying the theoretically learned knowledge to daily life, to put it into practice. Bringing knowledge to bear, establishing a relation between knowledge and daily life, experiencing knowledge in daily life are different statements of students in the first theme at similar starting points. There are also students (11.1%) who state an opinion on using events observed in daily life reaching the information in class. These expressions include explanations such as perceiving the lesson content as a part of daily life, explaining knowledge by using daily life events and using daily life events as lesson content which can be counted as contra directional with the first theme. In addition, students also defined the transfer to daily life, depending on its effect on learning (8.9%). It has been seen that they use expressions such as increasing persistence, better comprehension of the subject, embodied teaching. Students then gave explanations in individual interviews supportive of these answers that they gave. Examples from these explanations are given below.

Ö22: *I immediately think about how to explain or understand a subject that I have learned by thinking practically. I immediately must implement the thing that I have learned so that it can be permanent.*

Ö31: *I understand giving examples from daily life about the subject that we will transfer, I understand relating it to daily life, for example where do we use force in daily life.*

Ö33: *I perceive it as transferring the scientific concepts that we have learned, the scientific events that we have seen in class to daily life. I perceive it as using these in daily life.*

Ö41: *let it be subjects in science, or subjects related to biology or chemistry or physics; it comes to my mind that we come across these in daily life and that we should be able to associate them with daily life.*

**Table 4.** *Opinions of prospective teachers about the use of transfer to daily life in biology lessons in university*

Status	f	%	Lessons	f	%	Subjects	f	%
Yes	86	85.1	General biology	47	37.8	Diseases	7	10.1
						Systems	6	8.7
						Nature, living and non-living beings	6	8.7
						Plants	4	5.8
						Environment	2	2.9
						Animals	2	2.9
						Blood groups	1	1.5
						Respiration and photosynthesis	1	1.5
						Environmental science	43	28.5
			Recognizing living things	4	5.8			
			Lifecycles	2	2.9			
			Ecology	2	2.9			
			Raising environmental awareness	2	2.9			
			Using the news	1	1.5			
			World organizations	1	1.5			
			Genetics	24	15.9	Blood groups	3	4.4
						Genetic structure of living beings	3	4.4
						Judicial events, paternal cases	2	2.9
						Relative relations	1	1.5
						Diseases	1	1.5
			Evolution	12	7.9	Function of wisdom tooth during the process	1	1.5
						Source of life	1	1.5
						Biology laboratory	5	3.3
			Biology laboratory	5	3.3	Investigating organ	3	4.4
						Environment observations	1	1.5
			Human anatomy	4	2.7	How systems keep the body in balance	1	1.5
			Plant and animal collecting	2	1.3			
Earth science	1	0.7						
Heredity	1	0.7	Blood groups	1	1.5			
Special subjects in biology	1	0.7	Benefits and harms of technology	1	1.5			
Partly	6	5.9	Environmental science	5	3.3	Our environment	1	1.5
						Environmental pollution	1	1.5
			General Biology	3	1.9	Support and movement model	1	1.5
			Genetics	2	1.3	Diseases	1	1.5
			Evolution	1	0.7			
No	9	8.9	-	-	-	-	-	
Total	101	100.0		151	100.0		69	100.0

Table 4 contains answers on whether association with daily life is made in the biology-based lessons that the students take. General Biology, Environmental Science, Genetics, Evolution, Biology laboratory, Human Anatomy, Plant and Animal Collecting, Geography, Inheritance, Biology Special Topics are compulsory and elective biology based courses. Students mostly (85.1%) stated that there is a place to association with daily life in these lessons. They also expressed their opinions about the fact that a transient amount of

place to transfer to daily life was given (5.9%) or that it was not used at all (8.9%). It is seen that the contents of these courses and the related instructors during the lesson refer to different topics while giving place to transfer to daily life. In addition, it can be said that the instructor uses the same daily life context through different subjects while giving examples from daily life. For example, associations related to diseases seem to be used for Genetic, Evolution and General Biology topics. It can be said that transfer to daily life is used more in general biology (37.8%) and environment (28.5%) courses.

In the individual interviews done later, it is drawn to attention that there are differences in the expressions of the students. A large majority of the students stated that transfer to daily life was done in the lessons, but that this was not enough. Below are examples from the individual interviews that were done.

Ö31: *frankly speaking, there is a lot of subjects in biology but I don't think that we use transfer to daily life in the biology course that is taught at the university. I think for that I would mostly say environmental science.*

Ö25: *it is done a lot in biology lessons. Especially the subject of living beings, to begin with, we are living beings. Even the subject of nutrition that we see, carbohydrates, fats and proteins for instance and their benefits in our body. Simply what do we do when we are ill? We take vitamin C. where do we learn this? We learn it in biology lesson. It becomes easier to implement it to life after we have learned it. Or if we gain a lot of weight and if we want to lose it, we can transfer to life things like where to start from, that we would use carbohydrates less, that we would use fats less since they are deposited in the body.*

Ö44: *there is place. In laboratory for instance, we had a lesson called plant and animal collecting, it was an elective course. For instance, I learned things that wouldn't come to my mind while I collected plants and that is how I started getting with it.*

Table 5 shows the opinions of prospective teachers regarding the effectiveness of their lessons in transfer to daily life. Prospective teachers have questioned the use of transfer to daily life in terms of the lessons they have given, and they have indicated in what sense it has influenced learning. According to this, students stated that transfer to daily life is used more frequently in field education courses because they are carrying out practical activities. They thought that the high rate of association with daily life in these activities, supporting the subjects with materials, causes such as how to narrate it to a student are effective in the use of transfer to daily life. At the same time, there are prospective teachers who indicate a reason in both education and field courses (29.5%) or particularly field courses (21.9%). Particularly, for both the education and the field courses, the rate of prospective teachers who stated an opinion such as "since we learn the subject in field courses and methods and skills used in (field) education courses " is 13.9%. in the field lessons, the opinions mostly (22.8%) are that it is due to applications in laboratories, greater association with daily life and subjects being nature and human. Below are examples of individual interviews with prospective teachers.

Ö31: *I think that the education courses are more effective. The reason is this: in biology 1-2, there is more theoretical knowledge and a teacher-based education, for instance we were designing material in Material Design, we were doing somethings on our own, it was more student-based, it was more contributive to me. Whereas in special education, it was mostly real life, there were more examples given in the lesson related to daily life.*

Ö35: *both are effective. Because education courses are related on a one-to-one basis daily to students' education but I suppose field courses are more effective. After all,*



*because our field is science and science is directly about daily life, place to several examples that are used in every field of my life can be given. I can say that majority is the same.*

*Ö41: is it easier to associate any subject of science or something that is related to the lessons we have taken in education courses? I think because it is from examples directly inside life, education courses are easier.*

**Table 5.** *Opinions of prospective teachers on the efficacy of their lessons in transfer to daily life*

Lessons	f	%	Codes	f	%
Field education courses	51	48.6	Since it is more practical	9	11.4
			Because there is more association with daily life	6	7.6
			Since subjects are supported with materials	3	3.8
			Since it brings teaching skills	3	3.8
			Since it explains how to narrate to a student	3	3.8
			Since it is related to learning	2	2.5
			Since it is for human behaviors	2	2.5
			Since it is effective in interpersonal communication	2	2.5
			Since it takes up more place in our lives	1	1.3
			Since it appeals to every group	1	1.3
			Since it is more important in teaching	1	1.3
			Since students take active roles	1	1.3
			Since it contains solid examples	1	1.3
Both field courses and field education courses	31	29.5	Since in field courses, we learn about the topic, the methods and the skills used in training courses	11	13.9
			Since they are interrelated	5	6.3
			Since they contain implementations	2	2.5
			Because in field lessons, daily life problems include implementation to life in education	2	2.5
			Because they include the principle of learning by doing and living	1	1.3
Field courses	23	21.9	Because there is human theme in their subjects	1	1.3
			Since there are applications in the laboratory	7	8.9
			Since it related more to daily life	6	7.6
			Since the subjects are nature and human	5	6.3
			Since science subjects make one more aware	1	1.3
			Since the abstracts are supported in concrete	1	1.3
			Since more subject is focused on	1	1.3
			Since if the knowledge in these lessons is inadequate, it wouldn't be transferred	1	1.3
Total	105	100.0		79	100.0

Table 6 shows the types of factors that prospective teachers take into consideration in terms of learning while transferring to daily life. According to these views, prospective teachers care a lot (42.1%) about the position of the teacher in transfer to daily life. They have explained the effectiveness of the teacher in the class, such as being in the role of the guide / lead, knowing the subject and describing the method, giving examples or teaching of the course being in the hands of the teacher. Laboratory use, learning / teaching approaches, strategies and methods, curriculum and course book are other factors. The theme of laboratory and learning approaches seems to be a little more important. Prospective teachers have expressed their opinion that the choice of approach or method should be transferable to daily life. It can be said that the laboratory is an important factor in terms of providing more practical activities / experiments and providing practical and concrete experiences. Examples of individual interviews with prospective teachers are given below.

Ö42: *all of them are effective but because now, students are practicing in the laboratories, it attracts their attention more and its effects are greater.*

Ö36: *laboratory; because it is a place where you need to be constantly active and most of the things that you learn are practiced over there. Because of this, we learn them by doing and it becomes easier to carrying the things that we have learned by doing to daily life.*

Ö36: *in my opinion, teacher is the most effective. Because teacher is the one who uses things like textbook, method, laboratory etc. and hence he is the one who narrates it all.*

**Table 6.** *Prospective teachers' views on the most important factor in transfer to daily life*

Factor	f	%	Codes	f	%
Teacher	74	42.1	Since he/she is in the role of guide/lead	12	9.2
			Since he/she is the most important factor	11	8.5
			Since he/she is the one who knows the subject and explains the method	6	4.6
			Since he/she is the one who teaches the subject	6	4.6
			Since model is the teacher	5	3.9
			Since teaching of the lesson is dependent on the teacher	4	3.1
			Since he/she is the one who gives direction to knowledge	3	2.3
			Being in continuous contact	2	1.5
			Necessity to be skilled gerektiği	2	1.5
			Being the one to associate the subject	2	1.5
			Being in interaction with the student	1	0.8
Laboratory	42	23.9	Turning it into practice	11	8.5
			Enabling learning by doing and living	11	8.5
			Presence of experiments/events	3	2.3
			Concretization with experiments	3	2.3
			Enabling improvement of skills	3	2.3
			Presence of practical events	2	2.3
			Being the first environment for transfer	1	0.8
			Being important in effective learning	1	0.8
Learning attitudes that are used	36	20.5	Being the way to narrate subject to a student	5	3.9
			There should be a student-based approach	4	3.1
			Selection should be made according to the student	3	2.3
			Selected approaches being important	3	2.3
			They should be life-based approaches	2	1.5
			Containing theoretical knowledge and application	2	1.5
			They should be approaches related to daily life	2	1.5
			Material, event and model being important	2	1.5
			There should be question/answer	1	0.8
Making transfer easy	1	0.8			
Curriculum	16	9.1	Boundary of curriculum / achievements	5	3.9
			It must contain event and explanation from daily life	3	2.3
			Including how the subject progresses	1	0.8
			It should be in their preparations	1	0.8
Textbook	8	4.5	Student studying from the book	3	2.3
			Providing an opportunity to check again and again	1	0.8
			Containing a lot of examples	1	0.8
			It should a material suited to the method	1	0.8
Total	176	100.0		130	100.0

## DISCUSSION and CONCLUSION

Prospective teachers attach immense importance to the use of transfer to daily life according to the findings obtained. Especially, they argue that the examples given from everyday life are more concrete and increase the permanence of information. They are justified by the examples given by their own learning experiences. Because of students considering science as a field where there are no personal or social relations, perception of science as a foreign culture is caused (Aikenhead, 2006). Therefore, it can be said that the transfer or relationship between science and daily life at school can create a positive attitude towards the science. One of the repeated criticisms based on the evidence of traditional school knowledge is the lack of relation with everyday life (Gibbs & Fox, 1999; Millar & Osborne, 1998; Osborne & Collins, 2000; Reis & Galvão, 2004; Reiss, 2000;). Especially when the limitations of learning events outside of school and the importance of association-based learning in the learning of science is taken into consideration (Yavuz Topaloğlu & Balkan Kızılcı, 2015), it is important that prospective teachers gain awareness by association and that they come to a state of being able to use it. This awareness lead future's teachers to global issues which they can use it in science lessons to teach with using daily life examples. Water purification, flood control, renewable energy, climate change or more local contexts can be used as daily life situations which effect on human life. In modern economics a major emphasis in business education has been to make the experience more authentic for students, and to instill skills that are transferable to real world applications (Cinebell & Cinebell, 2008). Grinenko, Makarova & Andreassen (2016) integrated the theoretical material with real life practice in their project and found that added value is expected to occur from graduated when employed in different companies/official services; an improved scientific competence in the regions is expected to strengthen both business and social services.

Prospective teachers pointed out the importance of transfer to everyday life, and at the same time they pointed out that the courses they had taken at university were deficient in associating to everyday life. It is especially important to indicate that they have less difficulty in the courses where association is included in the understanding of the topics. However, the value they give to transfer to daily life may also refer to the presence of other causes that positively influence their views on the use of transfer to daily life in their lessons when they become teachers. It has been a subject laid emphasis on by researchers that there is a profound relationship between the information and context to be transferred and how it should be done (Gilbert, Bulte & Pilot, 2011), but it has been pointed out by prospective teachers that it is key factor in a better understanding of the subject. Prospective teachers therefore seem to be positively approaching the use of transfer to daily life in teacher education in the field of science.

Gilbert et al. (2011) identified association with daily life as widening of the extent of learning by integrating everyday events, in addition to the learning that the students perform at school, into these learnings. The answers that the prospective teachers gave to the question of how to associate with everyday life show that they have a lot of knowledge about the concept. Most students responded with using the knowledge learned in class, or associating it or practicing it in everyday life. This description, which shows that the transfer of information is one way, is less complete than the definition of Gilbert et al. (2011). Therefore, it is suggested that more attention should be paid to reading and research in this subject, which prospective teachers attach importance to. Most of the prospective teachers have indicated that they will use the transfer to their daily life during their teaching period, which means updating and deepening their knowledge of the concept. The use of transfer to daily life has changed in biology lessons in university.

General biology and environmental science draw attention as the subjects where the rate of transfer is greatest. In addition, the contexts used in transfer can show similarities between

courses. In Altunoglu and Atav (2005) studies, teachers talked about the shortcomings in biology textbooks, they mentioned that there is little room for current information and that there is not enough association with daily life while the topics are being taught. The transfer to daily life is indicated as the result of many researches that have positive attitude towards biology lessons (Acar & Yaman, 2011; Lubben & Campbell, 1996; Rayner, 2012; Riesoco, 1995;). Therefore, regardless of the contexts used in the lessons, the transfer to daily life can be used entirely in biology-based lessons. Since the contexts used in the lessons are similar, it can be said that association with daily life can be made in all biology-based lessons. But one of the criticisms that should not be forgotten about association to everyday life is that the curriculum content is so fragmented that there may be inconsistencies in the conceptualization of learners' knowledge and this can prevent a significant mind map (Gilbert et al., 2011). Therefore, it is important that the transfers to daily life made in different courses are consistent. Otherwise, prospective teachers may be confronted with problems related to the learning of scientific knowledge, especially misconception. It should be noted that teachers have transferred their conceptual misconceptions to their own students (Çepni, Küçük & Ayvaci, 2003).

Prospective teachers seem to have a more positive attitude towards field education courses when considering the concept of transfer to daily life. This can be explained by the fact that different models in field education courses are processed for practice and the students are directed to the activities that connect between daily life and science. It is suggested that education based on specific standards and models is given in field courses, field education and practical lessons (Meriç & Tezcan, 2005), in the context of which association with daily life is an important option. It has been seen that prospective teachers have made explanations in this direction in the individual interview session. Thoughts of prospective science teachers on the course content of field lessons being tough and not addressing teacher qualifications (Demirtaş, Cömert & Özer, 2011; Şahin Taşkın & Hacıömeroğlu, 2010), may have directed them to a more positive attitude towards the field education courses. But it should not be forgotten that without the knowledge of the field it is impossible for the teacher to produce ideas or practice (Çepni et al., 2003). Therefore, it is suggested to teach the knowledge in the field lessons as well as how to use this information or to practice in which practical areas it will work.

Prospective teachers see teachers as the biggest factor in using the transfer to daily life in the classroom. Laboratory use and learning approaches draw attention as the other factors. The common feature of these factors is the inclusion of active learning activities and practical activities, which are supported by the opinions of the teacher candidates. The fact that the teacher is mentioned as the most important factor is because he/she is considered as the decision mechanism in education. Demirtaş et al. (2011) concluded that teacher candidates had low self-efficacy especially in the areas of mathematics and science. Prospective teachers' deficiencies in the field information can lead to this situation. It should be taken into consideration that the different applications mentioned earlier in the field information lessons will help teacher candidates in this respect and positively affect their distrust about providing student participation (Demirtaş et al., 2011). Sumarni, Sudarmin, Wiyanto and Supartono (2016) stated in the study that they have done parallel to the results of this study that science learning that takes place as a result of everyday life events and phenomena being related to concepts, processes and contexts with scientific knowledge will be more meaningful and contextual.

It becomes more important that prospective teachers make up for their shortcomings in their science field knowledge, that the prospective teachers at university give more place to association with daily life in the field courses that they have taken, that they lay a stronger emphasis on the concept of association with everyday life in the training courses that they

have taken at university and that they improve themselves to the level of being able to make an association between the events occurring in their surroundings and science subjects. It is suggested that, especially in pedagogical subject areas such as special teaching method, emphasis is placed upon learning of models which are based on real life just like problem based learning and which provides improvement of skills in this context (Akçay 2009).

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## Turkish Early Childhood Education Curriculum from the Perspective of STEM Education: A Document Analysis

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### ABSTRACT

The current study aimed to examine Turkish early childhood education curriculum prepared for 36–72 month children relative to science, technology, engineering, and mathematics (STEM) education. To that end, 240 developmental features, 65 objectives, and 230 indicators under developmental fields in the curriculum and 40 sample activities in a teacher activity book were analyzed by adopting content analysis. The data were analyzed in the light of “A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas” developed by the Committee on a Conceptual Framework for New K–12 Science Education Standards within the National Research Council. Analyses revealed that the curriculum and teacher activity book included core ideas and concepts related to STEM education and it had most of the characteristics of STEM education. Finding out the existence of STEM education-related aspects of the early childhood education curriculum inspires conducting further studies that will help early childhood educators’, academicians’, and policy makers’ focus on integrating and implementing STEM education practices not only in Turkey but also in countries adopting similar early childhood education curriculums.

**Keywords:** STEM education, early childhood curriculum, policy.

### INTRODUCTION

The STEM acronym is used to focus on an understanding of the integrated nature of the disciplines of science, technology, engineering, and mathematics as well as their importance in the long-term academic success of children, economic well-being (Quigley & Herro, 2016), and development of communities (Han, Rosli, Capraro & Capraro, 2016). STEM education embraces grades from preschool to the post-doctoral level and learning settings of formal (e.g., classrooms) and informal (e.g., afterschool programs) education (Gonzalez & Kuenzi, 2012). To illustrate, STEM education has been recognized in the U.S. as an important educational reform and described as an instructional approach to prepare children for the current century’s global economy (Yakman & Lee, 2012).

Raising innovative minds underlies the future wealth of countries, and STEM education helps societies raise children who have innovative mentalities (Corlu, 2012). STEM education





eliminates the complications of a widely used education system that segregates these four disciplines separately into a transdisciplinary curriculum (Guyotte, Sochacka, Constantino, Walther & Kellam, 2014). On the contrary, STEM integrates these four disciplines through the use of real-world practices (Vasquez, Sneider & Comer, 2013). Concordantly, Stohlmann, Moore, and Roehrig (2012) emphasize that current research conducted in the field of curriculum development highlights that much of the latest and most worthwhile knowledge necessitates more than one discipline. In this regard, STEM education is of capital importance in the sense of facilitating transformation of theoretical knowledge to practice and product (Akgunduz et al., 2015) by being an integrated approach (Stohlmann et al., 2012). Consequently, educators, including STEM educators, might set goals of providing learning experiences that are realistic, collaboration-initiating, and thinking-oriented and that foster real-world problem solving (Siew, Amir & Chong, 2015).

An efficient STEM instruction benefits from children's early desire to investigate and experience (National Research Council [NRC], 2011). Hence, the base of STEM education goes back to early childhood years (Moomaw, 2013). Indeed, each young child is an eager STEM investigator who is inclined to find out and invent. In the early years, the growing child is more interested in the magic of mathematics and science. For example, s/he may wonder about how people get an idea on how the weather will be a few days later (Wynn & Harris, 2012). In addition to being the first adopters of technological devices (STEM Smart Brief, 2013), they are endowed with curiosity, creativity, critical thinking, and cooperation, which are the essential characteristics of learning in STEM education (Chesloff, 2013). While constructive play like block play lay the foundations of engineering in early years, the main principles of earth sciences are learned by means of some activities such as the observation of weather and experiences with water and mud. In addition, young children start to learn some skills such as number sense, critical thinking, scientific inquiry, and problem solving, which are the basics for gaining STEM concepts, in their early childhood years (Aldemir & Kermani, 2016). Indeed, research indicates that 50% of cognitive development, which is a foundation for problem solving, scientific inquiry, and critical thinking skills (Clements & Sarama, 2000), progresses until the age of four (Shonkoff & Phillips, 2000). In these early years, experiences have an extreme impact on a wide range of skills that children learn and improve later in life (Aldemir & Kermani, 2016; Fidan & Erden, 1993; Ministry of National Education [MoNE], 2013; National Association for the Education of Young Children [NAEYC], 2010; Oguzkan & Oral, 2003). For instance, future academic achievement of children is directly associated with language; early literacy; mathematics; and social, emotional, and cognitive skills gained through early childhood education (ECE) programs (NAEYC, 2009; Entwisle & Alexander, 1998). Therefore, to gain not only necessary skills but also necessary knowledge, attitudes, and habits, an education program that is a guide for a well-planned education and guidance services has great significance in helping children in early ages (Aral, Kandır & Yaşar, 2001).

As Ong et al. (2016) emphasized, every child should be exposed to STEM opportunities from their early ages, participate in inquiry-based learning in collaboration with their peers, and have the opportunity to solve real-life problems. On the other hand, in literature, it is stated that early childhood educators have got a common question: what should be learned to help young children become ready for school and be successful at school as well as be good academically? As proposed, all these outcomes can be reached after implementing a certain curriculum (Katz, 2010). In preference, an answer for the stated question of the teachers might be provided for early childhood educators via focusing on STEM education. It is claimed that well-planned, stimulating, and developmentally appropriate STEM activities help preschoolers to have high levels of STEM understanding (Aldemir & Kermani, 2016).

In recent years, STEM education in early childhood years has become one of the major research areas in early childhood education (Aldemir & Kermani, 2016; Aronin & Floyd, 2013; Bagiati & Evangelou, 2015; Beede et al., 2011; Katz, 2010; Lindeman, Jabot & Berkley, 2013; Moomaw & Davis, 2010; Ong et al., 2016; Sharapan, 2012; Sullivan, Elkin & Bers, 2015; Xu, 2008). Studies concerning STEM education conducted in Turkey mostly aimed to introduce STEM education (Corlu, Capraro & Capraro, 2014; Navruz, Erdogan, Bicer, Capraro & Capraro, 2014; Sahin, Ayar & Adigüzel, 2014; Yamak, Bulut & Dündar, 2014) and to reveal STEM conceptualizations of teachers (Akaygun & Aslan-Tutak, 2016; Corlu & Corlu, 2012). All in all, to our best knowledge, a limited number of studies have been carried out on early childhood STEM education in Turkey (Soylu, 2016). When STEM education initiatives are investigated in Turkey, it is observed that STEM practices vary depending on school grades (elementary education, secondary education, and high school), types of schools, and teacher characteristics (Corlu, Capraro & Capraro, 2014). Moreover, some community-based activities are encountered such as the STEM project initiated in 2014 by the Kayseri Provincial Directorate for National Education and the STEM project targeting disadvantaged students, particularly girls, prepared by İstanbul Aydın University. However, these projects mostly focus on elementary and higher grades rather than preschool children. What is more, Turkey National Contact Points in the Scientix project (General Directorate of Innovation and Educational Technologies (YEGITEK)) have performed some promotion activities (Scientix Science and Mathematics Education Conference, MoNE, performed Scientix workshops, social media online promotions, online webinars, etc.). In this project, Turkey takes place under the liability of the General Directorate of Innovation and Educational Technologies (MoNE, 2016). Even if all these initiatives are crucial to the development of STEM education in Turkey, as Soyly (2016) emphasized, there is a need for projects, initiatives, and scientific research that integrates STEM into ECE curriculums. In a similar way, as Corlu (2014) stressed, coming leading research subject areas that would be conducted within the scope of STEM education in Turkey might be the examination of the contents of the curriculum and textbooks. In addition, offering a route map and implications concerning STEM education in Turkey, Akgunduz et al. (2015) stressed that national standards about how STEM education might be integrated into the current curriculum should be determined. Respectively, in the STEM Policy Report revealed by MoNE (2016), it is stated that an emergent STEM action plan should be started. The proposed plan is composed of the following five steps:

1. Establishing STEM education centers
2. Conducting STEM education research with the cooperation of universities at these centers
3. Training teachers in a way such that they can adopt the STEM education approach
4. Updating curriculum in a way such that it could involve STEM education
5. Creating teaching environments for STEM education and providing course materials to schools (MoNE, 2016, p. 31).

Although the first two steps have been partly accomplished by some initiations, there is still a need for developing a policy to train teachers and update the curriculum as well as the need for a policy to create learning environments and materials for STEM education.

In line with the policy goals and needs of Turkish MoNE, STEM education research revealed that STEM education is scarcely integrated into early childhood curriculum (Aldemir & Kermani, 2016). Moreover, present data on young children's school readiness and their achievements in the fields of science and mathematics signify that we are failed to satisfy required support our children for being "STEM Smart" (STEM Smart Brief, 2013). According to Aldemir and Kermani (2016), the reasons for the bare integration of STEM education and

low achievement in STEM disciplines might be partly related with inadequate professional development of teachers in relation to STEM education since the quality and effectiveness of teachers have a great effect on students' educational experiences (Epstein & Miller, 2011; Nathan, Tran, Atwood, Prevost & Phelps, 2010). By considering the Turkish government's policy attempts on STEM education while at the same time referencing the needs of early childhood educators about how to focus on STEM education in their learning environments, it is found crucial to examine currently applied ECE curriculum in terms of the possibility of adapting it to STEM education before any curriculum integration policy developed in early childhood STEM education.

In this way, this qualitative study was conducted with the aim of examining the content of the ECE curriculum prepared by the Turkish Ministry of Education (MoNE, 2013) in detail in terms of similar and different characteristics with the STEM education approach. In addition, this study intended to investigate the availability of Turkish ECE curriculum for STEM integration. Providing an analysis document reached by scientific methods for experts who study STEM education in early childhood years signifies the importance of the current study. For the mentioned purposes, the answer to the below mentioned research question (RQ) was searched:

**RQ:** Does the Turkish ECE curriculum (curriculum booklet and curriculum activity book) include characteristics overlapping with the STEM education approach?

**a) Common Characteristics of the Turkish ECE Curriculum with STEM Education**

The ECE curriculum applied in Turkey intends to enhance the welfare of Turkish citizens and society and support and accelerate economic, social, and cultural development by raising citizens whose personality and traits are promoted evenly and healthily in physical, mental, moral, psychological, and emotional terms. It also aims to raise individuals who are able to think freely and scientifically as constructive, creative, and productive individuals in order to make the Turkish nation a prominent member of contemporary civilization (MoNE, 2013). For detailed information about the major characteristics of ECE curriculum applied in Turkey, please see Table 1.

According to the program, early childhood education is built on some basics that focus on the development of children's imagination and creative and critical thinking skills as well as the ability to express their feelings (MoNE, 2013). The above-mentioned skills are found relevant with the characteristics of preschool STEM education. Indeed, Katz (2010) stated that resources and opportunities that lead young children to explore, investigate, and develop their existing abilities should be provided to children. Similarly, in STEM education, each child is an active learner who constructs his/her knowledge by experiencing their environment and engages with solving real-world problems (Yakman & Lee, 2012). STEM education defends that each child is born an investigator (NRC, 2007), and exploration, experimenting, problem solving, and measuring are indispensable parts of their learning (Sharapan, 2012).

The Turkish MoNE 2013 ECE curriculum is prepared taking into consideration the necessity of appropriate learning environments including whole child, family, school, and community contexts. In the program, schools are expressed as primary agents, providing developmentally appropriate learning environments for children and creating parental involvement environments (Demircan & Erden, 2015). Moreover, the program is spiral in terms of approach and eclectic in terms of model. It has a progressive characteristic since it aims to develop children in all developmental areas with respect to their developmental levels, interests, and needs (MoNE, 2013). In a similar way, hierarchical structures, which depend on prior knowledge to identify future understanding, mostly provide a basis for STEM subjects (STEM Smart Brief, 2013). Since individuals may continue to learn scientific subjects

throughout their lives, learning can progress from early childhood to 12<sup>th</sup> and higher grades. Indeed, such progression relies on earlier understanding and promotes increasingly sophisticated knowledge (NRC, 2012).

**Table 1.** Major characteristics of Turkish ECE curriculum

Curriculum Documents	Main Characteristics	Explanation
Curriculum Booklet (111 pgs)	Developmental Characteristics and Objectives and Indicators	The program aims to promote social, emotional, motor, cognitive, language, and self-care aspects. For each developmental area, it is aimed that children are supported through objectives which are necessary to reach and through indicators which are the observable form of these objectives.
	Setting and Learning Centers	Learning centers include different materials chosen regarding objectives and indicators of activities in daily plan. According to the program, the main learning centers in an early children classroom are the block center, dramatic play center, art center, book center, music center, and science center.
	Activities	Structured, semi-structured, or non-structured Turkish language, art, drama, music, movement, play, science, mathematics, and preparation for reading and writing are the types of activities proposed to be conducted in classrooms. These activities can be conducted in an integrated way individually or in small or large groups. Both the outdoors and the indoors can be used as a setting for the activities.
	Monthly Education Plan	It serves as a guide for teachers since it is a plan including special occasions, parent involvement activities, assessment processes, concepts, objectives, and indicators that will be used to prepare integrated activities.
	Daily Education Flow	The plan in which teachers give information regularly about what to do on that day. It includes routine activities such as starting time for the day, play time, activity time, assessing the day, nutrition, and relaxation time.
	Assessment of Children	Development observation forms and development reports are offered as some sorts of assessment of young children. Moreover, teachers are offered to prepare a Development File that covers children's works selected by them and letters coming from parents, children's developmental observation forms, and developmental reports.
	Assessment of the Program	Activities made during the school day and the daily education process are assessed through activity-related speeches, work sheets, presentations, memory cards, drawings, exhibitions, posters, and photographs. Moreover, a monthly plan and activities that are prepared and applied by teachers are essential for assessing the program. These daily assessments shed light on assessing the monthly plan.
	Self-Assessment of Teacher	Self-assessment of teachers is expected to be conducted by teachers, which promote their motivations and improve their creativity and strength.
Curriculum Activity Book (91 pgs)	40 Activities for 48–72 month children	In the booklet, there are integrated and exemplary activities for 36–48, 48–60, and 60–72 month children. For each activity, related objectives, indicators, materials, new words, concepts, learning process, suggestions for assessment of children, parent involvement ideas, and adaptation for children with special needs in the classrooms are stated.

**Note:** The appendix of the program book is comprised of a development observation form, a development report, a format for the monthly education plan, a format for the activity plan, a situation chart related to allow for concepts in monthly education plans, a situation chart related to allow for objectives and indicators in monthly education plans, a list of special occasions, a format for halftime daily education flow, a format for fulltime daily education flow, an exemplary halftime daily education flow, and points to take into consideration in supporting children with special needs.

In addition, the curriculum gives great importance to play-oriented learning, which helps children think critically, make plans, test their practices, express themselves, ask questions, make investigations, and solve problems and discuss them to obtain results. Similarly, approaches like play-based learning, which supports firsthand experiences, active participation, and learning through experience, can be offered as appropriate ways of STEM implementation in early childhood education (Soylu, 2016). Indeed, play can be transmitted into a learning experience if teachers purposely plan STEM experiences concentrated on core concepts and skills, allow children to explore and reflect their theories, and explore more by means of open-ended questions posed by them (STEM Smart Brief, 2013).

As previously mentioned, the Turkish ECE curriculum and STEM education adopt some common principles. This study offers a response to the question of to what extent these principles coherent with STEM education were reflected in the content.

## **METHODS**

### **a) Research Design**

In the present study, the Turkish ECE curriculum (curriculum booklet and curriculum activity book), which guides early childhood education practices in Turkey, was examined within the scope of STEM education by using the content analysis method. Content analysis is a research technique that enables researchers to investigate human behaviors indirectly by analyzing their products such as textbooks, articles, newspapers, advertisements, songs, political statements, novels, pictures—virtually all types of communication. Moreover, through the examination of professional and general publications, content analysis facilitates investigating changing trends in education (Fraenkel, Wallen & Hyun, 2012). Similarly, in this study, the MoNE early childhood education curriculum revised in 2013 was investigated with regards to STEM education.

### **b) Data Collection**

The data were collected in the light of “A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas” developed by the Committee on a Conceptual Framework for New K–12 Science Education Standards (2012) within the National Research Council. Indeed, during the data collection process, some steps were followed. Even if all four researchers were English speaking, their native language is Turkish. Therefore, as a first step, the framework was translated into Turkish by the researchers to strengthen the possibility of researchers’ consensus on the meaning and indicators of practices, crosscutting concepts, and disciplinary core ideas. Secondly, codes were assigned to each of the practices, crosscutting concepts, and disciplinary core ideas according to their titles and subtitles. For instance, “asking questions and defining problems” under the title of “Scientific and Engineering Practices” was named “8Main1,” while “cause and effect: mechanism and explanation” under the title of “Crosscutting Concepts” was named “Inter2” (see Table 2). Then, each code was searched in the curriculum booklet and curriculum activity book and marked in the related parts of the documents. Lastly, codes found in the curriculum booklet and curriculum activity book were counted separately for each of the documents.

In this way, all developmental features, objectives, and indicators toward five developmental fields; each information under the headings of planning and practicing early childhood education (learning centers and activity types) and assessment of early childhood education (assessment of children, assessment of program, and self-assessment of the teacher), which can be a guide for early childhood educators in the curriculum; and sample

activities in the teacher activity book constituted the units of analysis of the study. In this context, 240 developmental features, 65 objectives, and 230 indicators under five developmental fields (cognitive development, socio-emotional development, language development, motor development, and self-care skills) in curriculum and 40 activities in the teacher activity book were examined using the prepared codes.

### **c) Data Analysis Procedure**

As in data collection, the framework (“A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas”) (NRC, 2012) guided the data analysis process of this study. The framework, prepared by 18 members who are known worldwide in their special fields (Next Generation Science Standards [NGSS], 2013) by examining various science standards at the national and international levels (Schweingruber, Quinn, Keller & Pearson, 2013), defines a new understanding of science education established on scientific evidence. In addition, the framework sketches the knowledge and skills that should be obtained by all students from kindergarten to the end of 12<sup>th</sup> grade (NGSS, 2013). In this regard, the aim of the development of this framework is to assure the appreciation of all students toward the beauty and fascination of science and their possession of enough knowledge about science and engineering to address public discussions on relevant issues. Moreover, this framework aims to ensure that all students carefully use scientific and technological knowledge connected with their daily life, maintain their learning in relation to scientific issues outside school, and have the competences to begin careers preferred by them containing STEM disciplines (NRC, 2012).

In this study, there were two major reasons for choosing this framework as a guide for the study. Firstly, the framework was developed by adopting some principles overlapping with the main characteristics of the Turkish ECE curriculum. For instance, the framework views children as innate investigators. In fact, from their earliest years, children construct their own ideas related to the social, biological, and physical worlds and those worlds’ ways of working. According to the framework, by listening to them and paying attention to the students’ ideas, an early childhood teacher can utilize what his/her students already know or can do in order to form a base for their future learning and understanding. In addition, the framework defends that experiences establish, expand, and refine knowledge. Therefore, not only knowledge but also practice is very important for children’s learning in science and engineering (NRC, 2012). In a similar manner with those two principles, originating in what the child knows and enabling the child by experimenting is also one of the main principals of the Turkish ECE curriculum (MoNE, 2013). Correspondingly, the framework adopts that a successful science education is based on capturing and keeping children’s attention and interests. This can be achieved through learning experiences connected with their own interests and their daily lives and curriculums considering children’s needs and interests (NRC, 2012). Indeed, the fourth and fourteenth principles of the Turkish early childhood curriculum touched on the same point. According to these principles, learning activities should be prepared by taking children’s needs and interests into consideration, and the curriculum should be prepared by considering the characteristics of the surrounding environment (MoNE, 2013). On the other hand, the framework is established on an education insight that defends that education should encourage children to ask questions or identify problems; seek for answers or solutions; plan investigations; and obtain, assess, share, and discuss information (NRC, 2012). Providing maximum amount of learning opportunities for children by means of planning, designing, interrogating, investigating, communicating, and producing is also one of the characteristics of the Turkish ECE curriculum (MoNE, 2013). By considering these common points, this framework was selected as the base for this study.

The second reason for selecting this framework for serving as a base for this study was related to the emergence of the STEM approach in the United States. Indeed, STEM was first introduced by the National Science Foundation in 2000 in the United States, but over time, it has begun to be recognized worldwide. Indeed, this framework has been utilized in the United States, the place where STEM education was born, as a guide for taking steps in the improvement of STEM education. For instance, K-12 science standards were determined (NGSS, 2013) and a large number of curriculums were developed in light of this framework (e.g., Corvo, 2014; Facchini, 2014). On the other hand, in Turkey, even if integrating STEM education into Turkish education curriculums is one of the aims of the five-year progress plan, unfortunately no national framework for adaptation has been developed yet. Indeed, for the sake of developing worldwide Turkish national science education standards, the use of a globally used framework like “A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas” might be considered as a starting point. Without doubt, for early childhood STEM learning, use of the framework will be a starting point to create a Turkish national framework. Therefore, the framework that has been widely used in the United States was used as a guide for this study.

The framework includes three main dimensions regarded as scientific and engineering practices, crosscutting concepts, and core ideas concerning science education (NRC, 2012, p. 3). In the present study, data were analyzed by searching the codes in light of these dimensions in the Turkish ECE curriculum. Indeed, these three dimensions and their sub-dimensions in the framework constituted of coding categories (see Table 2). For the teacher activity book, basic scientific skills were investigated because the booklet includes development areas and outcomes that are related to skills planned to make young children gain. In a similar way, crosscutting concepts were investigated for the teacher activity book because crosscutting concepts can be easily investigated in exemplary cases like activities. In both the teacher book and activity book, basic scientific skills are investigated because they are considered as cores of STEM learning (see Table 2).

Three researchers who are early childhood education specialists and have focused their studies on STEM education in early childhood examined the data independently. Then, those three researchers who coded the teacher activity book and an objective researcher put the codes in their final form by coming together. The same process was followed for the curriculum. At the first meeting of the coders, a consensus was built on the codes at the ratio of 75% for the curriculum and 66% for the teacher activity book. Since an agreement of over 70% was not reached between the coders for the teacher activity book, they had a discussion on the differences. After their discussions, they reviewed the data and came together again. At the second meeting, a consensus was reached between the coders at the ratio of 79%. Lastly, by using the Statistical Package for Social Sciences (SPSS, version 22.0 for Windows) program, the frequencies and distribution of each coding category on the coded materials were obtained.

**Table 2.** Three dimensions of the framework that constitute coding categories

<i>Coding Categories</i>	<i>Codes</i>	<i>Coded Document</i>
<b>1. Scientific and Engineering Practices</b>		
Asking questions and defining problems	8Main1	Curriculum
Developing and using models	8Main2	
Planning and carrying out investigations	8Main3	
Analyzing and interpreting data	8Main4	
Using mathematics and computational thinking	8Main5	
Constructing explanations and designing solutions	8Main6	
Engaging in argument from evidence	8Main7	
Obtaining, evaluating, and communicating information	8Main8	
<b>2. Crosscutting Concepts</b>		
Patterns	Inter1	Curriculum & Teacher Activity Book
Cause and effect: Mechanism and explanation	Inter2	
Scale, proportion, and quantity	Inter3	
Systems and system models	Inter4	
Energy and matter: Flows, cycles, and conservation	Inter5	
Structure and function	Inter6	
Stability and change	Inter7	
<b>3. Disciplinary Core Ideas</b>		
<i>Physical Sciences</i>	DP	Teacher Activity Book
Matter and its interactions	DP1	
Motion and stability: Forces and interactions	DP2	
Energy	DP3	
Waves and their applications in technologies for information transfer	DP4	
<i>Life Sciences</i>	DL	
From molecules to organisms: Structures and processes	DL1	
Ecosystems: Interactions, energy, and dynamics	DL2	
Heredity: Inheritance and variation of traits	DL3	
Biological evolution: Unity and diversity	DL4	
<i>Earth and Space Science</i>	DES	
Earth's place in the universe	DES1	
Earth's systems	DES2	
<i>Engineering, Technology, and Applications of Science</i>	DET	
Engineering design	DET1	
Links among engineering, technology, science, and society	DET2	

## FINDINGS

### a) Findings regarding the ECE Curriculum Booklet

The present study aimed to examine the content of the Turkish ECE curriculum (MoNE, 2013) prepared for 36–72 month children in terms of STEM education. As summarized in Table 3, eight scientific and engineering practices were given place in the curriculum. However, “asking questions (for science) and defining problems (for engineering),” and “using mathematics and computational thinking” (17.3%) were the two most touched principles in the curriculum. On the other hand, “planning and carrying out investigations” (8.6%) (NRC, 2012, p. 3) was the principle that was given the lowest place. The distribution of and some examples signifying the existence of the eight main scientific and engineering practices in the curriculum are presented in Table 3.



**Table 3.** *Distribution of eight main practices across the curriculum*

<i>Curriculum</i>	<i>Eight Main Practices</i>	<i>n</i>	<i>f(%)</i>	<i>Sample Citations (MoNE, 2013)</i>
	• Asking questions (for science) and defining problems (for engineering)	8	17.3	Children should be able to develop and test their hypotheses, to reason and solve problems (Types and explanations of activities, Mathematics activities, p. 43)
	• Developing and using models	5	10.8	...be able to do three-dimensional works (Types and explanations of activities, Art activities, p. 45)
	• Planning and carrying out investigations	4	8.6	S/he offers diverse solutions to the problem, chooses one of these solutions, and says the reason for his/her choice (Objectives and indicators, Cognitive development, Objective 14)
	• Analyzing and interpreting data	5	10.8	Preparing a weather condition board (Types and explanations of activities, Science activities, p. 48)
	• Using mathematics and computational thinking	8	17.3	S/he does additions and subtractions by using objects (Objectives and indicators, Cognitive development, Objective 16)
	• Constructing explanations (for science) and designing solutions (for engineering)	5	10.8	S/he produces solutions to the problems (s/he offers various solutions to the problem, selects one of the solutions, says the justification of the selected solution, selects another solution when s/he does not come to the solution, offers creative solutions to the problem) (Objectives and indicators, Cognitive development, Objective 19)
	• Engaging in argument from evidence	6	13.0	S/he explains the cues concerning her/his prediction, examines the real condition, and compares the prediction with the real condition (Objectives and indicators, Cognitive development, Objective 2)
	• Obtaining, evaluating, and communicating information	5	10.8	S/he pays her/his attention to object-condition-event and explains in detail (Objectives and indicators, Self-care skills, Objective 1)
Total		46	100	

When objectives and indicators that presented each developmental field were examined, results indicated that the eight main practices mostly accumulated on the cognitive development field. In fact, all of the eight main practices took place in the cognitive developmental field (95.9%), while only “constructing explanations (for science) and designing solutions (for engineering)” (NRC, 2012, p. 3) was included in self-care skills (4.1%). However, none of the language, social-emotional, motor, and self-care skills developmental fields are associated with the eight main practices of the framework (see Table 4).

**Table 4.** *Distribution of eight main practices in the developmental fields.*

Curriculum	Eight Main Practices	Developmental Fields				
		Cognitive	Language	Social– Emotional	Motor	Self-Care Skills
	• Asking questions (for science) and defining problems (for engineering)	5	0	0	0	0
	• Developing and using models	4	0	0	0	0
	• Planning and carrying out investigations	4	0	0	0	0
	• Analyzing and interpreting data	6	0	0	0	0
	• Using mathematics and computational thinking	11	0	0	0	0
	• Constructing explanations (for science) and designing solutions (for engineering)	7	0	0	0	2
	• Engaging in argument from evidence	5	0	0	0	0
	• Obtaining, evaluating, and communicating information	5	0	0	0	0
	Total	47	0	0	0	2
	<i>f</i> (%)	95.9	0	0	0	4.1

In addition, results indicated that crosscutting concepts were also involved in the curriculum. The most mentioned concepts were “scale, proportion, and quantity” (20.4%) and “stability and change” (20.4%), while “patterns” (6.8%) (NRC, 2012, p. 3) was the least mentioned concept. Table 5 summarizes sample citations and distribution of crosscutting concepts on the data obtained in the curriculum.

**Table 5.** *Distribution of crosscutting concepts in the curriculum*

Curriculum	Crosscutting Concepts	<i>n</i>	<i>f</i> (%)	Sample Citations (MoNE, 2013)
	• Patterns	3	6.8	S/he creates patterns by using objects (Objectives and indicators, CD, Objective 14)
	• Cause and effect: Mechanism and explanation	5	11.3	S/he says the reasons and results of other people’s feelings (Objectives and indicators, SED, Objective 4)
	• Scale, proportion, and quantity	9	20.4	S/he says the proportion of objects or entities (Objectives and indicators, CD, Objective 5)
	• Systems and system models	7	15.9	S/he completes the missing pieces in a picture by looking at the example (48–60 month developmental features, CD)
	• Energy and matter: Flows, cycles, and conservation	5	11.3	Examining natural and unnatural materials (Types and explanations of activities, Science activities, p. 48)
	• Structure and function	6	13.6	S/he says the intended use of objects and entities (Objectives and indicators, CD, Objective 5)
	• Stability and change	9	20.4	S/he makes balanced movements (Objectives and indicators, MD, Objective 2)
Total		44	100	

When the distribution of crosscutting concepts in each developmental field and their objectives and indicators were examined, results indicated that, as in the eight main practices, crosscutting concepts were mostly concentrated in the cognitive development field (90.9%). On the other hand, signs of “cause and effect: mechanism and explanation” were found in social–emotional development (3.6%) and “stability and change” were found in motor development (5.4%) (see Table 6).

**Table 6.** *Distribution of crosscutting concepts in the developmental fields.*

Curriculum	Crosscutting Concepts	Developmental Fields				
		Cognitive	Language	Social– Emotional	Motor	Self-Care Skills
	• Patterns	5	0	0	0	0
	• Cause and effect: Mechanism and explanation	7	0	2	0	0
	• Scale, proportion, and quantity	11	0	0	0	0
	• Systems and system models	9	0	0	0	0
	• Energy and matter: Flows, cycles, and conservation	6	0	0	0	0
	• Structure and function	7	0	0	0	0
	• Stability and change	5	0	0	3	0
	Total	50	0	2	3	0
	<i>f</i> (%)	90.9	0	3.6	5.4	0

#### b) Findings regarding Curriculum Activity Book

The codes related to crosscutting concepts were searched not only in the curriculum but also in the curriculum activity book. According to the results, the activity book included a great number of findings concerning STEM education. However, it was found that the distribution of these concepts was quite scattered among the activities. Indeed, the “scale, proportion, and quantity” concept constituted more than half of the distribution (52%), while there were a limited number of activities addressing “energy and matter” (2%), “stability and change” (3%), and “systems and system models” (4%) (NRC, 2012, p. 3) (see Table 7).

**Table 7.** *Distribution of crosscutting concepts in the activity book*

<i>Activity Book</i>	<i>Crosscutting Concepts</i>	<i>n</i>	<i>f (%)</i>	<i>Sample Citations (MoNE, 2013)</i>
	• Patterns	8	8	Children sort the balls from big to small, from soft to harsh, and from light to heavy (Activity 12).
	• Cause and effect: Mechanism and explanation	18	18	Children say the reason for their predictions (Activity 3).
	• Scale, proportion, and quantity	52	52	Children talk about magnitudes, shapes, and similar and different aspects of foams (Activity 1).
	• Systems and system models	4	4	Taking photographs of the created shadows and drawing the bounds of a friend's shadow at different times of the day. Then, communicating about the lengths of the shadows in the taken photographs and created drawings (Activity 15).
	• Energy and matter: Flows, cycles, and conservation	2	2	It talked about how water put in a deep freeze will change (Activity 5).
	• Structure and function	13	13	Children respond to the teacher's questions such as what for, why, and how we use (Activity 8).
	• Stability and change	3	3	It draws attention to the appearance of the staff when looked from above (Activity 18).
Total		100	100	

When the activity book was examined in terms of discipline core ideas taking part in the framework, it was found that there was a large body of findings concerning physical sciences. In addition, the number of findings relating to life sciences and earth and space science was equal to each other, while there were a limited number of findings concerning engineering. When we consider that there are 40 sample activities in the activity book, it was revealed that the number of activities, including crosscutting concepts, is limited. While “physical sciences” (48.7%), especially “matter and its interaction” (25.6%), was mostly touched, “life sciences” and “earth and space science” (20.5%) evenly took place in the curriculum. On the other hand, the frequency of activities in “engineering, technology, and applications of science” (10.25%) (NRC, 2012, p. 3) was quite little when compared with other core ideas. Indeed, any activity related to the “heredity: inheritance and variation of traits” subtitle of “life sciences” and the “Earth's place in the universe” subtitle of “engineering, technology, and applications of science” (NRC, 2012, p. 3) core ideas was not come across in the teacher activity book (see Table 8).

**Table 8.** *Distribution of discipline core ideas in the activity book*

<i>Activity Book</i>	<i>Discipline Core Ideas</i>	<i>n</i>	<i>f (%)</i>	<i>Sample Citations in the Activity Book</i>
	<b><i>Physical Sciences</i></b>	19	48.7	
	• Matter and its interactions	10	25.6	Put colorful water in ice bar molds and put into deep freeze by immersing ice cream sticks or toothpicks in it (Activity 5)
	• Motion and stability: Forces and interactions	3	7.6	Children try to manipulate objects by blowing them (Activity 9)
	• Energy	4	10.25	By means of a light source, shadows are cast upon paper (Activity 15)
	• Waves and their applications in technologies for information transfer	2	5.1	Photographs of the created shadows by means of a light source were taken by children (Activity 15)
	<b><i>Life Sciences</i></b>	8	20.5	
	• From molecules to organisms: Structures and processes	2	5.1	Children examine worms, insects, and leaves existing in the soil (Activity 31)
	• Ecosystems: Interactions, energy, and dynamics	4	10.25	The children are told that the ice of the glaciers has melted due to the climate change and that this melting prevents the polar bears from reaching their homes (igloo). Children discuss their solutions to this problem (Activity 26)
	• Heredity: Inheritance and variation of traits	0	0	
	• Biological evolution: Unity and diversity	2	5.1	Children examine worms, insects, and leaves existing in the soil omitted from the hole (Activity 31)
	<b><i>Earth and Space Science</i></b>	8	20.5	
	• Earth's place in the universe	0		
	• Earth's systems	1	2.5	Children make observations in the garden. Diverse objects are examined. Children talk about how their garden seems, what is in the garden, and think about what we can do to make our garden more beautiful (Activity 11)
	• Earth and human activity	7	17.9	Children think about what we can do to make our garden more beautiful (Activity 11)
	<b><i>Engineering, Technology, and Applications of Science</i></b>	5	10.25	
	• Engineering design	4	10.25	Children create an image of their classroom by placing materials such as Lego (Activity 18)
	• Links among engineering, technology, science, and society	0	0	
Total		39	100	

## **DISCUSSION and SUGGESTIONS**

According to the results, eight main practices that encourage the understanding the production of scientific knowledge and engineering solutions better (NRC, 2012) took part evenly in the curriculum. This finding signifies that STEM might be integrated into the current ECE curriculum. However, a clear, balanced distribution of the eight main practices in the developmental fields was not encountered. Indeed, the eight main practices taking part in the referenced framework accumulated highly in objectives and indicators of the cognitive development field both in the curriculum and activity book. On the other hand, the notion of “practices” is preferred in the framework to refer inquiry and not only cognitive but also social and physical practices in science (NRC, 2012). Indeed, in early childhood years, STEM activities enable children to find out materials by using their senses. In this way, they can comprehend significant scientific and mathematical associations like the concepts of more or less and speedy or slow from an early age. Moreover, STEM serves children by improving their vocabulary, encouraging their collaboration, and transmitting their learning into their future experiences (Moomaw & Davis, 2010). Getting in contact with science and beginning to learn scientific language increase their acquisition of science and direct them to think as a scientist. This interest gained by children who are willing to investigate what is happening around them can be increased in the rest of their lives. (Andersson & Gullberg, 2014). Therefore, objectives and indicators in the curriculum related with other developmental fields like language, socioemotional, and motor development can be enriched by considering STEM practices, and activities can be planned in the direction of these objectives and indicators.

When the curriculum and activity book were examined in terms of crosscutting concepts, findings revealed that “patterns,” “cause and effect,” “scale, proportion, and quantity,” and “structure and function” were mentioned in the curriculum less than the activity book. In addition, in a similar way with the eight main practices, crosscutting concepts did not distribute evenly in the five developmental fields and mostly accumulated in the cognitive development field. In this regard, by considering the sample activities in the activity book, enrichment of objectives and indicators in the curriculum in terms of crosscutting concepts may be one of the implications of this study. Since crosscutting concepts are essential to the comprehension of science and engineering and serve as a bridge for children that attaches knowledge from differing disciplines to the logical and scientific understanding of the world (NRC, 2012), activities should touch on them evenly, especially if these activities are sample activities that teachers practice in their classroom. For instance, a preschool teacher can introduce the “stability and change” concept in a music activity by drawing children’s attention to the fluctuating sounds in a classical music composition or the “pattern” concept by means of songs of plush birds, which sign in different patterns (Moomaw & Davis, 2010)

Besides, findings in relation to discipline core ideas revealed that physical sciences occurred frequently in the activity book. By considering the requirement to be involved in a wide variety of play-based developmentally appropriate learning experiments in physical, life, and earth sciences which lay the foundation of later understanding and “big ideas” (Hoisington & Winokur, 2015), this can be considered as a positive finding in terms of the Turkish ECE curriculum. On the other hand, a limited number of findings were found in relation to engineering, technology, and applications of science. Indeed, no activities linking engineering with technology, science, and society was encountered. However, engineering, including determining a problem, producing solutions, and testing them out (Sharapan, 2012), takes place naturally in preschool children’s activities constructive and dramatic play (Hoisington & Winokur, 2015). By considering that preschool teachers may lack pedagogical knowledge related to integration of engineering with technology and other disciplines (Bers, 2008), the teacher activity book may give sample activities that integrate engineering with

other disciplines and provide opportunities for their classroom implementation. In addition, even the crosscutting concepts were often mentioned, there was a limited emphasis on discipline core ideas. This finding can be a sign of adequate basis for interdisciplinary activities but an inadequate interdisciplinary activity number. Within this context, giving wide coverage to interdisciplinary activities in which the crosscutting concepts were distributed evenly is the other follow-up point of this study.

Even when each STEM discipline takes place in the curriculum, the integration of these disciplines into the curriculum and their application in various activities may be increased as the awareness about STEM education increases. Hence, future studies aimed at improving STEM awareness may examine the reflection of this integrated curriculum on classroom practices.

The Turkish Industry and Business Association (TUSIAD, 2014) highlights the emergency of establishing a STEM education strategy. For the association, in Turkey, students should take STEM education and employment opportunities in this area should be increased (MoNE, 2016). Moreover, teacher education and curriculum integration were stated as policy goals of STEM education in Turkey. In this process, it is very important to consider that any curriculum used in early learning centers is going to be implemented by the teachers. That is why the first policy to foster in Turkey in terms of STEM education after curriculum analyses might be offering STEM education training for teachers.

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## Myths, Islamic View, and Science Concepts: The Constructed Education and Knowledge of Solar Eclipse in Indonesia

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### ABSTRACT

This study examines Indonesian students' constructed knowledge of solar eclipse. It investigated the embraced myths, religious view—particularly that of Islam, and science concept that build students' comprehension of the solar eclipse. A survey was done in Bandung (Indonesia), where the solar eclipse took place on March 9, 2016, to 529 students (categorized on age and educational level) and 67 lecturers, and interviews with college students. Results showed that students' belief on mystical stories decreased along with the older of the age and the higher of their educational level. Furthermore, most lecturers have good understanding about the solar-eclipse rituals and myths, in which this supports the student understanding. The interviews revealed that while some myth-based practices were still embraced, students' understanding of the solar eclipse is still dominated by the science concept and the Islamic religious views that they have learned since their elementary education. The literature showed that two of eleven solar-eclipse rituals and myths in Indonesia are relevant to the science and Islamic views. Therefore, the myth, science concept, and Islamic view on the solar eclipse phenomena should be delivered since the elementary education. This study recommends teachers to integrate science with real-life context to enrich students' understanding while clarifying false information.

**Keywords:** Science concept, solar eclipse, myth, islamic view.

### INTRODUCTION

Integrating science with other disciplines, such as socio-cultural and religion, has been widely applied, considering its practical aspects. (Küçüközer & Kocakülah, 2007) The incorporation of socio-cultural knowledge and science is important to maintain the national identity (Parmin, Sajidan, Ashadi, Sutikno, & Maretta, 2016).

Involving both scientific and socio-cultural aspects, solar eclipse is an interesting subject to discuss. Therefore, the understanding on the solar eclipse phenomenon is required, specifically for integrating student's knowledge in science, culture, society, and religion (Kavanagh, Agan, & Sneider, 2005).



During the solar eclipse, the solar disc is blocked by the Moon (Nandiyanto *et al.*, 2016). The color of the sky is changing, the shadow is moving, the shadow bands, the sun's corona, prominences, and chromospheres are observable, and the sun's diamond ring is formed. Moreover, planets and stars suddenly become visible against the darkening sky. Because of its spectacular incident, the ancient people have associated solar eclipse with several myths and legends (Mohapatra, 1991), such as (i) the appearance of the demons, (ii) the symbol of God's anger, disasters, and destruction, (iii) the sun devouring by a giant or dragon, (iv) the battle between the sun and moon (v), etc. The ancient people also believed that some activities must not be performed during the solar eclipse, e.g. the prohibition to eat, travel, stare the sun, and construct a house (Mohapatra, 1991; Hope-Ross, Travers, & Mooney, 1988). Further, they required pregnant women and children to stay indoor and hide under the table (Mujab, 2016). Some of the myths and rituals are carried over until today although less and less people observe them. Some Indian students believe that the eclipse is caused by the devouring of the sun by the demon Rahu (Mohapatra, 1991). In the 1980s, several Javanese people believed in the compulsion to stay indoor during the eclipse (Keeler *et al.*, 1988).

The constructed knowledge is inevitably influenced by what lingers in society. As the world's most populous Muslim country, the knowledge of solar eclipse in Indonesia is built not only upon what is taught in modern science classrooms but also upon what Islam has taught and the pre-Islamic myths, which are passed down through folklores and daily practices. This study, employing an interdisciplinary approach, clarifies how much the pre-Islamic myth, Islamic view, and science concept constructed the students' knowledge.

It has been found that science at schools and universities is taught separately from other disciplines. For example, the textbooks on science for junior high school, published by the National Education Department of Indonesia, contain only brief explanation about solar eclipse from scientific point of view. In fact, introducing myths and rituals to students is also important as an attempt to preserve the local cultural treasure (Kalkan & Kiroglu, 2007; Parmin, Sajidan, Ashadi, Sutikno, & Maretta, 2016). Further, if the relationships between science and other disciplines are not discussed well, there is a condition where some students could ignore ideas that have no scientific value.

Applying such an approach, the study enriches the scholarly conversations, considering the limited studies of how Muslims respond to solar eclipse through the religious perspective. This study will inspire teachers to deal with and teach the diverse perspectives in culture, religion, and science to their students (Bayraktar, 2009; Kalkan & Kiroglu, 2007; Kavanagh, Agan, & Sneider, 2005; Lederman, 1992; Mugaloglu & Bayram, 2009; Parmin, Sajidan, Ashadi, Sutikno, & Maretta, 2016). Elsewhere, we have conducted researches from scientific point of view, for example investigation of some meteorological parameters (i.e. solar light intensity and radiation (Paramitha, Zaen, & Nandiyanto, 2017), atmospheric pressure (Riza *et al.*, 2016), photovoltaic system (Nandiyanto, Rusli, Purnamasari, Abdullah, & Riza, 2017), temperature (Paramitha, Zaen, & Nandiyanto, 2017), humidity (Paramitha, Zaen, & Nandiyanto, 2017), and wind condition (Paramitha, Zaen, & Nandiyanto, 2017; Riza *et al.*, 2016)) and photodecomposition profile of organic material (Nandiyanto *et al.*, 2016) during the solar eclipse. Incorporating the social science's point of view, this study identified the constructed knowledge of solar-eclipse in Indonesia. We investigated students' belief on several mythical stories, understanding of Islamic view, and the science concept relating to the solar eclipse. The study employed a mixed method, combining a survey to students and teachers and interviews with college students. Bandung was selected as a study area because it experienced a partial solar eclipse of March 9, 2016 (Figure 1 and Table 1).



**Figure 1.** Path of the total solar eclipse over Indonesia on March 9, 2016. The field site was located at Universitas Pendidikan Indonesia, Bandung, about 550 km from the central axis of the eclipse totality, and experienced a 88,76 % eclipse at 07:21 local time (LT) (00:21 Universal Time). The path of solar eclipse was adopted from BMKG Indonesia (source: <http://hangnadim.kepri.bmkg.go.id/berita/berita/33/GERHANA-MATAHARI-TOTAL-9-MARET-2016.html>; retrieved on March 2016).

**Table 1.** Data of solar eclipse timing at several places in Indonesia. Data was obtained from Badan Meteorologi, Klimatologi dan Geofisika (BMKG) Indonesia

Site	Latitude	Longitude	Elevation, meters above sea level (m)	Time of first contact (LT)	Time of maximum eclipse (LT)	Time of fourth contact (LT)	Maximum obscuration of solar disk (%)
Padang	0.95°S	100.35°E	6	06:21	07:20	08:27	95,41
Bandung	6.91°S	107.60°E	728	06:19	07:21	08:32	88,76
Jakarta	6.18°S	106.83°E	8	06:19	07:21	08:31	88,76
Surabaya	7.24°S	112.74°E	5	06:21	07:25	08:39	83,08
Denpasar	8.65°S	115.22°E	33	07:22	08:27	09:42	76,53
Kupang	10°19'S	123°39'E	101	07:28	08:37	09:55	65,49
Pontianak	0.02°S	109.34°E	3	06:23	07:27	08:40	90,95
Banjarmasin	3.33°S	114.59°E	8	07:33	08:30	09:27	98,17
Makassar	5.14°S	119.41°E	8	07:25	08:34	09:54	88,54
Manado	01°29'N	124°51'E	10	07:34	08:29	10:15	96,66
Ambon	03°43'S	128°12'E	9	08:33	09:29	11:16	86,91

## THE CULTURAL, ISLAMIC, AND SCIENCE VIEWS ON THE SOLAR ECLIPSE

### a) The Myths of the Solar Eclipse

The rituals pertaining to the solar eclipse vary among places in Indonesia. The ancient people traditionally believe that the solar eclipse is a dangerous phenomenon, which takes place due to the anger of a supernatural power. This makes solar eclipse phenomenon in Indonesia to be attractive for not only to students and local society but also tourists from abroad (Haristiani *et al.*, 2016). Thus, in observance of the March 9, 2016 solar eclipse, the Indonesian Postal Service launched a special edition stamp (Figure 2). The picture illustrates that the Sun is gradually eaten and then released by an atrocious ogre, named Batara Kala, the God of darkness. It is appreciated as an attempt to preserve the local cultural treasure; however, it was also critiqued to deliver false information that may mislead people to

ignorance. Such a myth has been long lived among Javanese people, and thus, solar eclipse—particularly total solar eclipse—is widely considered an extraordinary event, during which people observe several taboos (Wiramihardja, 2014; Keeler, 1988; Kleden-Probonegoro, 2008). They believed that pregnant women and children should stay indoor to avoid Batara Kala's anger. They also believed that several activities, some of which are eating, looking at the sun, constructing a house/building, and celebrating a marriage, should not be done. Moreover, they were recommended to take a bath and purify their house and heirlooms.



**Figure 2.** The special edition stamp issued by the Indonesian Postal Service in observance of the 2016 solar eclipse (source: <http://www.posindonesia.co.id/index.php/berita/154-penerbitan-prangko-seri-gerhana-matahari-total-2016>; retrieved on June 2016).

The pre-Islamic Sundanese myth believed that the sun and the moon were lovers, who were separated (Wiramihardja, 2014). The solar eclipse happened when they met each other; therefore, people on the Earth must beat rice mortar with pestles to make noise to annoy and separate them again (Mujab, 2016). These stories also lingered among the pre-Islamic Sumaterans. To avoid the demons, they masked children's face with charcoals. The pre-Islamic Bugineses in Sulawesi believed that they must do certain rituals and make charity to the gods to prevent the king and the kingdom from any calamity (Pabbajah, 2012). The Dayak Tribe of Kalimantan did some rituals during the solar eclipse (Sillander, 2006). The rituals are: (i) covering their head to prevent gray hair, (ii) shaking the tree to ask for harvesting, and (iii) washing the heirlooms.

As Islam entered the archipelago in the 13<sup>th</sup> century, the rituals incrementally change. Today, more than 80% Indonesians are Muslims. As recommended by Islam, most Muslims perform an eclipse prayer at the mosque during the solar eclipse.

### **b) The Islamic View on the Solar Eclipse**

In contrast to the traditional myths, Islam emphasizes on the virtue of worshipping during the solar eclipse. Several *hadiths* (the Prophet's exemplariness) assert that the natural phenomenon has nothing to do with someone's death (Dawud, 1984; Bukhâri, 1997). Detailed information is shown in the following:

Narrated Al-Mughira bin Shu'ba:

*"The Sun eclipsed in the life-time of Allah's Messenger on the day when (his son) Ibrahim died. So the people said that the Sun had eclipsed because of the death of Ibrahim. Allah's Messenger said, "The Sun and the Moon do not eclipse because of the death or life (i.e. birth) of someone. When you see the eclipse offer Shalat (prayer) and invoke Allah."*

(Bukhari, Book: 16; Hadith: 1043)

Narrated Abu Bakr (RA):

*We were with Allah's Messenger when the Sun eclipsed. Allah's Messenger stood up dragging his cloak till he entered the Mosque. He led us in a two-Rak'a prayer till the Sun (eclipse) had cleared. Then the Prophet (p.b.u.h) said, "The Sun and the Moon do not eclipse because of someone's death. So whenever you see these eclipses offer Shalat and invoke (Allah) till the eclipse has cleared"*

(Bukhari, Book: 16; Hadith: 1040)

Aishah narrated that

*The Prophet (p.b.u.h) said: "The Sun and the Moon do not eclipse due to the life (birth) or death of anyone. So when you witness it (an eclipse), supplicate to Allah, the Mighty & Sublime, say the Takbir and give charity."*

(Sunan Abu Dawud, Book of The Prayer for Rain; Hadith: 1191)

Asma narrated:

*"The Prophet (p.b.u.h) would command that slaves be freed during the eclipse prayer."*

Instead of imposing prohibition, the *hadiths* assert that the solar eclipse phenomenon is a reminder from God of the Day of Judgment. Therefore, Muslims are recommended to offer worships, such as: (i) praying (*Shalat*), (ii) giving charity (*Shadaqa*), (iii) freeing slaves, and (iv) asking the God for forgiveness from the torments of the grave.

During the March 9, 2016 solar eclipse, many Indonesian mosques conducted an eclipse prayer. Different from that of the June 11, 1983, in which people were strictly recommended to stay indoor, the March 2016 eclipse prayer was held either indoor or outdoor. Many worshippers even brought eclipse glasses with them and observed the eclipse process while attending preach after the prayer.

### c) The Scientific View of the Solar Eclipse

Solar eclipse is a natural phenomenon when a solar disc is masked by the Moon for few minutes and happens at least twice a year (Littmann, Espenak, & Willcox, 2008). This occurs only when the Moon is positioned between the Earth and the Sun. Total solar eclipse happens when the Moon covers the Sun completely. Meanwhile, partial solar eclipse happens when the Moon covers the Sun partially (Nandiyanto *et al.*, 2016). In addition, some meteorological parameters, such as temperature, pressure, wind speed, gravity, humidity, geomagnetic field, ionospheric electron content, and radiation, were reported to change during the solar eclipse (Paramitha *et al.*, 2017; Nandiyanto, Rusli, Purnamasari, Abdullah, & Riza, 2017; Riza *et al.*, 2016). Several researchers also reported the changes in chemical properties in the atmosphere, such as the ozone concentration, and gas composition (Nandiyanto *et al.*, 2016).

Although solar eclipse influences some organic material reactions (Nandiyanto *et al.*, 2016), the solar eclipse has almost no impact to humans, except when they look at the solar eclipse by naked eyes. Solar retinopathy is a well-recognized clinical entity of macular damage, which is caused by viewing the Sun (Ben, Laabidi, Maalej, Rannen, & Gabsi, 2008).

Solar retinopathy is divided into two groups: (i) True retinal burns, which happens to the person who gazes the Sun through gathering optics, such as the telescope or binoculars, and (ii) photoretinitis, which happens to the person who looks at the Sun directly and gets excessive blue light and the few short-wavelength UV photons to the retina. The impact of the solar eclipse on the eyes has been reported. Hundreds of people in Java in 1983 were diagnosed to be blind and two or three people lost their sight for several days after looking directly at the solar eclipse (Keeler, 1988).

## **METHODOLOGY**

### **a) Sample**

A survey was conducted to the students in Bandung to know their belief in the solar eclipse rituals and myths. The students were grouped based on the ages and the educational levels into 12-15 (junior secondary students; group I), 16-19 (senior secondary students, group II), and 20-25 years (undergraduate students, group III). Number of students in group I, II, and III were 77, 157, and 295 students, respectively. For a comparison, we also took a survey to the 67 lecturers.

We also interviewed college students who took actions during the partial solar eclipse in March 2016. We asked their knowledge of the solar eclipse that they learned from their family and schools and the acts they undertook during the March 2016 solar eclipse.

### **b) Instrument**

In the survey, the student completed a short questionnaire about the solar-eclipse rituals and myths consisting of 11 questions on a three-point Likert scale, which was developed from a previous study (Mohapatra, 1991) and adapted to the Indonesian local culture (Table 2). The results were analyzed using SPSS software to get a precise trend about the respondent's belief on the solar-eclipse rituals and myths. Formulated based on the survey results, the interviews were guided by a list of questions on what kind of knowledge and understandings that the students obtained from their parents, extended family, teachers at school, community, and religious teachers. The questions were formulated based on the survey results.

### **c) Data Collection**

The data was collected during nine days prior to the solar eclipse of March 9, 2016 (from February 25 to March 4, 2016). The instrument was distributed to students upon permission. The participants were informed about the study objectives and the instructions that they had to follow while completing the instruments, which took 15 minutes to complete. We held group interviews, consisting of 2 (two) students, to allow us to confirm the other student's experience. Each of these took 45 minutes.



**Table 2.** *Students and teachers/lecturers' responses to the questionnaire (%)*

Rituals/myths	Believe				Not believe				Not know			
	I	II	III	T	I	II	III	T	I	II	III	T
1 Solar eclipse is related to the appearance of the demon Batara Kala	6	19	3	15	55	51	82	66	39	31	15	19
2 Eating during solar eclipse causes indigestion	7	0	2	1	51	87	77	81	42	13	20	18
3 Looking the Sun during solar eclipse causes eye damage	87	64	66	72	7	24	24	19	6	10	13	9
4 Constructing a house during solar eclipse causes the collapsion	10	9	4	10	46	64	71	73	44	27	25	26
5 Should not celebrate a marriage during solar eclipse	5	21	9	13	50	62	69	73	45	17	29	13
6 Pregnant women should hide under the table during the solar eclipse	5	31	2	12	50	55	74	72	45	14	23	16
7 Children should stay indoor during the solar eclipse	17	13	15	10	41	59	62	70	42	27	23	18
8 Should go to the worship places during solar eclipse	46	51	56	61	16	29	28	28	38	20	16	10
9 Should give charity during solar eclipse	17	24	25	33	31	40	39	25	52	36	36	42
10 Should take a bath after solar eclipse	6	27	4	10	30	44	71	70	64	29	25	19
11 Should purify the house and heirlooms (if any) after solar eclipse	5	4	4	6	31	56	63	64	66	40	34	30

Note: Group I, II, and III correspond to 12-15, 16-19, 20-25 years of student, respectively. Group T is the teacher/lecturer

#### d) Data Analysis

Data obtained from the survey was analyzed using SPSS software in two steps. First, the percentage of responses in each question was calculated to identify the student and lecturer's perception on solar eclipse myths and rituals. Second, the correlation coefficient over students' responses, compared to that of the lecturers, was calculated to find out the relation between students-lecturers' perceptions. The interview data was analyzed qualitatively to support the quantitative survey data. It also serves to confirm the survey data.

## RESULTS

As shown in Table 2, more than 50% of students of group I, II, and III did not believe in the relation of the solar eclipse to the appearance of the demon Batara Kala, as told in the Javanese myth. Most of students of group I, II, and III did not believe in these following rituals: (i) eating during solar eclipse (more than 50%), (ii) constructing a house (more than 40%), (iii) celebrating a marriage (more than 50%), (iv) staying indoor for pregnant women and children (more than 40%), and (v) purifying the body, house, and heirlooms after the solar eclipse (more than 30%). However, most of students have known and believed that looking solar eclipse by naked eye causes eye damage (more than 60%). In line with these results, the percentage of the belief in praying rituals during the solar eclipse was relatively high (more than 40%), while some students did not know about the giving charity ritual (more than 30%).

The correlation coefficient (Table 3) shows the relation between students and lecturers' responses. The type of response for respondents who "believe" is more than 0.90, whereas that for respondents "not believe" is more than 0.80. The type of response in the "not know" is more than 0.50.

**Table 3.** The correlation coefficient over students' response compared to the teachers/lecturers

Types of response	Correlation coefficient between group of students and teachers preferring the same response (%)		
	Group I and T	Group II and T	Group III and T
Believe	0.920	0.914	0.979
Not believe	0.829	0.852	0.946
Not know	0.570	0.772	0.784

Note: Group I, II, and III correspond to 12-15, 16-19, 20-25 years of student, respectively. Group T is the teacher/lecturer

## DISCUSSION

Most of students did not believe in the rituals and the myths pertaining to the solar eclipse. Generally, the percentage of students who believed in the rituals and myths in group I were higher than group II and III. The students' mystical belief decreased along with the older of the age and the higher educational level, confirming that age has correlation to a better logical, rational, and abstract thinking. (Barlia, 2016) Furthermore, almost all lecturers (group T) had good understanding about the solar-eclipse phenomena in the scientific view, which encourage them to deliver it in the classroom. Indeed, lecturers' understanding on the nature of science relates to students' conception. (Lederman, 1992; Bayraktar, 2009; Çoban, 2011; Sariodlan & Kucikozer, 2015)

### a) The understanding of the solar eclipse phenomenon

More than 50% of respondents did not believe that solar eclipse has a relation to the appearance of the demon Batara Kala (Table 2). This is due to the scientific knowledge they received at school. They understood that the solar eclipse occurred due to the orbit of the Moon and the Earth.

The higher percentage of students of 20-25 years of age proved their higher critical thinking ability. This result agrees with Piaget's theory that students at the upper primary stage develop a better logical, rational, and abstract thinking than those at the under stage (Simatwa, 2010). The disbelief in the mystical stories might be affected by their good understanding on Islam, which sees this phenomenon as a remembrance from God.

A number of interviewed students recalled their parents or grandparents' stories of the solar eclipse. Tira (pseudonym, 18) said, old people told him prior to his elementary school years that the eclipse happened because a giant creature ate the Sun. When he heard the story, Tira bought it and believed in it. But, as he entered elementary school and learned about the scientific view of the eclipse, he learned that the phenomenon occurred due to the Sun and the Moon's movement in the solar system. As the oldies' story gradually disappeared and was no longer told, Tira learned that the scientific perspective is logical and well-explained the natural event.

#### **b) The prohibition of eating food**

About 50% of respondents did not believe in the prohibition of eating food during the solar eclipse. Although several people believed that consuming foods during solar eclipse causes indigestion due to the possible increases in the number of germs and viruses during the solar eclipse (Mohapatra, 1991), there is no scientific study proving that solar eclipse can be harmful to the food. Moreover, there is no Islamic prohibition of eating food during the solar eclipse; instead, as a Muslim, it is recommended to offer prayer. The prohibition of eating food was in fact not very popular among students. The interviewed students never heard of this, let alone believed in it. Those who embraced Islam religiously also never heard of any recommendations to fast during the solar eclipse.

#### **c) The prohibition of celebrating a marriage and constructing a house**

Although the ancient people believed that constructing house during the solar eclipse could cause the house to collapse, most of the respondents (more than 40%) did not believe in it. Students' disbelief in this mystical story might be caused by the science perceptions that were delivered by the teachers/lecturers at schools. This is also confirmed by the percentage of lecturers' disbelief as much as 73% (Table 2). Most students did not recognize the prohibition of celebrating a marriage and constructing a house. They even could not grasp the logical connection between this prohibition and the solar eclipse.

#### **d) The prohibition of looking at the Sun**

Different from the above results, most of respondents (more than 60%) believed in about the possible blindness that might be caused by looking the sun (Table 2). The students told us that they obeyed the prohibition, either scientifically or mythically, due to their fear of blindness caused by looking at the sun using naked eyes. Amin (18, pseudonym) said that as he grew up, he looked for a scientific reason of the prohibition and learned that the sun's ray intensity during the eclipse could not be accommodated by the naked eyes and thus might cause blindness.

Relating to these statements, several researches have proven that looking solar eclipse with naked eyes causes some damages on the eyes (Dhir, Gupta, & Jain, 1981; Michaelides, Rajendram, Marshall, & Keightley, 2001; Codenotti, Patelli, & Brancato, 2003; Hope-Ross, Travers, & Mooney, 1988; Schatz & Mendelblatt, 1973; MacFaul, 1969; Keeler, 1988; Ben, Laabidi, Maalej, Rannen, & Gabsi, 2008). Indeed, this information has been delivered well to the students during their study by the teacher or the lecturer.

#### **e) Recommendation to stay indoor and hide**

The percentage of students' disbelief on the compulsion to staying indoor and hiding for pregnant woman was relatively high (more than 40%) (Table 2). The students were warned by their parents to stay indoor during the solar eclipse. Like other students, Indria (19, pseudonym) and Amin were excited to witness their first experience encountering the solar eclipse in March 2016 but as their parents insisted that they stayed at home, they decided not

to join the observations that were held by many groups in the city. Instead, they watched the broadcasts in the televisions. Their parents were afraid of any harm that could happen to them caused by the solar eclipse.

The interviewees showed that the students have never heard of the recommendation to hide for pregnant women. To this end, there is no medical evidence which relates between solar eclipse and pregnancy condition. Indeed, psychological condition of pregnant women must be considered. The eclipse phenomenon should not make pregnant women stressed out that cause the baby born prematurely (Peacock, Bland, & Anderson, 1995; Glynn, Schetter, Hobel, & Sandman, 2008).

#### **f) The recommendation to pray**

Most respondents (more than 40%) believed that offering prayers and making a charity during the solar eclipse were recommended (Table 2). The recommendation to pray has been well known among Muslim students since they were in their elementary school years, taught by their religion teachers. Tira said that although the March 2016 was his first experience of encountering the solar eclipse, he has always performed lunar eclipse prayers before. When he was young, he believed that the prayers would help the Sun to get free from the giant creature that ate it but as he grows older and comprehended the scientific concept of why and how the solar eclipse occurred, he believed that offering a prayer was his way of asking for God's protection and of expressing his gratefulness for God's favors. Many college students chose to stay in the mosque to listen to Islamic sermons. On the day of the solar eclipse, they found that the day was felt serene due to the *takbir*, a repetitive recitation praising God's greatness, heard from mosques. The students' actions might be affected by their understanding on Islam since they were young. The high responses to offering the prayer and making a charity showed that Islamic values have been a culture in society.

#### **g) The recommendation to purify the body, house, and heirlooms**

About 30% of the respondents did not believe that after the solar eclipse, people were supposed to purify their body, house, and heirlooms (Table 2). The interviewed students acknowledged that they were not familiar with such a recommendation as well. This ritual has no scientific base but still alive in some ancient tribes in Indonesia, such as Dayak Tribe.

Based on the above results, most students and lecturers did not believe in mystical stories relating to solar eclipse, which were irrelevant to the scientific and Islamic views. This indicates that both students and lecturers have had integrative understanding about this topic. (Kucuk & Çepny, 2015). The students' belief on some mystical stories decreased along with the higher class level, which proved higher logical thinking ability. In addition, high number of correlation coefficient also indicates that there is relation between student-lecturer's perceptions. Lecturers' knowledge and attitude toward science will affect their students (Lederman, 1992; Mugaloglu & Bayram, 2009). The results also showed that there were a number of students' errors in perception about solar eclipse myths which was carried over until today. Therefore, in this case, the role of lecturers is very important to clarify false information that may mislead student to ignorance. It is recommended for the teacher, especially for Muslims, to relate science concept of solar eclipse with socio-culture and Islamic views to enrich students' understanding of science (Bayraktar, 2009; Kilinc *et al.*, 2014). Further, enhancing students' understanding of the nature of science is the main objective in the science education (Lederman, 1992).

## CONCLUSION

We conclude that some cultural rituals are relevant to the science and the Islamic views, such as the prohibition to look at the sun directly and to offer a prayer during the solar eclipse, whereas other rituals are irrelevant. Based on the survey results, the students' belief in some mystical stories decreased along with the older of age and the higher educational level. Almost all lecturers have good understanding about the solar-eclipse rituals and myths; this supports students' comprehension. The interview results are also in a good agreement with the survey result. While some myth-based practices were still embraced, students' understanding of the solar eclipse was still dominated by the science concept and the Islamic religious views that they have learned since their elementary education.

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## “Yin” in a Guided Inquiry Biology Classroom – Exploring Student Challenges and Difficulties

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### ABSTRACT

Student encountered challenges in performing guided inquiry learning (GIL) activities are a minority literature in science education, but may provide valuable inputs to developing science process skills vital to scientific literacy. This study determined the challenges and difficulties by science-oriented students in performing GIL activities in biology. Cluster sampling determined the participants in the pre-survey (69 grade 8 students) and the actual investigation (30 grade 8 students). A validated survey questionnaire pre-identified the six major difficulties of the students. Validated student and expert questionnaires assessed the level of difficulty in each of the task on the six pre-identified challenges. Results show that science-oriented students and the experts assessed the following with a fair difficulty level: background knowledge; performance of laboratory procedure; managing extended activities; designing an experiment; and writing a laboratory report. The same group assessed the task – data analysis to be “difficult.” The upper (high average to superior IQ) group and lower (average to above average) groups of science oriented students provided a non-significant difference in their difficulty assessment of all the tasks. However, replicating the study to include low cognition students from non-science oriented schools may provide a wider perspective of these student-encountered difficulties and challenges in GIL.

**Keywords:** Challenges and difficulties, Guided Inquiry Learning, Science Process Skills, Scientific Literacy, Inquiry-based learning – 5Es

### INTRODUCTION

Success in learning science may be attributed to several factors such as interest, motivation, student engagement (Beal & Stevens, 2007; Broussard & Garrsion, 2004; Johnson, 1996; Sandra, 2002; Skaalvik & Skaalvik, 2006; Zhu & Leung, 2011) and content knowledge (Cavallo, Rozman, Blinkenstaff, & Walker, 2003). Ultimately, this success is gauged on students’ scientific literacy which has been one of the major global goals of science education which countries aspire to achieve (Australian Council for Educational Research, 2014; Fensham, 1985; Hobson, 2006; Tan, 2004). Like any other country, the Philippines push forth to achieve a scientifically and technologically literate country. To promote scientific literacy to the students and the society, Anderson (2002), and Ozdemir and Isik (2015) found





scientific inquiry as a vital approach and science process skills are the important part of it. Thus, it becomes significant to look into inquiry learning and process of assimilating science process skills.

### *Inquiry-Based Learning*

Inquiry-based learning (IBL), as described by Beyer (1979) is a promising method for developing deep understanding of science concepts and content. Literature (Bybee, 2002; Siebert & Macintosh, 2001; Wilke & Strait, 2005; Aktamis, Higde, & Ozden, 2016) indicate that deeper learning occurs when students are more actively engaged in the process. This learning occurs when students explore authentic problems using tools and skills of the discipline and which requires more active student participation and higher order thinking skills. Accordingly, it is a learning framework that activates student engagement to develop a full range of scientific skills. Apparently, Leach and Scott (2002, 2003) tracked its success with the original five-step inquiry process by Beyer as: 1) define a problem; 2) develop a hypothesis; 3) search for evidence; 4) draw a conclusion; and 5) test the adequacy of the conclusion. Students engaged in these steps may develop science concepts and scientific process skills—features and capabilities of IBL that helped strengthen the science education of HongKong Education Bureau (EDB, 2008) to promote student’s scientific thinking. The same IBL features propelled the Philippine science education community to adopt the approach to its K-12 program to develop scientific literacy among its students. Colburn (2000) categorized inquiry based learning in three approaches: structured, guided, and open inquiry itemized in ascending order of the learner’s autonomy over the setting investigation problem and planning problem-solving procedures. Significant distinctions between these approaches distinguished the amount of scaffolding and the level of independence given to the learner. Healey and Jenkins (2009, p.72) believed that guided and open inquiry are necessary to build motivation then structured inquiry may be used to further develop students’ research skills. Several research findings (Hakkarainen, 2003; Marshall et al., 2009; Song & Looi, 2012) suggest that guided inquiry approach is especially suitable for young learners, as teachers are able to match the level of investigation and scaffolding with the learners’ ability. Moscovici (2003) confirmed this suggestion that guided inquiry learning are appropriate for middle school and high school students.

Inquiry-guided learning or guided inquiry-based learning according to Green (2003) promotes classroom practices that help students improve, sharpen, and follow through their own questions, and develop a habitual sense of inquiry. In several related studies, researchers (Cooper, 2014; Green, 2003; Farrell, Moog & Spencer, 1999; Jin & Bierma, 2011; Repinc & Juznic, 2013; Aktamis, Higde, & Ozden, 2016) documented guided inquiry’s success in bringing students to engage in learning and to learn science concepts in deep ways. Roles are eminent in guided inquiry learning. Lee (2011) reports that guided inquiry worked best with the following sequence: K-presentation of knowledge/content; i1 and i2 – guided inquiry skill development; I – inquiry; i3 and i4 – guided inquiry skill development; and so on. Success of guided inquiry learning correlates to Kulhthau, Maniotes, and Caspari’s (2012 p.33) concept of student engagement on their “third space,” in which students make connections to their real world and where the learning is applicable to it immediately.

### *Challenges and Difficulties in Guided Inquiry Learning*

However, though researchers (Krajcik et al., 1998; Kong & Song; 2014; Song & Looi, 2012; Yeo & Tan, 2010; Aktamis, Higde, & Ozden, 2016) agree that inquiry learning may bring about the best in students, other researchers (Brown et al., 2006; Spencer, 2006) identified several limitations of inquiry learning. These were the same findings reported by

Mohamed (2008) and Rajan and Marcus (2009) who retold that students dislike inquiry learning when first exposed to the method as they feel unequipped to do the tasks. Teachers also find inquiry learning time consuming (Nidup & Yodyingyong, 2015), thus, resulting to economizing on the number of topics covered.

Edelson, Gordin, and Pea (1999) identified the most significant challenges to the successful implementation of inquiry-based learning: motivation; accessibility of investigation techniques; background knowledge; management of extended activities; and practical constraints of the learning context. Other studies reported the following difficulties and challenges: slow process, handling of laboratory apparatus and its uses, observation skills, fear of handling chemicals and glass wares (Nidup & Yodyingyong, 2015); incapability of using tools, inability to design their experiment, and comprehend terms such as hypothesis, variables and data collection (Pewnima, Ketpichainaronga, Panijpanb, & Ruenwongsaa, (2011); and difficulty in searching and organizing information (Rola, Abrantes & Gomes, 2004). These challenges in inquiry learning implementation may have hindered several success stories for this approach. Thus, Song and Looi (2012) tried to balance the two approaches (inquiry and guided inquiry) and developed the 5E inquiry-based pedagogical model: engage, explore, explain, evaluate, and extend; which the Philippine K – 12 education program adopted to implement the science curriculum. Though there are several aforementioned literature on difficulties encountered in implementing inquiry learning, studies on difficulties and challenges attributed to guided inquiry is a minority with only Lee (2012) emerging to have conducted a study on opportunities and challenges in inquiry-guided learning in the collegiate level and not on the K – 12 program, thus, the focus of the study.

#### **PURPOSES OF THE RESEARCH STUDY**

Generally, the study aimed to identify the challenges encountered by the Grade 8 students in performing guided inquiry-based activities in Biology. Specifically, it sought to answer the question:

1. What is the level of difficulties of Grade 8 students in performing guided inquiry-based activities in Biology given the following challenges:

- a. background knowledge;
- b. performance of laboratory procedures;
- c. management of extended activities;
- d. designing an experiment;
- e. data analysis; and
- f. writing a laboratory report?

2. Is there a significant difference between the level of difficulties in each major challenge encountered by the upper and the lower groups of Grade 8 students in performing guided inquiry-based activities?

#### *Scientific Literacy, Science Process Skills, and the 5E's*

As a major goal of the Philippine education system, efforts of government agencies push forth to achieve a scientific and technologically literate country. As found, scientific inquiry is vital and science process skills are the important part of the quest towards scientific literacy. Other researchers (Akben, 2011; Aktamis & Erin, 2008; Colvill & Pattie; 2002) confirm these reports and even further postulated that activities which consist of basic and integrated process skills are its dimensions. Process skills are transferable intellectual skills, suitable to all scientific endeavors. Accordingly, the American Association for the

Advancement of Science (AAAS, 1998) identified these 14 science process skills generally classified into two groups as basic skills and experimental or integrated skills.

The 5E Instructional model used by Song and Looi (2012) to balance inquiry and guided inquiry learning was developed in 1987 by the Biological Science Curriculum Study (BSCS) led by Roger Bybee. This 5E's, consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. BSCS (2006) defined each phase with specific function and which contributes to the teacher's coherent instruction and to the learners' formulation of a better understanding of scientific and technological knowledge, attitudes, and skills. Researchers (Oszevgec, 2006; Ergin, Kanli, & Unsal, 2008) explored the effectiveness of the students' materials developed using the 5E model on their achievement and attitudes. However, a majority of investigations in GIL relates the approach to acquiring skills and better student achievement and a minority for difficulties and challenges encountered by students in implementing GIL. Thus, the study focuses on challenges rather than success, to contribute to the existing literature on GIL, process approach, and scientific literacy.

## **METHODS**

### **Research Design and Participants**

Cross-sectional survey collected information from a sample drawn from a pre-determined population. Randomly selected 69 Grade 8 student-participants answered the pre-survey questionnaire to initially identify the major challenges of the students in guided inquiry based activities prior to implementation. Three content experts validated (descriptively and quantitatively) and evaluated the questionnaires for both the teachers and the students. Aiken's content validity coefficient determined the content validity indices of the major instruments of the study. Ten students randomly selected from the initial set of (69) participated in the pilot administration to establish reliability (descriptive) of the major research instruments used.

Thirty Grade 8 students with age range of 13 to 15 years identified through cluster sampling technique comprised the sample of the study. Sixty percent were males and 40% are females. They were pre-grouped through random group assignment to form 6 heterogeneous sets. Within the groups, tagging identified those students belonging to the upper group (U-with Very Superior/Superior/High Average IQ) and the lower group (L-with Above Average/Average).

### **Research Instruments**

#### *Pre-survey Questionnaire*

This instrument is a validated researcher-designed pre-survey questionnaire on the major student challenges (background knowledge, access to resources, performance of laboratory procedures, motivation, management of extended activities, designing an experiment, identifying variables, formulating hypothesis, data collection, analysis of data, and writing the laboratory report) in performing inquiry-based activities in their previous Integrated Science class. This instrument includes a major item on ranking the entire pre-identified and literature-based student encountered challenges students in conducting inquiry activities (Appendix A). The validation process included only a descriptive validation by content experts due to the simplicity of the questionnaire structure.

#### *Activity Guides*

These set of activities included contextualized and customized guided inquiry (GI) activities with instructions for students and major questions that directed their research activities. These GI activities are problem based learning-influenced activities that highlight

in their structure the “background” that placed the context of activity and the “question” that sets the student into thinking about the solution (hypothesis) to a presented real-life problem. Students are also provided directions so as to determine how to: 1) test the hypothesis, 2) analyze data, and 3) conclude and apply. Appendix B shows a sample of the GI activity. Content experts validated all activities in terms of content and structure with an overall Aiken’s content validity coefficient ( $VK=.933 \square 1$ ) interpreted as content valid (Aiken, 1985).

#### *Questionnaire for the Students*

A validated researcher-designed instrument with 12 open-ended questions used to gather data on the difficulties encountered by the students in performing the inquiry-based activities limited to the pre-identified challenges. This instrument included probing questions that may deduce very informative qualitative data on student encountered challenges in all the phases of the GI. Aiken’s validity coefficient for this instrument ( $VK = .91 \square 1.0$ ) is suggestive of a high validity coefficient (Aiken, 1985), which means that all experts found the contents of all the activity as valid.

#### *Questionnaire for the Experts*

This instrument is a validated researcher-designed instrument used by the experts in assessing the difficulties/challenges encountered by the students in performing certain aspects of the inquiry-based activities. This instrument includes both a Likert scale section which emphasize the six pre-surveyed student encountered challenges with several major indicators per surveyed challenge and an open-ended section where the evaluators may provide descriptive comments. Aiken’s validity coefficient for this instrument ( $VK = .92 \square 1.0$ ) is suggestive of a high validity coefficient (Aiken, 1985), which means that all experts found the contents of all the activity as valid.

### **Data Collection**

#### *Stage 1: Preliminary*

The pre-survey questionnaire identified the major challenges of the students in performing guided-inquiry investigations based on their prior experiences. The students ranked each challenge based on their perception as to which is the most challenging and the least challenging. Local contextualization modified readily available activities customized to the local traditions and materials, and to the prescribed learning competencies by the Philippine Science High Schools system – the locale of the study.

At least three identified experts validated all research instruments in terms of correctness and accuracy of the content and structure of the instruments in this study. Interviews and consultations with these experts established the reliability of the activity guides. In consonance with the study of Morales (2014), ten randomly selected Grade 8 students identified terms in the texts which for them are difficult to understand to improve the readability of the instrument prior to implementation.

#### *Stage 2: Data Collection*

The conduct of the activities was facilitated with invited superiors from the same science high school to monitor and supervise the guided-inquiry implementation. The participants accomplished the four inquiry –guided activities for the whole quarter. They worked in small pre-determined groups in a flexible learning system for them to have extended activities (conducted beyond the regular sessions). After completing the four activities, they submitted group written output and individual written output. The outputs and actual observations provided the experts the data necessary to assess the challenges or

difficulties encountered by the students in the pre-determined challenges of inquiry-based learning.

After performing all the activities, the researcher-designed questionnaire administered to students partially determined the specific difficulties the students encountered in terms of the major challenges in performing inquiry-based activities. The identified experts assessed student output, specifically the laboratory reports and actual observations to identify student difficulties in conducting guided-inquiry based activities. Interviews clarified which task did they encounter difficulty and provided rich qualitative data on the differences in the level of difficulty of the different tasks. Interviews with experts verified their quantitative assessments of student difficulties and challenges.

### Data Analysis

In the pre-survey, each rank carries the same equivalent point as follows: rank 1, scores a point; rank 2 scores, 2 points, etc. The calculated and ranked sums of ranks for each challenge provided the upper six challenges with the least sum of ranks as the major challenges of the students. In the implementation of GI activities, the Likert scale identified, quantified, and interpreted the specific difficulties and challenges of the students on the different aspects of inquiry-based activities. Independent samples t-test established the significant difference in the challenges encountered (determined through the Likert scale instrument) by the two groups (upper and lower) of participants. Consolidated data analysis triangulated the difficulties identified by the students, assessed by experts and thematic groupings of open responses.

## FINDINGS and DISCUSSION

The study sought to explore student challenges and difficulties in conducting guided inquiry learning activities. The pre-survey conducted identified hierarchically (according to rank) six major challenges of the students in performing guided inquiry based activities in Biology as: 1) writing the laboratory report; 2) designing an experiment; 3) management of extended activities; 4) analysis of data; 5) performance of laboratory procedures; and 6) background knowledge. These six major challenges were the identified fairly to very difficult (Edelson, Gordin, & Pea, 1999; Nidup & Yodyingyong, 2015; Pewnima, Ketpichainaronga, Panijpanb, & Ruenwongsaa, 2011; Rola, Abrantes & Gomes, 2004).

Student Challenges and Difficulties in Guided Inquiry Learning (GIL) Activities in Biology

In this study, Table 1 presents the six major challenges in a procedural sequence in conducting GIL activities.

**Table 1.** *Challenges and difficulties of students implementing GIL activities*

<b>Difficulties</b>	<b>Topics</b>	<b>Mean</b>	<b>SD</b>	<b>Interpretation</b>
<b>Background Knowledge</b>	Population density and species richness	3.38	0.77	Fairly Difficult
	Factors that limit population growth	3.43	0.62	Fairly Difficult
	Ecological interactions	2.97	0.98	Fairly Difficult
	Air pollution and acid rain	3.04	0.84	Fairly Difficult
<b>Performing Laboratory Procedures</b>	Measuring mass	3.00	0.10	Fairly Difficult
	Measuring temperature	3.18	0.23	Fairly Difficult
	Measuring volume	2.70	0.37	Fairly Difficult
	Measuring length	3.63	0.23	Not Difficult

	Measuring area	3.05	0.50	Fairly Difficult
	Constructing ecological quadrat	3.60	0.26	Not Difficult
	Measuring the acidity of a solution	3.73	0.20	Not Difficult
	Using the microscope	2.03	0.37	Difficult
<b>Management of Extended Activities</b>	Conducting a group meeting for planning	3.17	0.76	Fairly Difficult
	Conducting a literature search for the investigation	3.22	0.69	Fairly Difficult
	Preparing the materials for the investigation	3.11	0.84	Fairly Difficult
<b>Designing an Experiment</b>	The students are able to design an experiment that can answer research questions	2.57	0.39	Fairly Difficult
	The students are able to design an experiment that contains appropriate and specific materials	2.72	0.28	Fairly Difficult
	The students are able to design an experiment that contains logical and realistic procedure	2.67	0.39	Fairly Difficult
	The students are able to design an experiment that contains variables/elements	2.70	0.19	Fairly Difficult
<b>Analyzing Data</b>	The students are able to present their data logically and appropriately	2.48	0.33	Difficult
	The students are able to analyze their data that directly address/ answer the research questions	2.61	0.28	Fairly Difficult
	The students are able to interpret their data accurately and appropriately	2.39	0.20	Difficult
	<b>The students are able to write a report that...</b>			
<b>Writing Laboratory Report</b>	• contains specific and directly related to the subject being investigated objectives	3.09	0.69	Fairly Difficult
	• contains accurate and well-written theoretical background related to the subject being investigated	2.89	0.91	Fairly Difficult
	• contains well-written methodology of the experiment	2.82	0.25	Fairly Difficult
	• contains properly labeled graphs/tables/chart	2.59	0.26	Fairly Difficult
	• contains well-written conclusion and recommendation	2.48	0.25	Difficult
	• free from typographical errors and neatly written	3.18	0.38	Fairly Difficult
	• free from grammatical error	3.22	0.40	Fairly Difficult

Generally, as rated by experts, the participants perceived the skills related to the conduct of GIL activities, presented in Table 1, as fairly difficult. It may be inferred that these students have a good understanding of the topics related to the GIL activities which may be sourced from students' profile. Their IQ ranges from average to very superior interpreted as possessing the capacity to acquire new learning and skills with proper guidance to being very quick-witted (Culture Fair Intelligence, 2000). They even rated as “non-difficult,” the three items in performing laboratory procedures (measuring length, constructing ecological quadrat, and measuring the acidity of a solution), but contradicts with their perception of difficulty in the aforementioned skills as expressed in their interview responses (e.g. “The most challenging is the quadrat sampling because it is hard to choose a random spot and count grasses and random organisms seem to have an infinite number.”). This contrasting result may imply that there are certain difficulties students encounter in conducting GIL activities as: handling laboratory apparatus and its uses, fear of chemical and fragility of glass apparatus (Nidup & Yodyingyong, 2015); researching information (Rola, Abrantes, & Gomes, 2009); identifying treatment, outcome, and control variables (Dasgupta, Anderson, & Pelaez, 2014); and comprehending hypothesis, variables, and data collection (Pewnima, Ketpichainaronga, Panijpanb, & Ruenwongsaa, 2009).

Consequently, experts assessed most of the “difficult” rating in analyzing data and writing laboratory reports. Specifically, they considered the following as difficult: 1) present their data logically and appropriately; 2) interpret their data accurately and appropriately; and 3) well-written conclusions and recommendations as difficult and challenging for the students. These results accord with the responses of the students for the specific challenges they encountered in analyzing their data. Their responses are as follows:

“Analyzing the data is hard. Understanding them and relating them to your background is hard because maybe limitations of the experiments.”

“Writing the conclusion because it is very hard to conclude if an experiment failed.”

It seems that these students find the analysis of the data task as most challenging probably because presenting and analyzing data in a more structured way is more familiar to them. Dasgupta, Anderson, and Pelaez (2014) reported the same results that middle school students have trouble interpreting findings when faced with natural variation. Also, their encountered difficulty ranges from writing the introduction and putting emphasis on difficulty in presenting their results to writing the conclusions, usually encountered when students shift from rhetoric writing to academic writing. Martin (1990), Neville (1996), Hocking (1995) and O’Toole (1994) reported the same key issue when a learner commences as university students and shifts from literary writing to scientific writing.

#### Comparing the Expert’ Assessed Challenges of Upper and Lower Groups

Comparing experts’ assessments of the groups in performing guided inquiry learning activities may provide inferences on which challenges are dominant in which set of students. Table 2 presents the comparison of expert assessed challenges of the upper group and the lower group of all the heterogeneous clusters.

**Table 2.** Comparing Upper and Lower groups' expert assessed challenges

Challenge	Group	Mean	Standard Deviation	Mean Difference	Df	t-statistics	p-value
Background Knowledge	U	3.20*	.27	.01	28.00	.11	.91
Performance of Laboratory Procedures	U	3.29*	.21				
	L	3.16*	.23	-.13	28.00	1.67	.11
Management of Extended Activities	U	3.21*	.47				
	L	3.12*	.31	-.09	28.00	.57	.57
Designing an Experiment	U	2.61*	.46	.12	28.00	.66	.52
	L	2.73*	.51				
Data Analysis	U	2.43**	.42	.14	28.00	.95	.35
	L	2.57*	.35				
Writing the Laboratory Report	U	2.93*	.33	.07	28.00	.69	.50

*L-Lower group, U-Upper group*

*\*Not Difficult, \*\*Fairly Difficult*

*\*\*\*Difficult*

In five out of six challenges (background knowledge, performance of laboratory procedures, management of extended activities, designing an experiment and writing the laboratory report) experts assessed the challenges encountered by both groups as fairly difficult. Though there are minute differences in the means of the upper and lower groups, these differences are not significant ( $p > .05$ ). The challenge encountered by the student in analyzing data, assessed by experts as difficult for the upper group and fairly difficult for the lower group also incurred a non-significant mean difference ( $p > .05$ ). It may be inferred from these results that differences in IQ levels of students do not provide differences in the student encountered challenges and difficulty in performing guided inquiry learning activities. Thus, chances that both groups of students will perform well if these difficulties are addressed are not imaginary ideas. The idea confirms Konikova's (2016) findings that IQ does not predominantly predict success, achievement and performance of students, but student motivation now plays a significant role in student success.

## CONCLUSIONS

As the Chinese proverb goes, "The gem cannot be polished without friction, nor man perfected without challenges." Difficulties usually surface in all human activity, even in the teaching-learning process. Thus, teaching and learning practices should focus on two tracks – attaining student achievement and addressing student difficulties. This teaching and learning principle does not only apply to select learning areas, but also perfectly fits learning science. Learning science in the new curriculum is not limited to applying inquiry learning for students to attain student achievement and inculcate scientific literacy. It also



highlights using the best possible method of inquiry (guided inquiry learning [GIL]) appropriate to the needs of the learner and learner’s developmental maturity to motivate the students to engage in science and encounter success and difficulties as well. Focusing on these student experiences may bring about the desired outcome – student engagement, complete assimilation of content and process skills and scientific and technological literacy. The majority of literature (Cooper, 2014; Green, 2003; Johnson, 2011; Jin & Bierma, 2011; Kam & Hoop, 2013), report the success of GIL in attaining student achievement. However, challenges and difficulties encountered by students in performing GIL activities are minority literature and must also be emphasized together with studies on using GIL as an approach to better the achievement of students if one needs to attain complete understanding of science concepts and scientific methods and processes of science. Understanding the difficulties and challenges encountered by students is like the principle of Taoism – you cannot attain the complete concept of inquiry learning and science process skills by only taking a look at the approach in terms of student achievement. You also need to see the other side of the coin—difficulties that may be addressed to further propel achievement of scientific literacy. This principle of learning is similarly projected by Grilley (2007) who described Taoists concept of “opposites define each other.” She explained that the very words used to describe things are meaningless without their opposites. Words such as big, bright and hot are strongly defined by their opposites small, dark and cold. Taoists labeled this principle as yin and yang. The yin yang theory is a kind of logic that connects things in relation to their whole (Shen-Nong, 2005) and a concept of duality forming a whole (Kochmer, 2016). Thus, in the concept of learning science, emphasizing achievement is one, and addressing difficulties completes the whole learning process. It is the idea that difficulty defines student achievement in science and that which propels students to achieve further, while this attained achievement drives more force for students to struggle and attain enhanced learning.

### **On challenges and difficulties**

Challenges and difficulties identified in this study may provide a significance to teaching and learning processes of science concept geared towards scientific literacy enhancement. These specific challenges may offer ideas for teachers and researchers on how to plan the curriculum and instructional materials to address these difficulties and challenges. The non-significant difference in challenges of the upper and lower group as assessed by experts may be an indication that even the good ones in terms of cognitive human faculty encounter the same difficulties and challenges as those assessed with lower cognition. Thus, cognitive processing may be different between the lower and the upper groups, but we can improve their achievement by addressing their difficulties. Finally, the results of this research may provide both practitioners and researchers; two views and perspectives in terms of Guided Inquiry Learning – that focused on using the approach for better attitude and achievement (the yang) and that which emphasize the challenges and difficulties (the yin) for the complete grasp of teaching and learning of science process skills.

### **Suggestions**

Only one science-oriented (Philippine Science High School) campus participated in this study; thus, future studies could use the same framework to extend the work to all science-oriented and non-science oriented high schools in the Philippines. Curriculum designers could develop instructional materials to address the identified student-encountered difficulties and challenges. They may also incorporate localized GIL activities to instil sustainability of the

Filipino indigenous practices and traditions while mastering science process skills and developing scientific literacy.

For more encompassing outcome, a longitudinal research may be done to expand data gathering and analysis as much as explore the learning and teaching aspects of science concepts that would apply a triangulation of the three domains of education: cognitive, affective, and psychomotor. Learners' evolution in all these domains of learning would be supervised and harmonized with the different stages of their psychological development. A series of professional development program on conducting and implementing GIL activities inclusive of disseminating student-identified challenges may be launched for the experimental process on the teaching aspect and as capability building for better delivery of science knowledge to our most valued clientele – students.

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**Appendix A**  
**Pre-survey Questionnaire for the Students**

NAME (optional): \_\_\_\_\_

SECTION: \_\_\_\_\_

**DIRECTIONS:** The following items are challenges that you may have encountered as you perform the different inquiry-based activities. Rank them from 1 to 11. 1 being the most challenging and 11 being the least challenging.

Rank	Challenge
	Background Knowledge
	Access to Resources
	Performance of Laboratory Procedures
	Motivation
	Management of Extended Activities
	Designing an Experiment
	Identifying Variables
	Formulating Hypothesis
	Data Collection/Presentation
	Data Analysis
	Writing a Laboratory Report

## Appendix B

### Sample Guided Inquiry Based Activity

#### *QUADRAT SAMPLING/BIODIVERSITY*

##### *Background*

*Biodiversity is defined as the total variety of life on Earth.* Species diversity refers to the different species in an ecosystem. It is sometimes called species richness. For example, there are five different species of plants in Area A and two in Area B. Thus, Area A is richer than Area B in terms of species.

Another important data that is being collected by ecologists in conducting ecological study is the population density of different species of organisms. It is calculated using the formula below:

$$\text{density} = \frac{\text{number of plants or animals}}{\text{area occupied}}$$

In conducting an ecological study, as it would be challenging to account for all the different organisms especially if the field of study is wide, sampling quadrats are used. An ecological quadrat is basically plot to isolate a standard unit of the study area. The data that will be gathered from these quadrats will represent the entire area of study. The sample quadrat is shown in Figure 1. It is typically 1 square meter in dimension.

In this activity, you will compare the species richness of plants and animals in two different areas in the school. In addition, you will account for the population density of plants in your chosen area of study. You will survey small areas within each ecosystem using a quadrat similar to the one shown in Figure 1. Finally, you will calculate the diversity index of your study area using the Simpson’s Diversity Index formula below.

$$D = 1 - \sum \left( \frac{n}{N} \right)^2$$

where:

D = diversity index

n = the number of individuals of a particular species

N = the total number of individuals

The value of  $D$  ranges from 0 to 1, with 1 representing infinite diversity and 0, no diversity.



*Figure 1. Sample Quadrat*

You may choose to compare any two areas in the vicinity of the campus. Examples include the grassy area near the entrance gate, nature's park, the small pond, and the garden.

### **Question**

Which area in school has a higher number of species of plants and animals?

How does population density of local plants differ between the two selected areas in the school?

### **Form a Hypothesis**

Recall your knowledge about ecosystem, community, population, and biodiversity. Write a hypothesis in your science journal.

### **Test Your Hypothesis**

1. Think of a way on how to test your hypothesis. You may use textbooks or online resources in planning your investigation. Consider the materials that you will use. How will you test your hypothesis?
2. Write in your science journal the procedure that you are planning to implement. Decide which two areas in the school you will consider in doing your investigation. Then, you will have to construct your quadrat (Use 5 quadrats/areas.). After deciding on the communities within the school premises, think of a way on how to ensure that the small areas (quadrats) within these communities are randomly selected.
3. Once you are ready to conduct your survey, consider the following questions:  
If you are planning to sample soil or water in your investigation, how will you do it?  
In accounting for the diversity of plants and animals, how will you identify them? (For this class, if identifying their common names is challenging, you may refer to them as Plant A, Plant B, etc.).

How will you describe other details about the area surveyed? Will you make a map to show the distribution of the plants/animals in your study area?

How do you plan to record and present your data?



What safety precautions do you need to take note of before conducting the activity?

4. Submit your detailed plan to your teacher. Write it on your science journal.
5. Implement your approved plans. Take careful notes as you conduct your surveys. Think of an appropriate way to present your data (table, graph, etc). What will you do to these data to answer your research questions?

### **Interpret Your Data**

1. Calculate the population density of the plants/animals you are studying.
2. Calculate the species richness in your areas of study.
3. Compare values of population density for the two areas that you surveyed. In which area are the plants denser? Do your data support your hypothesis? Explain why or why not.
4. Compare and contrast the characteristics of the two ecosystems that you studied. How are the characteristics of each ecosystem related to the species richness? What could have been the factors for it to be more diverse?

### **Conclude and Apply**

1. Compare your data with those of others in the class. Take note of the similarities and differences in the data. What conclusion can be made from these data?

### **Important Notes:**

1. In planning your investigation, consider the available resources in the laboratory/school. You may also consider bringing materials from your house to conduct the investigation.
2. Set-ups must only be done in school. You are expected to submit a laboratory report on your findings.
3. Prepare a Material Safety Data Sheet for every activity.

### **Suggested Reading Materials:**

1. <http://www.dartmouth.edu/~bio21/exercises/Sampling.handout.pdf>
2. Miller, K., et.al. (2008). Prentice Hall Biology. Boston Massachusetts. Pearson Education, Inc.
3. Biggs, A., et.al. (2008). Glencoe Science Biology. USA. McGraw-Hill Companies, Inc.
4. <http://geographyfieldwork.com/SimpsonsDiversityIndex.htm>

## Inquiry-based Professional Development Practices for Science Teachers

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### ABSTRACT

In science education reform movements, there is an emphasis on teaching science through inquiry, and teacher education is an important part in this process. In this context, this study aims to investigate the effect of inquiry-based professional development training on science teachers' beliefs and self-efficacy about inquiry-based teaching and science process skills. A group of 30 science teachers participated in the study. The data collection tools used were "Beliefs about Inquiry-based Teaching Scale," the "Inquiry-based Science Teaching Self-efficacy Scale," and the "Science Process Skills Test." During two days of short-term professional development training, teachers attended five workshops that introduced the inquiry method. Analyses of the collected data showed that professional development training was effective in improving teachers beliefs ( $t = -6,57$ ;  $p = .00$ ), self-efficacy ( $t = -5,80$ ;  $p = .00$ ), and process skills ( $t = -5,76$ ;  $p = .00$ ). The results of the study suggest that additional research about the improvement of students' science learning and about the effect of professional development on different variables such as teachers' learning design skills should be done.

**Keywords:** Inquiry-based teaching, professional development, self-efficacy, belief, science teachers.

### INTRODUCTION

Recent studies have reported that students' interest in science and mathematics has decreased as has their interest in making a career in these fields (European Commission, 2007). Although many countries made effort to handle this issue, the current situation is unsatisfactory. Therefore, several countries changed their education systems, including Turkey that adopted a constructivist learning theory in its national science education program in order to create science-literate citizens in the future. A constructivist learning theory concerns an individual's mental information processing. This approach emphasizes that knowledge forms through one's own active mental process not transferring from one to another and suggests the efficacy of inquiry-based teaching (Duban, 2008; Schroeder & Zarinnia, 2001).

Inquiry involves asking questions or seeking knowledge, searching and getting knowledge about something. The inclusion of the term "inquiry" in education was proposed by John Dewey, a science teacher who asserted that science is taught only by the inclusion of students' personal knowledge and thus, encouraged teachers to use the inquiry method as a



teaching strategy. In inquiry-based learning (IBL), students try to investigate and understand the things around them by working like a scientist. This type of learning provides opportunities for students to develop the skills (observing, measuring, collecting data, drawing conclusions etc.) needed during their lifetime, learn to deal with problems that cannot be solved, deal with changes and difficulties in their understanding, and revise researches for solutions (Kılınç, 2007). IBL further provides an understanding of core scientific facts, the acquisition of skills needed for understanding these facts, an understanding of the nature of science, and the development of positive attitudes toward science (Aktamış, Hiğde & Özden, 2016; Chiappetta & Adams, 2004). Researchers have provided much evidence about the advantages of IBL (Kahn and O'Rourke, 2004; Kılınç, 2007; On, 2010; Patrick, Mantzicopoulos & Samarapungavan, 2009; Yaşar & Duban, 2009). In one of these studies, an inquiry-based earth system curriculum was implemented in fifth grade classrooms of five different schools. The results revealed a significant improvement in students' success: 92% of them learned science from the curriculum (Lambert & Whelan, 2008). IBL was reported to be effective in increasing students' academic achievement and developing positive attitudes toward science and inquiry skills (Taşkoyan, 2008); furthermore, it was showed that IBL contributes to individuals' mental development and working skills as a team and helps the development of reading, writing, and language skills (National Science Foundation, [NSF], 2000).

IBL helps science teachers in teaching science to their students who have the ability to think critically, generate creative solutions to problems, and become scientifically literate by following scientists' methods. In IBL classrooms, teachers' roles vary as diagnostic, motivator, guide, innovator, experimenter, investigator, modeler, advisor, collaborator, and learner (Crawford, 2000). One study about teachers' roles in IBL classrooms mentioned that teachers must encourage students to discuss their views and explore and put forward their ideas by asking questions that lead to critical thinking, and must provide students with enough time to answer (Chin, 2007). Some research, however, has revealed inadequate implementation of inquiry-based instruction. According to these findings, teachers stated that following:

- They were reluctant to use IBL because of their inadequate knowledge (Lederman, 1992).
- They lacked experience of using IBL (Arslan, Ogan Bekiroğlu, Süzük & Gürel, 2014; Kleine, Brown, Harte, Hilson, Malone & Moller, 2002).
- They had beliefs about inquiry as it is appropriate for only bright students.
- There was a discrepancy between science content and their beliefs (Keys & Kang, 2000; Wallace & Kang, 2004; Windschitl, 2002).

Teachers' beliefs about self-efficacy also cannot be ignored alongside negative beliefs and the lack of knowledge about inquiry. Albert Bandura's concept of self-efficacy beliefs has been used to express an individual's judgments. In this context, the examination of teachers' self-efficacy beliefs is important. Studies have indicated that teachers' self-efficacy beliefs affect their performance and motivation (Caprara, Barbaranelli, Steca & Malone, 2006), and only teachers with high self-efficacy can perform IBL (Dawson, Cavanaugh & Ritzhaupt, 2006).

Moreover, it is important for teachers to have a thorough understanding of and develop awareness about the science process skills needed to implement IBL. Students make observations, ask questions, design and conduct experiments, establish a hypothesis, test the hypothesis by making predictions and interpreting the results, and share findings with others. Students' science process skills can be developed by an inquiry approach that allows them to

use these skills. For teachers, having knowledge about science process skills in addition to subject-matter knowledge can better engage their students in active learning practices. Existing literature has also reported that students' gains toward science process skills vary statistically according to the teachers' level of using science process skills (Aydoğdu, 2006).

As indicated earlier, the effect of IBL depends on teachers' knowledge of this method (Abd-El-Khalick & Lederman, 2000). It is usual for teachers to face difficulties while implementing new pedagogical approaches. Studies have indicated that curriculum reform movements are shaped and changed by teachers' understanding and beliefs (Keys & Bryan, 2001); reform movements in education require changes in teachers' beliefs and values (Anderson, 2002), and teachers return to traditional curricula in the absence of professional training (Bybee, 2002 cited by Lawrence, 2003). Researchers have thus regarded it as important to provide professional development and other support to teachers in order to help them implement IBL (Bodzin & Beerer, 2003; McIsaac & Falconer, 2002). In this context, successful professional development training can lead to the following:

- It can help in changing teachers' beliefs and practices (Cohen & Hill, 2000; Garet, Porter, Desimone, Birman & Yoon, 2001).
- It is an important aid for teachers to determine the aims that affect students' behaviors in classrooms and schools (Young, 2001).
- It provides ways to increase students' academic achievement (Falk, 2001 cited by Villegas-Reimers, 2003).
- It helps teachers in creating an investigator class culture and IBL experiences (Supovitz & Turner, 2000).
- It causes positive, strong, and important development in terms of teachers' attitudes and practices (Supovitz, Mayer & Kahle, 2000).
- It provides means for teachers to keep their knowledge and skills up to date (European Union, 2010).
- It provides opportunities for teachers to transform their theoretical knowledge to observable behaviors in their classrooms (Birman, Desimone, Porter & Garet, 2000).

A great deal of research exists about inquiry-based professional development. Results of these researches indicate that professional development training is effective both on teachers' content knowledge (Capps & Crawford, 2013; Lewisa et. al, 2011) and their pedagogical knowledge about the inquiry method (Brand & Moore, 2011; Lotter, Harwood & Bonner, 2007). Despite this large number of studies about inquiry-based professional development, unfortunately, studies examining teachers' beliefs and self-efficacy are limited and the evaluation processes of these studies are unclear. Science process skills are fundamental to inquiry. Therefore, this study, as distinguished from previous studies, included science process skills and formative assessment strategies training in professional development training.

This study aimed to investigate the effect of inquiry-based professional development activities on science teachers' science process skills, beliefs about the inquiry method, and self-efficacy beliefs. The following problems were investigated in the study:

- Is there any significant difference between science teachers' pretest and posttest scores on the tool "Science Process Skills Test"?
- Is there any significant difference between science teachers' pretest and posttest scores on the tool "inquiry-based science teaching self-efficacy scale"?
- Is there any significant difference between science teachers' pretest and posttest scores on the tool "beliefs about inquiry-based teaching scale"?

## METHODS

### a) Research Design

In this study, one group pretest-posttest design which is one of the weak experimental design was used. In this model, measurements of one group were made before and after the treatment. According to this model, if posttests have higher scores than pretests, it is due to the effectiveness of the treatment (Fraenkel and Wallen, 2003). Although this model is weak, it is preferred because this study focuses on a training program. However, to increase the validity of this study, qualitative and quantitative measurements were considered in the data collection process. The experimental process of this research is as follows:

**Table 1.** *Experimental process of the research*

Group	Pretest	Implementation	Posttest
Science teachers	-Science Process Skills Test -The Inquiry-based Science Teaching Self-efficacy Scale -Beliefs about Inquiry-based Science Teaching Scale	Inquiry-based professional development activities	-Science Process Skills Test -The Inquiry-based Science Teaching Self-efficacy Scale -Beliefs about Inquiry-based Science Teaching Scale -Semi-structured Interviews

### b) Participants

Teachers' volunteerism and accessibility was the basis for the determination of participants. Hence, convenience sampling was employed (Fraenkel & Wallen, 2003). Thirty science teachers (17 females and 13 males) from various middle schools in İzmir participated in the study.

Three of the female teachers had 0–5 years of teaching experience, two had 6–10 years, three had 11–15 years, and nine had 16 or more years of professional experience. Three of the male teachers had 0–5 years of experience, two had 6–10 years, and eight had 16 or more years of professional experience.

### c) Data Collection Tools

This study used the tools the “Science Process Skills Test,” the “Inquiry-based Science Teaching Self-efficacy Scale,” “Beliefs about Inquiry-based Teaching Scale,” and semi-structured interviews to collect data.

**Science Process Skills Test:** This test was used to determine changes in teachers' science process skills. The test was developed by Enger and Yager (1998) and was adapted to Turkish by Koray, Köksal, Özdemir, and Presley (2007). It includes 31 multiple-choice questions and its KR-21 reliability coefficient is .81. This study only used 10 questions related to skills (making observations, hypothesizing, predicting, planning and investigating, making scientific communication, and interpretation) in professional development training.

**The Inquiry-based Science Teaching Self-efficacy Scale:** This scale was developed by Smolleck (2008) and was adapted to Turkish by İnaltekin and Akçay (2011). It comprises 69 five-point Likert-type items, and the Cronbach alpha value of the scale is reported as .83.

**The Beliefs about Inquiry-based Teaching Scale:** This scale is used to determine whether a change in teachers' beliefs about inquiry has occurred. It was developed by

Dockers (2010) by examining the existing scales in the literature and was adapted to Turkish by the researcher (Kocagül, 2013). The scale comprises two parts and includes 44 items. In the adaptation process, the scale was applied to 372 preservice science teachers, and validity and reliability studies were performed on the obtained data. As a result of factor analysis, it was noted that while the first part of the scale comprises only one factor called “characteristics of inquiry,” the second part of the scale comprises two factors called “barriers related to method” and “barriers related to teachers’ lack of knowledge.” The Cronbach alpha reliability value was found to be .87 for the first part and .83 for the second part. The Cronbach alpha value for the whole scale was .78.

**Semi-structured interviews:** Interviews were conducted with nine randomly selected teachers after the training in order to determine their views about training and inquiry-based teaching. To provide validity, the study utilized the views of two teaching staff members and three research assistants.

#### **d) Data Analysis**

To analyze the quantitative data, a paired sample t-test was conducted by using the software SPSS-15. The level of significance in this comparison was determined to be .05. In the analysis of qualitative data obtained from semi-structured interviews, the teachers’ statements were recorded with their permission and then transcribed.

#### **e) Application**

The study presupposed that the inquiry method is not as difficult to implement as it is thought but that it can be practiced in classrooms by making small changes in the current lesson plans. For this purpose, five workshops were prepared by utilizing web-search-related professional development and related literature. The first of the workshops illustrated three different approaches that can be used to practice inquiry in classrooms. The second workshop focused on science process skills developed through short-time activities. In the third workshop, teachers experienced an inquiry-based lesson as students. In the fourth workshop, teachers examined the differences between the types of activities in order to determine which one of them is adapted to the inquiry method, and discussed the pedagogical effects of this differentiation. They studied formative assessment strategies in the last workshop. Experts in the field weighed in on the suitability of the workshop activities. These professional development activities were carried out for two days. Although it was not expected that variables such as beliefs and self-efficacy would change in such a short time, two days were preferred for the implementation of workshops. In this training, as it was only aimed that something useful could be done for teachers’ awareness about inquiry-based teaching, any change in teachers’ beliefs and efficacies can be interpreted as a criterion for measuring teachers’ awareness. There were three workshops on the first day and two on the second day. Before the professional development training started, quantitative data collection tools as pretests were applied to teachers. Before each workshop, short presentations were made for teachers about the purpose of the activity, their tasks, and the points they should focus on during the processes. Participants prepared for the next workshop with a 20–25 minute break between each workshop held on the same day. Teachers performed inquiry-based professional development activities in the form of station work based on group work. In station work, the number of groups was determined according to the activity. For example, in the first workshop, teachers were divided into three groups of 10. In the second workshop related to science process skills, teachers were divided into seven groups, each comprising 3–4 teachers. In context of station work, teachers had time to complete the task on their table, and they passed to the next table as the time for the first task ended. After completing the activity,

discussion sessions were organized, wherein the teachers shared their data among themselves and discussed how they could implement this activity into their classrooms and how it contributed to their development as teachers. After completing all of the workshops, quantitative data collection tools as posttests were applied to the teachers again. In addition, semi-structured interviews were conducted with nine teachers selected randomly in order to determine the gains of IBL both for them and their students. These interviews were used for supporting the quantitative data.

## FINDINGS

Table 2 shows the statistical scores of teachers' answers to quantitative data collection tools before and after the training.

**Table 2.** Average Scores of Teachers' Answers Given to Quantitative Data Analyses and Results of *t*-Test

	N	$\bar{X}$	sd	t	p
<b>Science Process Skills Test</b>					
<b>Pretest</b>	30	13,53	1,83		
<b>Posttest</b>	30	15,47	1,68	-5,76	.00*
<b>The Inquiry-based Science Teaching Self-efficacy Scale</b>					
<b>Pretest</b>	30	255,07	12,78		
<b>Posttest</b>	30	273,30	18,04	-5,80	.00*
<b>Beliefs about Inquiry-based Teaching Scale</b>					
<b>Importance Pretest</b>	30	70,87	4,31		
<b>Importance Posttest</b>	30	75,47	3,32	-6,57	.00*
<b>Teaching Pretest</b>	30	64,13	5,67		
<b>Teaching Posttest</b>	30	68,70	7,74	-3,39	.00*
<b>Learning Pretest</b>	30	40,30	10,27		
<b>Learning Posttest</b>	30	38,23	9,67	1,49	.14
<b>Barriers Pretest</b>	30	50,77	6,70		
<b>Barriers Posttest</b>	30	60,33	7,06	-5,76	.00*

\*p < .05 difference is significance.

Teachers who attended training showed significant development in terms of science process skills, self-efficacy toward inquiry-based science teaching, importance given to the inquiry method, inquiry teaching preferences, and perceived barriers about inquiry.

According to Table 2, only the posttest scores of the learning inquiry method decreased. Data obtained from the semi-structured interviews also supported positive gains related to variables. After the science process skills workshop, teachers stated that before the workshop, they had inadequate knowledge about science process skills, and they learned new skills in the workshop. For example, one teacher said the following about science process skills gains:

“I learned the concept of making scientific communication. Until this time, I thought that scientific communication is possible only by verbal way. But now, I learned the importance of scientific communication in inquiry activities and this can be done via graphics, tables and etc.”

Similarly, teachers were aware of their competencies to implement the inquiry method into a classroom and stated that there were positive improvements and changes in their self-efficacy beliefs after the training. The following are sample expressions related to self-efficacy:

“Questions that I asked to plan activities were more restricted before. Because I tried to give information in theory directly. But now, I can let them prove this information themselves.”

“I learned better about how I applied the inquiry method to activities in my lessons.”

“Inquiry method creates changes in terms of teachers. Teachers can provide learning environment to be more interesting and intriguing and so he/she can encourage students to query, investigate, and debate.”

“I have been renewed with this training. This gives energy to me and also I realized my limits and this realization created a break.”

Teachers also stated that their beliefs about the inquiry method as well as their self-efficacy beliefs changed and improved. In this context, the majority of teachers made comparisons between their lessons and an inquiry-based lesson, realized the contributions of the inquiry method to students, and expressed the changes in their ideas. Some sample expressions are as follows:

“I think that inquiry method can encourage students not to be afraid of risks and decide with senses.”

“I think that traditional activities create a more restricted learning environment for students. But students are more free to investigate and make experiments in inquiry activities. For this reason, I think that inquiry activities can lead students to become more responsible in their researches.”

“Inquiry method allows students to query via their own hypothesis instead of accepting information directly and it increases the retention of information.”

“Instructions of activities in our lessons are clear and so students’ working is more restricted and they are not free. I thought that teaching a lesson like this can be more enjoyable and students can be more active.”

“Instructions of activities in my lesson were given clear and they hadn’t been adapted to inquiry. After this training, I realized that I allowed my students to query in a limited way. They didn’t query by their own hypothesis. Now I am aware of inquiry method as a teacher.”

“I saw that it wasn’t as difficult as I thought. I realized that it is required to design activities for each topic. I also realized that I have biases and judgments for inquiry method because of traditional methods that have been used for years. I saw that I get used to simplicity and luxury of traditional methods to teach science. I realized that adapting activities to inquiry requires time so team work is important to achieve this.”

However, it was also seen that some teachers maintained their negative beliefs to inquiry. They said that the following:

“I am very sad not to practice this method in my class. Because crowded classrooms and recklessness of students about science process skills prevent me to use inquiry method in my class”.

Per the results of this study, it can be said that inquiry-based professional development activities positively affect teachers’ skills needed for practicing inquiry and their self-efficacy and beliefs. This may suggest that similar professional development training can bring significant changes to teachers’ ideas about using inquiry in their classrooms.



## DISCUSSION and CONCLUSION

This study was conducted to test the hypothesis that inquiry-based professional development activities affect teachers' science process skills and their self-efficacy and beliefs about inquiry.

The first problem was expressed as, "*Is there any significant difference between science teachers' pretest and posttest scores on the science process skills test?*" The analysis showed a statistically significant increase in teachers' scores. Theoretical instructions about science process skills during the process and teachers' active involvement in the activities may have an effect on this result. This finding is in line with previous reports from researchers that the inquiry method is effective to develop preservice teachers' science process skills (Ateş, 2004) and that professional development training improves teachers' nature of science understandings (Yeşiloğlu, Küçüker, Taşdelen & Köseoğlu., 2012).

The second problem was expressed as, "*Is there any significant difference between science teachers' pretest and posttest scores on the inquiry-based science teaching self-efficacy scale?*" The analysis related to this query showed that there was a significant development in teachers' self-efficacy beliefs. During the training, it was emphasized that practicing inquiry method is not as difficult as it is thought, and it can be practiced by making small changes in activities and use of language. This may have affected teachers' self-efficacy beliefs. This result supports the findings of other studies indicating that introductory workshops about inquiry are effective to develop teachers' self-efficacy beliefs (Eshach, 2003) and that professional development trainings increase teachers' self-efficacy from a low to a high level (Roberts, Henson, Tharp & Moreno, 2001).

The analysis related to the third problem, expressed as "*Is there any significant difference between science teachers' pretest and posttest scores on the beliefs about inquiry-based teaching scale?*" showed that there was a significant development in teachers' scores on the importance attributed to inquiry, their thoughts related to the frequency of using inquiry, and the perceived potential barriers about inquiry. Activities in professional development training might have been effective and resulted in this finding. This training aimed to introduce the inquiry method during the activities. In this context, three different approaches to practice inquiry, adaptation of activities to inquiry by making small changes, and an example of an inquiry-based lesson are included in the training. Teachers' active participation in the activities is believed to have a positive influence on the development of their beliefs. Consistent with the results of other studies, the findings of this study indicate that inquiry-based professional development has a positive effect on teachers' views about inquiry (Capps & Crawford, 2013) and teachers' understanding (Lotter et. al., 2007) and beliefs (Cohen & Mill, 2000; Hubbard & Abell, 2005). The fact that some teachers maintain negative beliefs about inquiry in interviews may be a result of their lack of inquiry experiences in the past. Some studies the literature have reported that teachers' negative beliefs about the inquiry method may stem from their inexperience about this method when they were college students and novice teachers (Akerson & Hanuscin, 2007; Kazempour, 2009).

This two-day training conducted with a group of 30 science teachers. An increase in training time may create differences. It can therefore be said that the preferred method of the current study creates limits on the interpretation of its obtained findings.

Future studies can investigate the extent to which teachers reflect their gains obtained from professional development training to their learning environments and the advantages of this reflection in terms of students and classroom culture.

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## Improving Creative Thinking Skills of Students through Differentiated Science Inquiry Integrated with Mind Map

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### ABSTRACT

In inquiry-based learning, teachers usually only apply one level of inquiry from the four available levels. The diversity of students should be a serious consideration. Differentiated Learning Science Inquiry (DSI) implements the four levels of inquiry. To train students' creative thinking, inquiry can be integrated with mind maps. This research aims to determine the difference in creative thinking skills between male and female students who were given three different science learning models i.e., DSI, DSI integrated with mind map (DSIMM), and the conventional model. This research was a quasi-experimental research, which used a nonequivalent pretest posttest control group design. The samples of the research were 96 students from three classes spreading across three junior high schools in Kediri, Indonesia. The data on students' creative thinking skills were taken from an essay test on science learning assessed using a creative thinking skills rubric. The results of the research showed that there was a difference in students' creative thinking skills for different models. The highest creative thinking skills were exhibited by the students taught using the DSIMM model. The results of the research also showed that there was a difference in creative thinking skills between the male and the female students. The male students had higher creative thinking skills than the female students. This was presumably because in the differences of brain anatomy affecting the students' pattern of learning and activities.

**Keywords:** creative thinking skills, differentiated science inquiry, gender, mind map

### INTRODUCTION

In the 21st century, the improvement of all pathways and levels of education have become the driving issues to prepare the students (Mahanal, Zubaidah, Bahri, & Dinnurriya, 2016). There is a demand for qualified human resources in order to be able to compete globally. Qualified human resources are the outcome of qualified education processes. Qualified education equips students with thinking skills. One of the skills students are predominantly trained in to achieve the objectives of education in the 21st century is creative thinking skills (Moon, 2008).



Boden (2001) stated that creative thinking is the ability to bring new ideas that are surprising and valuable in many ways. Creative thinking is related to novelty, to the ability to create something, to implement new forms, to generate a lot of imaginative skills or to make something that already exists into something new (Greenstein, 2012). Furthermore, Abraham (2016) stated that creative thinking is a form of expressing oneself in a unique way.

Various indicators of creative thinking have been revealed by some experts. According to Treffinger, Young, and Selby (2002) there are five indicators of creative thinking, i.e., (1) fluency, the ability to generate ideas, ways, suggestions, questions, and alternative answers smoothly within a certain time; (2) flexibility, the ability to generate various ideas, answers, or question, where the ideas or answers are obtained from different viewpoints by changing the ways of thinking and the approaches used; (3) originality, the ability to generate phrases, ways, or ideas to solve a problem or make a combination of parts or elements unusually and uniquely that was unthinkable by others; (4) elaboration, the ability to enrich, develop, increase, describe or specify details of the object, idea, product, or situation to make it more interesting; and (5) metaphorical thinking, the ability to use a comparison or analogy to make a new connection.

Students' creative thinking skills which are different from one another require a learning condition involving a learning experience, so that the potential of creative thinking can develop (Yusnaeni, Corebima, Susilo, & Zubaidah, 2017). Creative thinking can be incorporated into learning by teachers, so teachers should be able to carry out the mandate of developing students' creative thinking skills. This is in accordance with the opinions of Wheeler, Bromfield, and Waite (2002), who stated that the teacher's task is to provide the best conditions for students to acquire relevant thinking skills. Creative thinking skills are considered to be very important for students (Baker & Rudd, 2001). Seyihoglu and Kartal (2010) stated that in order to face the challenges of modern life which is dynamic and full of uncertainty, it is necessary to develop creative thinking skills in learning. In fact, these creative thinking skills are the foundation of science (Hadzigeorgiou1, 2012). Thus, creative thinking skills need to be trained through learning, especially in science learning.

Based on the results of a preliminary study in science learning, it was revealed that the creative thinking skills of students in junior high schools in Kediri, Indonesia, were still low. Fuad, Zubaidah, Mahanal, and Suarsini (2015) stated that based on the results of a creative thinking test with the score range 0 -100, the total mean score on the indicators of creative thinking was 18.03. The scores on each indicator of creative thinking also showed low results. The indicators of creative thinking along with the scores obtained were as follows: (1) flexibility (18.75), (2) originality (12.05), (3) elaboration (16.28), and (4) fluency (15.90).

Science teaching in Indonesia mostly focuses on memorizing science concepts (Baskoro, Corebima, Susilo, Zubaidah, & Ramli, 2017). Science learning should put more emphasis on students' activities through inquiry (Harris & Rooks, 2010; Olson & Horsley, 2000; Ozdemir & Isik, 2015; Wyatt, 2005) and provide opportunities for students to develop their creative thinking skills (Davis, Sumara, & Luce-Kaper, 2000). The inquiry learning model is considered to be the most basic and widely used for encouraging creative thinking skills in science learning (Johnson, 2000; Kind & Kind, 2007; Meador, 2003). This was also supported by various researches, which have proven that inquiry learning can train students' creative thinking skills (Michalopoulou, 2014; Nurhadi et al., 2016).

Many sources explain the stages of inquiry learning, one of which is Llewellyn (2011); it mentions the following stages: (1) inquisition, starting with a question to be investigated; (2) acquisition, brainstorming the possible answers; (3) supposition, selecting a statement to be tested; (4) implementation, designing a plan; (5) summation, gathering evidence and drawing conclusions; and (6) Exhibition, sharing and communicating results or findings.

Llwellyn (2013) divides inquiry into four levels. The levels are differentiated by the amount of teacher intervention toward the students or based on the amount of guidance given by teachers to their students. Level 1 is demonstrated inquiry where the role of the teacher is to provide the problems, to plan the procedures, and to analyze the results. Level 2 is structured inquiry where the role of the teachers is to provide the problems and to plan the procedures while the students analyze the results. Level 3 is guided inquiry where the role of the teacher is only to provide the problems, while the students plan the procedures and analyze the results. Level 4 is self-directed inquiry where the students carry out all the activities, from providing the problems to planning procedures, to analyzing the results.

In practice in the classroom, the implementation of one level of inquiry sometimes encountered obstacles because each student in the class was different. Diversity is related to readiness, interest, learning style, and speed in receiving and processing information. In science learning, teachers usually select one type of inquiry model to be applied to all students for a particular topic. In fact, the implementation of one type of inquiry in one class has a disadvantage, which is not accommodating students' development levels. It means that if the teachers applied inquiry level 4, students having low ability would find it difficult to follow the lesson well. Conversely, if the teacher applied inquiry level 1, students having high ability would quickly get bored because it would be too easy for them. Therefore, a learning model that accommodates such diversity is very necessary.

DI (Differentiated Instruction) based-learning, developed by Llwellyn (2011) for science learning, can basically be used to cope with the diversity of students in the classroom. It is based on the reality that teachers usually choose one level of inquiry to be applied to all students for a particular topic. In fact, each level has its own advantages and disadvantages. For this reason, the Differentiated Science Inquiry (DSI) model which applies different types of inquiry according to students' needs, is introduced.

In DSI learning, the class is divided into four major groups based on students' abilities, from lower ability to higher ability. At level 1 (demonstrated inquiry), the teacher provides the problems, planning procedures, and analyzes the results. At level 2 (structured inquiry), the teacher provides problems and planning procedures while analyzing the results is by students. At level 3 (guided inquiry), the teacher provides only problems while the planning procedures and analysis of results are by students. At level 4 (self-directed inquiry), the students conduct all the activities, ranging from providing problems, planning procedures, and analyzing the results (Fuad, Zubaidah, Mahanal, & Suarsini, 2017).

Through the implementation of DSI learning, it is expected that each student will get the same opportunities for development (Llwellyn, 2011). The same opportunities to develop will be achieved if students receive instructions in accordance with the level of their readiness, interests, and learning styles so that it enables them to maximize their ability (Tomlinson, 2001). In DSI learning, the classes are divided into four major groups or posts or stations. This division is based on the level of students' readiness, interests, and learning styles. The learning given to each group represents the level of inquiry.

In addition to inquiry, to train creative thinking skills, mind map-assisted learning needs to be developed (Keles, 2012). In science learning, the mind map has been widely recommended and used in various ways to help teachers and students develop organized knowledge bases on particular topics at the intermediate level (Ritchie & Volkl, 2000). Mind maps can be integrated with other techniques that have the constructivist approach philosophy. This technique relies on images and the relationship with one another through the use of pictures, words, numbers, logic, and color to become a unique way. Mind map is a technique that stimulates the left brain and the right brain and makes visible the process of thinking, gives the big picture and details of something at the same time, makes it easy to

manage and understand the information effectively and systematically, improves the ability to think creatively and innovatively, and improves retention (Buzan, 2002).

A study by Al-Jarf (2009) showed that the mind map was a powerful technique for improving students' abilities to generate, visualize, and organize ideas. The students involved in the study stated that the mind map encouraged their creative thinking, and they could generate and organize ideas for writing faster. Mind map is also a tool that converts tacit knowledge into explicit knowledge. For instance, by reading particular lesson materials, students learn from the book or other resources, and then, constructing a mind map, students convert their tacit knowledge into explicit knowledge in their mind map (Handoko, Nursanti, Harmanto, & Sutriyono, 2016). The mind map can be integrated with a variety of learning models with the aim of encouraging students' abilities to explore the relationships between information and stimulating students to think creatively (Davis et al., 2000). The teachers also believe that the mind map can enhance students' creative thinking (Keles, 2010; Seyihoglu & Kartal, 2010; Weinstein, 2014). In relation to science learning, the mind map is a learning tool that can be used to help students learn science (Steyn & Boer, 1998).

In addition to the diversity of students in terms of readiness, interest, and learning style, diversity can also be in terms of gender. Gender is a general term referring to both male and female (Fin & Isaac, 2012). Gender is a grammatical classification of nouns that generally have two sexes. The word "gender" is derived from the English language; gender means "sex." Gender refers to the psychological and socio-cultural dimensions, male and female. Gender is related to how males and females think, act, and feel (Santrock, 2011).

Various studies related to the correlation between gender and creative thinking skills had different results. Some claimed that gender did not give a significant difference to creative thinking skills (Baer & Kaufman, 2008; Bakir & Oztekin, 2014; Charyton & Snelbecker, 2007; Kaufman, 2006; Potur & Barkul, 2009; Tsai, 2013). A study in Pontianak, Indonesia, revealed that there were no differences in students' creative thinking skills related to gender either for the students taught using problem-solving learning models or students taught using conventional learning (Hodiyanto, 2014). However, some other studies revealed that gender gave a difference in creative thinking skills (Hoff, 2005; Matud, Rodriguez, & Grande, 2007).

Various researches revealing the significance of gender for creative thinking skills are divided into two different groups. One group of researchers states that males are more creative than females (Proudfoot, 2015; Singh, 2014; Stoltzfus, Nibbelink, Vredenburg, & Thyrum, 2011). Another group of researchers reveals the opposite—that females are able to think more creatively than males (Reuter et al., 2005; Wolfradt & Pretz, 2001).

Male students had significantly higher creative thinking skills than female students (He, Wong, Li, & Xu, 2013; Stoltzfus et al., 2011). This difference is because men are more interested in science, engineering, and technology compared with women (Baer, 1997). Another opinion stated that men tended to show more dominance of the area of the brain associated with cognition of semantics and decision-making, while women showed more dominance in language processing and social perception. Furthermore, when they think divergently, the area associated with declarative memory tends to actively work in men. It was also reported that there was no difference in concept understanding between men and women. The difference lies in the problem-solving ability. Males have a better problem-solving ability than females (Gok, 2014). Problem solving is closely related to creative thinking skills.

The physical difference between males and females can be seen in their brain anatomy that affects the patterns of learning and activities of the human brain (Gurian, Stevens, & Patricia, 2010). The male brain tends to grow and to have more complex spatial abilities such as mechanical design, measurement, orientation, abstraction, and the manipulation of physical



objects. The area of the cerebral cortex in males performs more on the spatial functions and tends to give a little portion to produce and process words. The set of nerves that connects the left–right brain or corpus callosum in the male brain is a quarter smaller than that in the female brain. The female brain can use both sides of the brain well; in contrast, the male brain tends to be able to use the right hemisphere of the brain maximally (Hines, 2004). The right brain is involved in imagination and creative thinking.

Based on the opinions and the results of research on creative thinking, it seems that there is a difference in creative thinking skills, which is affected by learning models and gender. Therefore, it is necessary to conduct a research, especially on science subjects, that aims to investigate (1) the differences in the creative thinking skills of students who are given three different science learning models, i.e., the differentiated science inquiry combined with mind map (DSIMM), the differentiated science inquiry (DSI), and the conventional model; (2) the differences in creative thinking skills between male and female students; and (3) the differences in creative thinking skills as a result of the interaction between learning models and gender.

## METHODS

### a) General Background of Research

This research was a quasi-experimental research, which used a pretest–posttest nonequivalent control group design. The independent variables of this research were the learning models (DSI, DSIMM, and conventional) and gender (male and female), while the dependent variables were students' creative thinking skills. The design of this quasi-experimental research is presented in Table 1.

**Table 1.** *Quasi-experimental research design*

Pretest	Group	Posttest
O <sub>1</sub>	X <sub>1</sub> G <sub>1</sub>	O <sub>2</sub>
O <sub>1</sub>	X <sub>1</sub> G <sub>2</sub>	O <sub>2</sub>
O <sub>1</sub>	X <sub>2</sub> G <sub>1</sub>	O <sub>2</sub>
O <sub>1</sub>	X <sub>2</sub> G <sub>2</sub>	O <sub>2</sub>
O <sub>1</sub>	C G <sub>1</sub>	O <sub>2</sub>
O <sub>1</sub>	C G <sub>2</sub>	O <sub>2</sub>

X<sub>1</sub> = DSIMM model, X<sub>2</sub> = DSI model, G<sub>1</sub> = Male, G<sub>2</sub> = Female, C = Conventional, O<sub>1</sub> = Pretest scores, O<sub>2</sub> = Posttest scores.

### b) Sample of Research

The population used in this research was all 7<sup>th</sup> grade students of junior high schools (JHS) in Kediri, Indonesia. The population spread across 51 schools. Three schools were randomly selected as the sample. An equality test was conducted on the chosen schools. Three research classes were randomly selected from the equal classes. The selected samples were students of JHS 2 Puncu, who were the control group and were treated using the conventional model. The experimental groups were the students of JHS 1 Ngadiluwih, treated using the DSI model, and the students of JHS 1 Papar, treated using the DSIMM model. Each class was assigned 32 students so that the total number of the research's samples was 96 students (Nfemale = 48; Nmale = 48). In each treatment class, the students were divided into eight groups based on the sequence of the pretest scores, from the lowest to the highest. Each group consisted of four students. The two lowest groups were given structured inquiry worksheets. The two highest groups were given self-directed inquiry worksheets, and the middle four groups were given guided inquiry worksheets.

Learning in a conventional class uses methods that are generally applied by teachers in Kediri, Indonesia. The methods are lectures, discussions, question and answer, and doing the student's worksheets. In the DSI class, learning is done by applying the DSI model with syntax inquisition, acquisition, supposition, implementation, summation, and exhibition. The class is divided into three major groups according to the students' abilities. In each group, only one level of inquiry is applied. The higher the students' abilities, the higher the level applied. Learning in the DSIMM class, in principle, is the same as in the DSI class. The difference is that in each syntax inquiry, the mind map technique is inserted. Thus, at the end of each learning activity, students present the topic that has been studied using a mind map that has been developed.

The subject in this study was science. The teaching material applied in the study covers the following: observing objects, microscope, laboratory safety, characteristics of living things, and the classification of living things.

### *c) Instruments and Procedures*

Instruments used in this learning activity included the syllabus, lesson plans, student worksheets, and test items. The instruments had been previously validated by two experts/science education experts and two education practitioners (science teachers). The validation was done by giving scores to each component on the validation sheet with the score range of 1–4. A score of 1 indicated “not valid,” 2 indicated “less valid,” 3 indicated “valid,” and 4 indicated “very valid.” The data analysis of the validation results was done by calculating the average scores from the experts and practitioners. The results of the validation showed the following scores: 3.72 (valid) for the syllabus, 3.67 (valid) for the lesson plan, 3.70 (valid) for the students' worksheet, and 3.95 (very valid) for the test items.

Reliability test was also performed for the essay test instrument for creative thinking skills. The reliability test involved 96 students who were asked to finish 12 questions that had previously been validated. The score of the 96 students was then tested using Cronbach's alpha with Statistical Package for the Social Sciences (SPSS) 23.0 for Windows. The reliability test showed that the score was 0.986 (very high reliability, acceptable).

The test instruments of creative thinking skills that were valid and reliable were used for collecting data on creative thinking skills. Data collection was done twice, pretest and posttest, on all three learning models. The scoring rubric was modified from Treffinger et al. (2002), with a range of 0–4. The scoring rubric was developed from each indicator of creative thinking skills. The scoring rubric of creative thinking skills is presented in Table 2. Data were analyzed using multiple regression to test the correlation between predictor and criterion using SPSS 23.0 for Windows.

This modified assessment was used to test students' creative thinking skills using an essay test. The format of the assessment was arranged based on many considerations, including the form of test often used by educators in Indonesia.

**Table 2.** *Scoring rubric of creative thinking skills*

Indicator	Criteria	Score
Fluency	Mentioning/writing five or more ideas, suggestions or different alternative answers	4
	Mentioning/writing three ideas, suggestions or different alternative answers	3
	Mentioning/writing some ideas, suggestions or alternative answers that are not very different	2
	Mentioning/writing one idea, suggestion, or alternative answer	1
	Not answering or giving a wrong answer	0
Originality	Mentioning/writing several interesting unique ideas that are logical, relatively new and relevant to the given problem	4
	Mentioning/writing several interesting unique ideas that are logical, relatively new, but not quite relevant to the given problem	3
	Mentioning/writing quite interesting unique ideas that are quite logical, relatively new and quite relevant to the given problem	2
	Mentioning/writing an ordinary idea that is logical and relevant to the given problem	1
	Not answering or giving a wrong answer	0
Elaboration	Explaining several logical details of an existing idea, so that the formulation of the idea becomes clearer and can be applied more easily	4
	Explaining one logical detail of an existing idea, so that the formulation of the idea becomes clearer and can be applied more easily	3
	Giving several logical details of an existing idea, but not quite relevant with the concept of the main idea, so that not making the idea becomes clearer	2
	Not adding any details of an existing idea, so that the formulation of the idea cannot be applied well	1
	Not answering or giving a wrong answer	0
Flexibility	Writing several alternative answers that are very logical and relevant to the given problem from different points of view	4
	Writing a few alternative answers that are quite logical and relevant to the given problem from different points of view	3
	Writing several alternative answers that are quite logical but less relevant to the given problem from different points of view	2
	Writing one alternative answer that is quite logical and relevant to the given problem with only one point of view	1
	Not answering or giving a wrong answer	0
Metaphorical thinking	Combining several ideas, modifying, and explaining the formulation of the ideas using a logical and coherent analogy	4
	Combining several ideas, modifying, but less able to explain the formulation of ideas using a logical and coherent analogy	3
	Combining several relevant ideas but not explaining the formulation of ideas using a logical analogy	2
	Less able to combine relevant ideas so that they become coherent as a whole	1
	Not answering or giving a wrong answer	0

Modified from Treffinger et al. (2002).

#### *d) Data Analysis*

The pretest and posttest scores of creative thinking were converted into a range of 0–100. Then, normality and homogeneity tests were performed on the data. Hypothesis testing was done on the condition that data distribution was normal and homogeneous. Analysis of covariate (ANCOVA) was performed to analyze (1) the differences in creative thinking skills between students taught using three different learning models: DSI, DSIMM, and the conventional model; (2) the differences in creative thinking skills between males and females; and (3) the differences in creative thinking skills as a result of the interaction between the learning models and gender. If there was a difference, a post hoc least significant difference (LSD) test was conducted to determine whether there was a statistically significant mean difference.

## RESULTS OF RESEARCH

The data obtained from the creative thinking skill test were analyzed using SPSS 23.0 for Windows. The analysis was preceded by a normality test using one-sample Kolmogorov–Smirnov test and a homogeneity test using Levene’s test of equality of error variances. The summary of the normality and homogeneity can be seen in Table 3.

**Table 3.** Summary of normality and homogeneity tests

Data group	Normality		Homogeneity	
	N	Sig.	Levene’s test	Sig.
Pretest of creative thinking	96	0.524	1.803	0.120
Posttest of creative thinking	96	0.430	1.480	0.204

Table 3 shows that the data have normal distribution and the data group has homogeneous variants (sig of normality and homogeneity > 0.05). Based on these prerequisite tests, the data can be further analyzed using ANCOVA. The results of the ANCOVA analysis regarding creative thinking skills based on the learning models and gender are shown in Table 4.

**Table 4.** Summary of ANCOVA test results

Source	df	Mean square	F	Sig.
Pretest creative thinking	1	1527.675	87.008	0.000
Learning models	2	1237.577	70.486	0.000
Gender	1	83.314	4.745	0.032
Learning models * Gender	2	2.706	0.154	0.857
Error	89	17.558		
Total	96			
Corrected total	95			

The results of the ANCOVA test on the learning models as shown in Table 4 found that the value of  $F = 70.486$  with a significance value of 0.000 ( $p < 0.05$ ). It means that there was a difference in the creative thinking skills among the students treated with the three different learning models. Furthermore, to determine whether there was a statistically significant difference, a post hoc analysis using LSD was conducted for the learning models. The results of the LSD test for the learning models are presented in Table 5.

**Table 5.** The results of the LSD test based on learning models

Learning model	Pretest	Posttest	Difference	Corrected	Notation
Conventional	24.94	67.06	42.12	66.19	a
DSI	22.53	75.33	52.80	75.85	b
DSIMM	22.85	77.66	54.80	77.99	c

The results of the LSD test in Table 5 show that there was a difference in the mean score of creative thinking skills based on the learning models. Based on the notation, the students taught using DSIMM achieved the highest score for creative thinking skills, and it was significantly different from the other groups. The students taught using the DSI learning model achieved a higher creative thinking skills score that was significantly different from the students taught using the conventional model. The students taught using the conventional

model achieved the lowest creative thinking skills score, and this was significantly different from the other groups.

Based on the results of the ANCOVA based on gender as shown in Table 4, the value of  $F = 4.745$  with a significance value of  $0.000$  ( $p < 0.05$ ). It means that  $H_0$  was rejected and  $H_a$  was accepted. Thus, there was a difference in the creative thinking skills between male students and female students. Furthermore, to determine whether there was a statistically significant difference, the LSD was performed for gender. The results of the LSD test related to gender are presented in Table 6.

**Table 6.** *The comparison of mean score of creative thinking skills in terms of gender*

Gender	Pretest	Posttest	Difference	Corrected	Notation
Female	24.05	72.76	48.72	72.41	a
Male	22.83	73.93	51.10	74.28	b

The results of the LSD test in Table 6 show that there was a significant difference in the mean score of creative thinking skills between male students and female students. The male students achieved a higher creative thinking skills score than the female students, and it was significantly different.

The results of the ANCOVA test on the interaction between the learning models and gender, as presented in Table 3, found that the value of  $F = 0.154$  with a significance value of  $0.857$  ( $p \geq 0.05$ ). It means that  $H_0$  was accepted and  $H_a$  was rejected. Thus, there was no difference in students' creative thinking skills as a result of the interaction between the learning models and gender.

## DISCUSSION

The results of the research revealed that there was a score difference in creative thinking skills for different learning models. The students taught using DSI achieved higher creative thinking skills than those taught using the conventional model, and the students taught using the DSIMM model achieved the highest creative skills of all the learning models. The results of this research are in line with previous research findings, proving that the implementation of the inquiry model and the use of mind mapping in learning improved creative thinking skills (Al-Jarf, 2009; Keles, 2010; Michalopoulou, 2014; Seyihoglu & Kartal, 2010; Weinstein, 2014).

The inquiry learning model implemented in this research class was proven to significantly contribute to the improvement of the creative thinking skill score. The results of this research, which are consistent with the research by Michalopoulou (2014), revealed that through inquiry students can express their ideas and feelings in various ways and can have fun learning. The opportunity to express ideas in a variety of ways and fun learning conditions are the basis for the development of five aspects of students' creative thinking skills, i.e., (1) fluency, (2) flexibility, (3) originality, (4) elaboration, and (5) metaphorical thinking.

Llewellyn (2013) also recommended implementing inquiry learning so that students are actively involved in the process of exploring and empowering their thinking ability. Through inquiry, students have many opportunities to generate and discuss ideas, make plans, brainstorm, find solutions, give arguments, satisfy curiosity, and develop creativity (Michalopoulou, 2008). This is in contrast to conventional learning where students tended to learn individually and were more passive in receiving information from the teacher or just working on the students' worksheet (Listiana, Susilo, Suwono, & Suarsini, 2016).

Conventional teaching is concerned with the teacher being the controller of the learning environment (Aktamis, Higde, & Ozden, 2016). This was what caused the students' creative thinking skills in the conventional class to be low.

The contribution of the inquiry learning model toward the improvement of students' creative thinking skills was also through the syntax of inquiry learning, which is in line with the nature of empowerment of creative thinking skills. Michalopoulou (2014) stated that the investigation activities formed the basis of inquiry learning. The investigation involves efforts by the students, either individually or in groups, to find the answers to the questions or problems with or without guidance from the teachers. The activities of collecting information; exploring the surroundings; observing forms, colors, movements, natural phenomena, and events; comparing; recognizing nature; listening; testing samples; smelling; touching; conducting experiments to test ideas, hypotheses, and questions that arise during hands-on activities; and having group discussions will encourage students' creative expression and affect their competence of creative problem solving (Christidou, 2008). In addition, learning inquiry that is properly implemented can make students active in the classroom, provide opportunities for students to learn the material through the exploration of questions and by learning how to develop hypotheses, help students learn in an enjoyable manner, help them obtain depth regarding the concept of a material, and help them use higher order thinking, including creative thinking (Lane, 2007).

The subjects of this research were junior high school students whose age ranged from 12 to 15 years. According to the level of cognitive development by Piaget, students were at the formal operational stage; at this stage, students are able to think abstractly and logically and can analyze in combination and give some possible solutions to problems (Cook & Cook, 2005; Slavin, 2006). However, students' abilities to think logically and abstractly differed in speed. The ease for the students to access the curriculum should be appropriate for the students' abilities in the class of DSI contributed to these capabilities. Students having low skill were given more assistance with the worksheet. This assistance will be reduced in line with the higher ability of students. DSI learning allowed the students to develop and maximize their ability because all students were given easy access to the classroom curriculum that suited their needs.

The inquiry model is suitable for learning science in junior high school. A similar thing also occurred in this research. This was because science learning was related to ways of finding out nature systematically. Thus, science is not only about the mastery of knowledge in the form of a collection of facts, concepts, or principles but also about the process of discovery. Science education is expected to become a tool for students to learn about themselves and their environment as well as learn about prospects for further development for applying it in their daily lives. This reality is supported by the opinions of Minstrell and Zee (2000), who stated that inquiry learning is the basis for learning science because it provides students the opportunity to apply science as scientists do.

The combination of inquiry and mind map in learning science contributed highly to improving creative thinking skills. This was because integrating a mind map at each stage of inquiry would facilitate the students in managing and understanding information effectively and systematically. The ability to manage and understand information is key to achieving the five aspects of creative thinking.

Mind map is an ideal technique to train creative thinking skills. This is because mind map utilizes all the skills commonly associated with thinking, especially imagination, linking ideas, and flexibility. Based on these assumptions, learning using mind map is expected to map the students' minds and provoke their thinking in all directions and bring brilliant and creative ideas (Buzan, 2012). Long & Carlson (2011) suggested that the use of mind mapping helped students make connections between previous material information and the material

being studied. Wheeldon (2011) also revealed that respondents who used mind mapping could remember, organize, and frame the reflection of their past experience.

The implementation of mind map in this research was consistent with previous research by Keles (2010), Seyihoglu and Kartal (2010), and Weinstein (2014). The research by Al-Jarf (2009) proved that mind map was a powerful approach to improve students' abilities to generate, visualize, and organize ideas. The students involved in his research stated that mind maps encouraged creative thinking, and they became faster in generating and organizing ideas for writing. The ability to generate and organize ideas is an important part of creative thinking (Treffinger et al., 2002). It is supported by Zip and Maher (2013), who said that the use of different colors and patterns of lines in mind maps is an effective means for students to express themselves creatively.

In addition to the learning models, gender differences also contributed to the differences in students' creative thinking skills. The results of this research indicate that there is a difference in creative thinking skills between male and female students. Thus, the results of this research support the previous research that stated that there was a difference in creative thinking skills in terms of gender (He & Wong, 2011; Hoff, 2005; Matud et al., 2007). However, these results are not in line with the previous studies that stated that gender did not give a significant difference to creative thinking skills (Baer & Kaufman, 2008; Bakir & Oztekin, 2014; Charyton & Snelbecker, 2007; Kaufman, 2006; Potur & Barkul, 2009; Tsai, 2013).

This research revealed that male students had significantly higher creative thinking skills compared with female students. These results are consistent with previous researches (Proudfoot, 2015; Singh, 2014; Stoltzfus et al., 2011). However, these are different from the other studies (Reuter et al., 2005; Wolfradt & Pretz, 2001).

Differences in creative thinking skills in science learning are because males are more interested in science than females (Baer, 1997). In addition, males have a better ability to solve problems and making decisions compared with females (Gok, 2014), which is also a reason why males are more creative than females.

Gurian et al. (2010) stated that the differences between males and females can be seen from the differences in their brain anatomy. The differences in brain anatomy affect students in determining their learning patterns and activities. The parts of the brain that are responsible for the ability of abstraction as parts of creative thinking are also more developed in males rather than in females. In addition, males are able to maximize the right brain that plays a role in the creative thinking ability (Hines, 2004).

Although there was a difference in students' creative thinking skills for the different learning models and gender, the interaction between the learning models and gender did not indicate any difference in creative thinking skills. It means that for each class taught using a specific learning model, between males and females no significant difference in creative thinking skills was shown.

Based on the results of this research, the researcher recommends implementing DSIMM, especially for the science subject, to train students' creative thinking skills. This creative thinking skill needs to be trained because it is one of the key skills required in the 21<sup>st</sup> century. In fact, students' creative thinking skills need to be trained through learning from an early age.

## CONCLUSIONS

The results of this research support the theory and the previous research that state that there is a difference in creative thinking skills between learning models and gender. The students who received DSIMM learning had the highest creative thinking skill. Overall, male

students are more creative than female students. These differences can be observed from the anatomy of the brain that affects the learning patterns and activities of the human brain. In males, the brain tends to grow and have more complex spatial. Males also tend to be able to maximally use the right hemisphere that plays a role in imagination and creative thinking.

This research was limited to the subject of science in junior high school. The research may be continued on the subject of science or other subjects at the elementary school or senior high school level. Future research can also focus on other thinking skills, such as problem solving and metacognition, among others.

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## Improving Secondary School Students' Scientific Literacy Ability Through The Design Of Better Science Textbooks

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### ABSTRACT

This study assessed ways by which science textbooks can be designed and developed to increase scientific literacy in secondary school students. . Here inThe research and development method was used. The draft of the new science textbooks was incorporated into school instruction using a non-equivalent control group design with pretest and posttest measures. The instruments used comprised a test of textbook quality test, a text's main idea readability test, and a scientific literacy ability test. Data on text's main idea's readability and textbook quality tests were analyzed qualitatively; an increase in scientific literacy was determined by the percentages of average normalized gains, Cohen's d and t-test. The results reveal that the science textbooks developed in from the research have medium to high readability for of their main ideas, appropriate quality to be used as students' handbooks or books accompanying teaching and learning, and can significantly increase scientific literacy.

**Keywords:** Scientific literacy, science textbook, design textbook of science, secondary school students, better science textbooks.

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### INTRODUCTION

One of the method by which to improve the quality of education in Indonesia is to improve the curriculum; however, education management of education in Indonesia faces many obstacles. In science, student achievements are assessed by two-large scale international surveys, namely the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA). In general, TIMSS aims to assess "what students know", while PISA attempts to find "what students can do with their knowledge."

The results of a PISA study indicated that the average scientific literacy score for Indonesian students was far below the international average, which shows that the scientific literacy in Indonesian students is still very low. According to the Kemendikbud. (2013), this low level of scientific literacy is caused, partly, by some of the PISA's testing materials which were not included in the Indonesian science curriculum, but also by the unavailability of science textbooks that meet the demands of the curriculum and the competency standards



for graduates. Not every change in the Indonesian curriculum has been accompanied by textbooks that are appropriate to for the new demands. More specifically, according to the Balitbang Depdikbud (2011), the low achievement levels of Indonesian students indicate that science teaching and learning in Indonesia has not emphasized scientific applications to the real world.

The large number of students who do not possess the basic skills in science is an important indicator of the quality of education. According to the Organisation for Economic Co-operation and Development (OECD, 2006), students who reach level one have limited scientific knowledge, which they apply only in certain familiar situations; they are also able to clearly and explicitly provide scientific explanations only according to the proof given. Students below level one are not able to display their basic scientific competencies in specific situations such as required by PISA in its easiest testing tasks. This lack of skills can inhibit a student's full participation in society and in the economy. High-quality science education is important not only for preparing students to pursue a career in the science fields, but also to contribute to preparing a population of citizens who are literate in science and who can "face current global challenges" (Wieman, 2007). In this regard, science education helps realize the students' potentials and contributes to the development of a nation's human resources (Reddy, 2006).

Science textbooks have great impacts on science education in schools. One of the goals of science education in the school is to prepare individuals for lifelong science education in the real world, therefore, it is important to study to what extent science textbooks are designed to meet that goal. Textbooks are an important resource in the teaching and learning process; therefore, efforts should be made to ensure that high quality science textbooks will be selected and recommended to schools. A high quality textbook is regarded as the main tool in promoting the education of a nation and its national development. Science teachers depend to great extent on existing textbooks. If the books do not have components of scientific literacy, such as investigative protocol, it is possible that the students will have inadequate information about scientific methods (Yager as cited in Chiappetta et al., 1991). Designing a textbook to increase scientific literacy does not only promote an understanding of scientific phenomena and concepts (Lemke, 2004), but also the ability to create collective interpretation using visual representations, mathematical connections, manual operations or techniques, and verbal concepts.

Basically, science textbooks help teachers to provide the organizational structure of the subject or lesson. Textbooks also provide various resources for the collection of additional information and the formation of clearer concepts. In addition, they help train students and develop the necessary science skills. Another benefit of textbooks is that they help reduce the problems associated with the students' lack of background information. Thus, one or more textbooks can be selected for teaching science, as long as they can provide added values (Lump & Beck, 1996). There are specific requirements for selecting learning resources. Ehindero (1994) stated that it is a teacher's responsibility to ensure that learning resources are in accordance with the goals of the curriculum and hence can help meet program goals; are selected to suit the more specific classroom learning regulations; are in accordance with the various intellectual abilities of students so that the learning resources encourage and motivate students to participate directly or indirectly; and are directed to help transfer and implement the appropriate teaching and learning in a new situation, increasing social interaction, and encouraging the skills and attitudes of problem solving.

Science textbooks are the key to developing scientific ideas and clarifying scientific concepts in the early stages of teaching and learning. They are the main source used by science educators worldwide to guide them in their teaching of the content and skills dictated by the curriculum. When teachers use textbooks as their guide for the curriculum and resource

for preparation their class syllabus, the quality of these textbooks has a great impact on the quality of their teaching (Lemmer et al., 2008; Newton & Newton, 2006; Ogan-Bekiroglu, 2007; Reys & Reys, 2006; and Brandt, 2005).

Within the education system, the issue of textbooks and instructional materials has become the subject of attention. For centuries, textbooks have been the key component in producing quality education. Ideally, they serve as a good complement for teachers and students to inquire. Where education, and ultimately the availability of teacher training, is very limited by resources, textbooks and instructional materials can play a very important role (United Nations Educational, Scientific and Cultural Organisation [UNESCO], 2003). Science textbooks are extremely important to both teachers and students, but studies are limited on how to create science textbooks for secondary school students that can empirically increase their scientific literacy. The majority of research reports reviewed or analyzed only the quality of textbooks already used in schools using specific indicators, such as those by Wang. (1998), American Association for the Advancement of Science (AAAS, 2006), and Idrees et al. (2014). The analysis of textbook quality in terms of the written language used has been largely conducted by Bazerman (1988), Halliday (1996), Lemke (1993), and Myers (1990a). There has also been research that analyzed the visuals in textbooks (Jacobi & Schiele, 1989; La Follette, 1990; Myers, 1990b; Veel, 1998; and Dimopoulos et al., 2003). In an attempt to increase scientific literacy, research has been conducted on the use of a specific learning model or method, such as problem-based learning (Ahtee & Varjola, 1998; Alsop, 2001; Lundeberg & Yadav, 2006), inquiry-based learning (Bryant, 2006; Campbell, 2006; Rudd et al. 2001), history-centred learning (Brown, 1991), and narrative-centered learning (Bezzi, 1999). Very little information available on the results of studies conducted on the efforts to increase scientific literacy in secondary school students using instructional materials in the form of science textbooks.

### **Purpose**

Thus, the aims of our study were to develop science textbooks for secondary school students that can accommodate the demands of the curriculum and the competency standards for graduates, and effectively increase the students' scientific literacy. The question identified for the study were as follows: 1) How is can we improve the readability of science textbooks ? 2). Has the scientific literacy of students who used the new science textbooks increased compared to those using the standard science textbooks? and 3) Is there any significant difference in increased scientific literacy between of the students using the science textbooks developed in this research and those using the standard science textbooks ?. This article contributes to the development of science by expanding the general model of the writing process proposed by Hayes and Nash (1996) and commonly used as a guide in writing a free essay on learning English. The method was developed into a model for the process of writing teaching materials for science learning.

## **METHODS**

### **a) Research Design**

We adopted the research and development method, for our study and implemented the following stages: preliminary research and information collection, planning, preliminary product development, preliminary testing, preliminary revisions, field testing, product revisions, field testing, final revision, and dissemination and implementation (Borg & Gall, 2010); however, the research and development was conducted up to only the field testing and product revisions atages. Two prototypes of science textbooks were developed in this research, namely for the secondary school students, in the eighth and ninth grades. This was done to test whether the draft science textbooks produced using the model for the process of

writing teaching materials have had the same tendency to increase the scientific literacy of the audience, regardless of the domain and level of students.

### **b) Procedure**

We developed the science textbooks using the model for the process of writing teaching materials (Sinaga et al., 2014). The steps in writing the textbooks were as follows: 1) Analyzing the secondary school science curriculum: core competencies, basic competencies, and graduates' competency standards in accordance with each level; 2) Formulating writing goals containing the statements of what competencies should be acquired by audiences after learning or reading the teaching materials, such as competency in scientific literacy and the knowledge that builds scientific literacy. Writing goals were elaborated using a series of indicators; 3) Selecting and sorting materials or contents that would be internally suitable and so that their breadth would be in accordance with the demands of the curriculum; 4) Outlining the sequence of discussions in the science textbooks; 5) Creating concept maps; 6) Revising the outlines; 7) Representing the concepts covered in the outlines and translating them so that each concept was created in multiple representations; 8) Translating outlines into writing by combining the verbal and visual representations so that the writing became cohesive; 9) Testing the quality of the science textbooks using stakeholders, namely teachers and a team of experts; 10) Testing the understandability or readability using secondary school students; 11) Using the results of the quality and readability tests to revise the drafts of the science textbooks; 12) Field testing by implementing the instructional materials in the schools' teaching and learning method. The field tests were conducted to identify whether there was a significant difference in scientific literacy between the students using the new science textbooks developed in the research and those using the standard textbooks.

The drafts of the new science textbooks were then evaluated by experts and secondary school teachers to gain feedback relating to following: a) the appropriate relationship between curriculum demands and goals and the contents of the science textbooks; b) the quality of the science textbooks as rated by the secondary school teachers; and c) the quality of science textbooks according to the experts. Twenty four ninth- grade and 10 eighth- grade secondary school teachers were recruited, and four experts were selected to provide assessments. In addition, the science textbooks were tested for their readability by the secondary school students. The feedback was then analyzed and used to determine the appropriateness of the science textbooks as teaching materials and to provide references for revising the drafts.

We used the quasi-experimental research method to field test the science textbooks at the schools because the researchers did not have the capability to randomly determine the number of participants and/or to ensure that the selected sample was homogeneous as was desired. In addition, the researchers were limited in their ability to fully control all research variables and implications for the treatment of the groups studied (Leedy & Ormrod, 2010).

This particular research design involved two eighth and ninth-grade classes that were divided into the experimental group and control group, respectively, using the nonequivalent control group design with pretest and posttest measures (Cohen et al., 2007). Teaching and learning activities in both the control and experimental classes were conducted using the same instructional method, namely the reading to learn method. The experimental class used the draft science textbook developed in this research, while the control class used the standard textbooks. Teaching and learning activities using the draft of the new science textbook in both the eighth and ninth grade classes was conducted in three meetings. The activities performed during the three meetings were the pretest, implementation treatment, and posttest at the final meeting. One chapter was taken from the science textbook drafts to be used to test teaching and learning success. For the ninth- grade class, a chapter from the science textbook on electrical energy and its uses was used; for the eighth- grade class, a chapter on the adaptation

of organisms to the impacts of the earth and moon's rotational movements and revolutions around the sun was used. Both chapters were chosen because they were so closely related to the life of the students and the environment. For example electrical energy is limited in Indonesia much so that it is not available to all those who live there. It is important to learn how to save energy, and how to use nature for renewable energy resources. It is also important that students understand the current problem in the environment and how to resolve them.

#### **c) Sample**

The study sample was purposively, determined without stratification; samples were selected based on specific goals (Arikunto, 2013). The subjects comprised 129 eighth and ninth grade students from the 2015/2016 academic year in a junior secondary school in Bandung. There were 64 ninth graders, who were divided evenly into the experimental and 65 eighth graders who also divided into the experimental and control groups, with 33 and 32 in each, respectively.

#### **d) Instrument**

The instrument by which to measure any increase in scientific literacy was designed by adapting and matching PISA's Test of Scientific Literacy Skill (TOLS)) (OECD,2013). The TOLS instrument for the ninth graders consisted of 35 multiple choice questions with four options per question. The validity of the instrument was evaluated using Pearson product-moment correlation, and its reliability was evaluated using Kuder-Richardson KR-21 (Arikunto, 2013). The correlation coefficient of each item was between 0.4 and 0.53, and its reliability coefficient was quite high, at 0.81. Meanwhile, the TOLS instrument for the eighth grade class comprised 25 multiple choice questions with four options for each question. The correlation coefficient of each item was within the range of 0.4 – 0.63, and its reliability coefficient was quite high, at 0.87.

#### **e) Data Analysis**

The data were analyzed by determining the percentages of average normalized gains and interpreted according to Hake's criteria (1998), while the difference between treatments was analyzed by determining Cohen's *d* (Coe , 2000) and a parametric test using the independent sample *t*-test aided by SPSS 23.

The analysis of the readability/understandability of a paragraph's main idea adapted the scoring rubric of the Georgia Department of Education (2004). and was interpreted using the classifications of readability categories by Rankin and Culhane, where an average  $\leq 40.0\%$  is considered low (difficult), an average between 40.0% and 60.0% considered moderate, and an average  $\geq 60.0\%$  under the high..

## **FINDINGS**

#### **a). Readability of the main idea of a paragraph in the new science textbooks**

The draft of the ninth- grade science textbook was tested onto 36 students. An average of 61.0% was obtained from the readability test of the main idea in one paragraph. The draft of the eighth- grade science textbook was tested on 72 students. An averaged of 73% and the average readability score of the main idea of a paragraph was 73.0% was obtained from the readability test of the main idea of one paragraph. These values indicate that the readability levels of the new science textbooks for both the eighth and ninth- grades, were in the high category. Based on the results of this readability test, the paragraphs in the science textbooks for the eighth and ninth grades were classified as readable.



### b). Scientific literacy increased in secondary school students

In both the experimental and control classes, was analyzed based on the pretest and posttest data by determining the percentages of average normalized gains, as shown in Table 1. From the analysis, we found that students from both the experimental and control groups experienced an increase in their scientific literacy, and the increase was categorized as medium.

**Table 1.** *Increased scientific literacy in the eighth- grade students*

	<pretest>	<posttest>	<g>
Experimental	47.51	76.12	0.55
Control	46	66.37	0.38

Based on PISA's framework, scientific literacy consists of the competencies and knowledge that build it. The domain of scientific literacy competencies includes explaining phenomena scientifically, designing and evaluating experiments, and interpreting data and scientific evidence. The knowledge domain that builds scientific literacy comprises content knowledge, procedural knowledge, and epistemic knowledge. The increase in each of these aspects in the students using the developed science textbooks is displayed in Table 2.

**Table 2.** *Eighth-grade students' Increased Scientific Literacy in each domain*

Scientific literacy domain	<pretest>	<posttest>	<g>
Explaining scientific phenomena	45.99	75.26	54.19
Evaluating and designing research	47.47	79.80	61.54
Interpreting scientific data and evidence	52.12	76.97	51.90
Content knowledge	45.83	76.52	56.65
Procedural knowledge	44.16	70.44	47.03
Epistemic knowledge	48.48	71.52	44.72

Based on the analysis results displayed in Table 2, we found that the new science textbooks developed for the eighth grade moderately increased scientific literacy in the six domains.

### c). The Impacts of different treatments on the eighth-grade students' increased scientific literacy

Based on the percentages of normalized gains shown in Table 1, both the experimental and control groups experienced a moderate increase in scientific literacy. To determine whether there was a difference in this increase between students using the new science textbook and those using the standard textbook, Cohen's *d* and *t*-test were conducted. The results are presented in Table 3.

**Table 3.** *Effects of using the new sciencetextbook*

Mexp	Mcont	STDEV exp	STDEV cont	Cohen's d
28.1	20.37	9.08	12.85	0.69

The data analyses demonstrated that the using the new science textbooks had positive impact on the scientific literacy of the eighth- grade students. This impact was within the medium effect range compared to that of those who used the standard textbook.

### d). Analysis of independent sample *t*-test

We used the Shapiro-Wilk test for gain normality at the level of  $\alpha = 0.05$ . The significance values of the experimental and control groups were 0.163 and 0.597,

respectively, meaning that the gain in both classes was normally distributed. We used the Levine statistic at  $\alpha = 0.05$ , for the homogeneity test for the increase in the scientific literacy. The significance value was 0.498; therefore. The data on the two classes were homogeneous.

We used the independent sample  $t$ -test at  $\alpha = 0.05$ , to test difference in the results showing that  $t = 3.388$  with  $Df = 62$  and sig. (two-tailed) = 0.001. It can be inferred from this that there was a significant difference in the increased scientific literacy between experimental and control groups.

#### e). The increased scientific literacy of the ninth -grade students

The increased scientific literacy from the pretest to the posttest was determined by calculating the percentages of average normalized gains. These are displayed in Table 4.

**Table 4.** Increased scientific literacy of the ninth-grade students

	<pretest>	<posttest>	<g>
Experimental	31.01	57.48	0.38
Control	31.75	50.32	0.27

We found that the ninth grade students who used the new science textbook had a medium increase in their scientific literacy, while those using the standard textbook had a low increase in their scientific literacy.

The increase of scientific literacy ability among students using the new science textbooks is shown in Table 5.

**Table 5.** Increased scientific literacy in ninth- grade students in each domain

Scientific literacy domain	<pretest>	<posttest>	<g>
Explaining scientific phenomena	28.91	65.38	51.30
Evaluating and designing research	25.0	64.94	53.25
Interpreting scientific data and evidence	30.59	61.47	44.48
Content knowledge	38.91	65.38	43.33
Procedural knowledge	25.0	52.84	37.12
Epistemic knowledge	30.59	56.47	37.28

The findings demonstrate that based on the percentages of the average normalized gains; there was a medium increase in the six scientific literacy competency domains in students using the new science textbook.

#### f). The impacts of different treatments on increased scientific literacy inf the ninth-grade Students

Based on the average normalized gains shown in Table 4, the experimental group realized a medium increase in scientific literacy, while the control group realized a low increase. To determine whether there was a significant difference in scientific literacy between two groups, we used Cohen's  $d$  and the statistical analysis of the independent sample  $t$ -test. The results of Cohen's  $d$  determination are shown in Table 6.

**Table 6:** Cohen's  $d$  of the ninth-grade's increased scientific literacy

Mexp	Mcont	STDEV exp	STDEV cont	Cohen's $d$
27.47	19.57	11.66	8.73	0.77

The value of Cohen's  $d = 0.77$  which indicates that the use of the new science textbooks had medium impact on increased scientific literacy in ninth-grade students compared to that in students who used the standard textbook.

#### **g). Statistical analysis of independent samples *t*-test**

We used the Shapiro-Wilk test to find the normality of sample with the aid of SPSS 23 at  $\alpha = .05$ . Based on the results of the gain normality test using the Shapiro-Wilk test, it was found that the significance values for the experimental and control classes were .722 and .363, respectively. The significance values of both groups were  $> .05$ , which means that the increased scientific literacy in both groups was normally distributed. The homogeneity test was done through a variance test aided by Microsoft Excel with the significance level of  $\alpha = .05$ . Based on the results the homogeneity test for the gain in both groups, we found that  $F < F_{table}$ , or  $2.03 < 2.87$ , therefore the variances of the experimental and control groups were homogeneous at the 95% confidence level.

Based on the previous test, the gain in both groups was normal and homogeneous, therefore, the hypotheses could be tested using parametric statistical tests with the independent sample *t*-test. The data of the gain were processed using SPSS 23. The hypothesis was as follows: the physics teaching and learning using the science textbooks developed in this research can more significantly increase the students' scientific literacy than the teaching and learning using the physics textbook commonly used in the school. The hypothesis is impartial to one of the samples; hence, one-tail (right) hypothesis testing was conducted. Based on the difference test of the two average gains of the experimental and control groups, we found that  $Df = 68$ ,  $t = 3.364$ , and  $\text{sig (two-tailed)} .001 < .05$ . It can thus be concluded that new science textbooks had an impact, which was, namely a more significant increase in scientific literacy than the use of the standard science textbook.

## **DISCUSSION and CONCLUSION**

Based on the analysis of the data on the readability of the new science textbooks for secondary schools, we found that the new science textbooks are more readable by students and are appropriate to be used either as a companion or main textbook in the schools. In other words, two book chapters from the draft of the new science textbooks are appropriate to be used in secondary schools.

One factor for this result was using is the model of the process of writing teaching materials to write the science textbooks, which appeared to have met the criteria of creating quality science textbooks, such as that put forth by Gu et al., (2004) and Roseman et al., (1999). The model of the process for writing teaching materials consists of several stages. The first stage is analyze the curriculum, which includes determining the intended audience, analyzing the curriculum, and writing a description of the teaching materials to be created. This stage ensures that the book's content will be in accordance with the curriculum and adjusted the intended audiences.

The second stage is formulate the writing goals of the science textbook, which is done after the writer learn about the core competencies, basic competencies, and graduates' competency standards. The goals contain statements of the competencies that will be acquired by the audiences after studying or reading the science textbook. The goals are elaborated in a series of indicators that describe the scientific literacy ability that will be acquired by the audiences. In this research, scientific literacy ability is elaborated into several domains. The quality of textbooks is defined as "quality in accordance with the goals" (Sursock, 2001). According to this definition, a quality science textbook is determined by its ability to support students and teachers in achieving the goals of science education (Kesidou & Roseman,

2002). The second stage of writing a science textbook is designed using its definition. This stage is also in accordance with the description of a quality textbook according to Roseman et al. (1999).

The third stage is to determine content coverage. Based on the results of curriculum analysis and goal formulations, as well as an analysis of the audiences' initial knowledge, the writer should then select and sort the material or content so that its breadth and depth will be in line with the demands of the curriculum. The content covered is then linked to its relevance in daily life. The phenomena presented are adjusted to the concepts covered in the subject matter. In addition, the learning activities are designed to encourage students to learn by working with real situations or through simulation. The phenomena and direct or indirect situations are used to encourage students to connect scientific concepts, make reasonable conclusions, and build their own knowledge. This stage is in line with the second and third categories used to determine the quality of textbooks in Roseman et al. (1999). The result of this stage is a list of subjects or topics and subtopics that will be described and developed in the new science textbooks.

The fourth stage is to draft an outline. The list of selected topics and subtopics are made into an outline, namely in the form of a sequence of discussions to be included in the planned science textbook. One of the criteria of quality textbooks is coherence; therefore, the outline should be evaluated in advance to ensure that it meets that criterion.

The fifth stage is to create concept maps. The concepts covered in the topic outline are mapped in a concept map. The use of concept maps on write teaching materials is supported by Candan et al (2006) who stated that concept mapping is still an effective tool for teaching scientific concepts in science courses. The stages of making the concept map follow those explained in the articles of Hale (2003), Novak and Gowin (1984), and Steitner et al. (2007). The concept maps provide the hierarchical arrangement of topics to be written. The sequence of creating concept maps begin with the key concepts, and processes to the general concepts, less general concepts and examples of applications. In this research, the textbook of one chapter were developed to increase the scientific literacy in the audiences; therefore, the examples in the concept map are those of the conceptual phenomena in nature and of applications found in the environment and in the students' daily lives. The writer revises the concept map by adding new concepts, eliminating unnecessary concepts, or selecting better concepts. This is one factor that provide a draft of one chapter in the science textbook that the students found easy to read and understand.

The sixth stage is to revise the outline. The result of concept mapping is the basis for revising the first outline to create a final outline with a sequence of the general to the specific or the specific to the general. Hence, the final outline will be created as the reference for writing the new science textbook. The writing process from the first to the sixth stages results in a draft or outline of a science textbook that meets the demands of the curriculum, is in accordance with the writing goals, is adjusted to the audiences, is arranged from the general to the specific or vice versa, and has considered the breadth and depth of the subject matter according to the goals. This process explains the findings of this research that show that the developed textbooks are of high quality.

The seventh stage is to create multiple representations of concepts. The purpose of using multiple representations of concepts in science textbooks is so that the students can easily understand them. The science textbooks developed in this research are intended for secondary school students. Secondary school students have varying backgrounds, therefore, they also have varying abilities to understand the information contained in textbooks. The new science textbooks should accommodate these varying audiences and abilities. One of the ways to do this is to have one concept represented by at least two modes of representation. Students who have difficulties in understanding the concepts represented by one modes of

representations can be aided using a different mode of representation. The final product in this stage is a list of multiple representations of each concept covered in each subtopic. Multiple representations of a concept can be created by, among other, means translating among the modes of representation.

The eighth stage is translate the outline into writing using multimodal representations. In this research, multimodal representation entails explaining a topic or subtopic by integrating verbal modes of representation (text/narration) with a visual mode, so that the written explanations will be more cohesive. This stage is an effort to ensure that the science textbook to meet the criteria in terms of coherence and cohesion, which are the characteristics of a quality textbook. The fifth to the eighth stage are in line with the four measures of the quality of textbook formulated by Roseman et al. (1999). The writing stages are an attempt to make the science textbook more readable for the audiences.

The ninth stage is to evaluate whether the goals are met. Problem sets are included in the textbooks to evaluate these goals.. A number of questions are posed to the students to asses their understanding after they have completed certain activities and help them apply their knowledge to daily lives. Questions, problems, and exercises are designed in line with the curriculum indicators and also to emphasize a higher order of thinking and applying these scientific concepts in daily life. The questions included under each topic or subtopic also consider each scientific literacy domain. The ninth stage is in conformity with the fifth and sixth categories of quality textbooks as stated in Roseman et al. (1999).

The integrated construction model of text understanding stresses that the knowledge domain encourages an understanding of the text; therefore, students with limited knowledge about scientific concepts will have difficulties in understanding science textbooks (Best et al., 2005). Chambliss and Calfee (1989) recommended that the content of a science textbook should be organized coherently and explicitly. The writer should link subjects by taking the students' initial knowledge into consideration and using functional devices, such as introductions, transitions, and conclusions. Carnine and Carnine (2004) also argued that the amount of unfamiliar information in secondary school textbooks will greatly decrease if the content is simplified and instructions are focused on some key concepts. To help increase a student's retention of the text's information, the writer should encourage an overview of key concepts in the chapter by providing questions embedded within each topic and questions for discussion related to the text.

The tenth stage is to review and edit the draft. The first draft of the teaching materials should be reviewed. The reviewing process is first done by the writer. Some question to consider during this process is as follow: a) Dose the draft conforms to the outline, or does it have a good hierarchy? b) Is there any concept with incorrect explanations or misconceptions? c) Is every concept correctly and properly represented to ensure that the audiences understand it easily; are the visual and verbal modes cohesive? d) Is the content contextual? and e) Have the sentences been written according to the guidelines of correct procedures? Each error or inappropriate text should be marked for revision. The results of the review will be the basis for the writer to edit the draft. The final product of this stage is the draft of the science textbook. The edited book will be the second draft of the teaching materials.

The eleventh stage is the readability or understandability test of the main idea and the quality test of the draft given to a number of students. The students are asked to read a chapter and then write the main idea from each paragraph. In addition, they are asked to write down each word or sentence that they cannot understand. The test of book quality is conducted by stakeholders, such as the teachers and experts in higher education. This quality test uses a five-rating scale questionnaire with columns for comment. Feedback from the readability and quality tests is use for reference for revising the draft to create the final draft of the textbook.

The writing process up to the eleventh stage accommodates the criteria for determining a quality textbook in terms of the language of the writing.

Based on the results of both Cohen's *d* and independent sample *t*-test analyses, we found that there was a significant difference in the increased literacy ability between students using the new textbook and those using the standard textbook. This significant difference was result of certain factors. The readability test shows that the science textbooks developed in this research was readable by audiences. This result shows that the students were able to easily process and understand the content or information in the new textbooks. This finding is in line with that put forward by Zimmerman et al. (2007) who stated that reading to understand involves a series of multifaceted and interconnected skills that enable students to accurately process and understand a text's information during the process.

The processes involved in reading to understand are to focus on relevant and important parts and to make connections between the information and previous knowledge. In addition, students should understand the meanings of each word and integrate many internal connections among the important and relevant pieces of information in one part (Baker, 1985; Cook & Mayer, 1988). To accommodate students in the process of reading to understand, the science textbooks during the third stage of writing, should be adjusted to audience's initial knowledge. This adjustment can be accomplished by analyzing the curriculum of the grade below the intended grade. The content covered should be connected to its application in daily life and the designed learning activities designed should encourage students to learn by working in real life situations or simulations. The phenomena and direct/indirect situations are used to enable students to connect scientific concepts, make reasonable conclusions, and build their own knowledge.

Scientific literacy according to PISA is the ability to apply the knowledge learned to solve problems encountered in daily life. According to Bloom's taxonomy, the cognitive level of the ability to apply knowledge to practice is achieved when students reach a certain level of comprehension. The case which with audiences understands content is determined not only by their ability to use reading strategies, but also the readability of the text itself. The stages of the development of science textbooks explained here have considered this idea, so that the stages begin with explanations to enable audiences to understand the concepts and then direct them to observe natural phenomena and various technological devices at home and around the school, which are the applications of the concepts being learned. Each concept described in the textbook should be always linked to an application in technology and daily life, although there is a limitation to providing examples from students' surroundings.

Some researchers such as Cook and Mayer (1988) and Magliano et al. (2005), have broadened the typical definition of understanding by suggesting results of in-depth understanding. Students are intentionally made to attempt to reach a more coherent understanding of the text they read. When reading difficult texts, a skilled reader will use various comprehension strategies to build more in-depth meanings. In the process of textbook development, each concept is explained using multiple representations. The findings of this research indicate that the use of multiple representations of concepts in writing of science textbooks can help students more fully understand scientific concepts and enable them able to pose questions/problems. This is in line with the findings of previous research on the use of multiple representations in science teaching and learning (see for example, Finkelstein et al., 2005; deLeone & Gire, 2005; Rosengrant et al., 2005; Meltzer, 2005; Kohl & Finkelstein, 2005; Rosengrant et al., 2006; Dancy & Beichner, 2006; Kohl & Finkelstein, 2006; Kohl et al., 2007; Kohl et al., 2008; Prain et al., 2009; Atila, et al., 2010., & Sinaga et al., 2015).

The textbooks developed in this research were written by taking into account the varying thinking and intellectual abilities of the students based on their diverse backgrounds. The strategy is to present teaching materials in the form of explanations of (concrete)

scientific phenomena, followed by helping students understand the concepts (abstract). This is done by balancing the design of science discourse/issues not only in the personal context, but also in local and global contexts. Even in a personal context, the example given of science discourse/issues is related to a student's daily life at all social levels. This practice is related to the attitudes expected in PISA's 2015 framework to increase scientific literacy.

Involving students with issues pertaining to daily life can train their ability to apply their scientific literacy. Presenting science discourse/issues is the main component in the textbook as a practical means by which to develop this ability. Some examples of science discourse adapted from scientific phenomena or issues students might encounter in daily life and in technology are included in the development of the science textbooks in this research. This ensures that the new science textbooks will be readable for students and will accommodate a transfer of knowledge. The practice is done by taking into account the statement of Chambliss and Calfee (1989) that there are several factors that can contribute to student's lack of understanding of the information contained in science textbooks. The science textbook itself can cause problems if the text is inaccurate, focused on isolated facts, boring, and unorganized. Furthermore, the development of science textbooks in this research we considered the argument of Carnine & Carnine (2004), who stated that texts containing too many concepts, or too many ideas simultaneously will be less clear and will fail to transfer knowledge.

### Conclusions

Increasing a secondary school student's scientific literacy can be done by using appropriately developed science textbooks. Secondary school science textbooks developed in this research using the model for the process of writing instructional materials have a medium to high category of readability of main ideas. The results of the implementing the new science textbooks in teaching and learning activities show that the textbooks can significantly increase student's scientific literacy in each domain, and that there is a significant difference in the increased scientific literacy between students using the new science textbooks and those using the standard textbook.

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## Analysis of Middle School Students' Views and Impressions about a Science Center \*

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### ABSTRACT

This study aims to evaluate middle school students' views about science centers as out-of-school learning environments. The study surveyed 195 5th-, 6th-, 7th-, and 8th-grade students attending Hatice Salih Primary School and Ahmet Cabuk Middle School in Province Bursa. It used a qualitative cross-sectional and longitudinal research design. For the purpose of the research, middle school students were helped to use the experimental setups at Bursa Science and Technology Center in company with instructors. Later, the students were asked to report their views and impressions about the science center through the "Science Center Opinion Survey". Students' views and impressions were compared based on grade levels. Accordingly, the participating students of all grade levels reported that they would like to come back to the science center, liked activities and experimental setups at the center, and found them fun and educative. However, the study found that a vast majority of the students of all grade levels, similarly, had difficulty in identifying science concepts that the experimental setups are related to.

**Keywords:** Science center, impression, middle school, developmental research

### INTRODUCTION

Out-of-school education can be defined as a teaching method or strategy which facilitates learners' active participation and includes educational and acquisition-focused activities that are difficult or impossible to do in a classroom and thus performed in nature or environment. Out-of-school education allows students to observe and research outside the school. Thus, students make inferences about subjects they deeply learn using their observations and can explain the cause-and-effect relationships between events (Eltinge & Roberts, 1993). Out-of-school education includes acquisitions from different sources such as libraries, museums, nature and science centers, aquariums, zoos, botanical gardens, arboretums, television programs, films and videos, newspapers, radios, books, the internet, public health organizations, environmental organizations, and family (Davies, 1998; Falk & Dierking 2010; Falk & Hannu, 1993; Kelly, 2000; Martin, 2004; Falk & Needham, 2011; Pedretti, 2002). Individuals themselves control what, why, how and when they learn in out-of-

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school education (Stocklmayer & Gilbert, 2003) which is defined as informal learning by researchers (Gerber & Marek, 2001). In this regard, Payne (1985) defines out-of-school education as an effective teaching method or approach that is used outside the school, includes activities difficult or impossible to do in a classroom and helps students specializing in the acquisitions involved in curriculums (as cited in Tatar & Bağrıyanık, 2012). A considerable volume of research has suggested that out-of-school settings help individuals understand science-related concepts, use scientific methods, acquire skills, enhance their knowledge, and take responsibility for their subsequent learning processes (Falk, 1997; Falk & Adelman, 2003; Falk & Storksdieck, 2010; Olson, Cox-Petersen & McComas, 2001; Rennie & McClafferty, 1996; Yavuz & Kılıcı, 2012). Additionally, such settings have been reported to positively affect students' achievement and knowledge and improve problem-solving skills.

Science centers, among of the out-of-school learning environments, are creative and dynamic spaces that undertake to help children, adolescents and adults to acquire the ability to perceive generally accepted scientific principles and facts, and understanding and comprehension skills. These organizations push their visitors' limits of creativity and imagination in areas such as technology, engineering, space sciences and rarely humanities. Thus, they play an important role in raising well-educated, curious, inquiring and questioning generations. They seek to help visitors create their own stories using their ideas and experiences and choose their own ways according to their own motivations (Afonso & Gilbert, 2006; Allen, 2004; Gregory & Miller, 1998). Visitors to these centers enjoy a fun and enjoyable time as they are also involved in individual learning. Unlike in-class learning, learning activities offered by these centers include those which shed light on everyday life, frequently evoke visitors' imagination and ensure a fun and social learning setting. Science, technology and discovery centers create a social learning environment with an understanding of enhancing visitors' knowledge and experience. In line with this created social learning, the main aims of these centers include surprising visitors, engaging their mind with questions and building their self-confidence through new learning (Johnson, 2009).

In Turkey, science centers have been recognized in recent years and the literature includes several studies that emphasize the importance of such centers and suggests their popularization (Çığrık & Özkan, 2015; Mills & Katzman, 2015; Salmi, 1993; Şentürk & Özdemir, 2014.). Çığrık and Özkan (2015) tried to determine the development of 6th-grade students' scientific process skills through live and do-learning activities carried out at the science center. They found that regular and scheduled visits to science centers are influential on students' scientific process skills. Şentürk and Özdemir (2014) investigated the effect of elementary students' visit to METU science center on their attitudes towards science and found that their visit had positive effects. Mills and Katzman (2015) also investigated the effect of elementary school students' trips to a science research and learning center on the change in their desires to learn and participate in science. According to the results of their research, there was an increase in students' desires to become a scientist and get interested in science after their trips. Additionally, Guisasola et al. (2005), Koosimile (2004) and Wellington (1990) also investigated the effects of such centers on the change in students' level of interest in science classes.

It is also clear from previous research that science centers have not been used sufficiently or extensively in science teaching as an out-of-school learning setting. Additionally, there is a need for studies in Turkey to determine the positive or negative effects of such out-of-school learning environments especially on science education; to help students, teachers and parents become aware and informed of this issue; and to identify ways of enhancing the permanence of learning in such environments.

Against this background, the purpose of this study is to identify middle school students' views and impressions about experimental setups covering various topics through visits to Bursa Science center as an out-of-school learning environment. For this purpose, answers to the following sub-problems were sought:

1. What are middle school students' views and impressions about the practices, activities and experimental setups at the science center?
2. Do middle school students' views and impressions about the practices, activities and experimental setups at the science center differ by grade levels?

## METHODS

This section includes the research model, detailed information about the students participating in the research, the applications carried out within the scope of the research, and the analyses on the data collected through these applications and data collection methods.

The study was carried out in order to obtain the views and impressions of middle school students about the practices and activities at science centers and to make comparisons according to different grade levels. The research was designed as developmental research which is one of the qualitative research methods. The cross-sectional method was used for the research. Developmental research, which is also defined as a descriptive research method, is used by researchers for their studies to analyze the lives of the individuals from different age groups and different cultures, and the changes and development of people's feelings, opinions, attitudes etc. in different time periods (Çepni, 2007; Şahin, 2014). The cross-sectional method, on the other hand, is defined as the longitudinal analysis of parallel groups simultaneously selected from a single population (Sahin, 2014). In this context, this study focused on taking the opinions of students of different grade levels (in other words, students from different age groups) about the science center and on evaluating their impressions.

### a) The Study Group

This research was carried out in the spring term of the 2013-2014 academic year. The population (universe) of the study consisted of middle schools in Bursa. The sample of the study included a total of 195 students in the fifth, sixth, seventh and eighth grades attending Hatice Salih Primary School and Ahmet Çabuk Middle School selected by random sampling method, which is one of the rationality-based sampling methods. In the random sampling method, samples are selected through a completely random method (Yıldırım and Şimşek, 2005: 104).

106 female and 89 male students participated in the research. Accordingly, 27 female and 16 male students from the fifth grade took part in the research. 24 female and 20 male students from the sixth grade participated in the study. The seventh grade took part in the study with its 25 female and 24 male students while 30 female and 29 male students from eighth grade participated in the program. The "Science Center Opinion Survey" was conducted in all classes as a final test, and the results obtained from the survey were compared.

**Table 1.** Number of students in the experimental and control groups according to grades

Grade	Female		Male		Total	
	f	%	f	%	f	%
5.	27	13,85	16	8,21	43	22,05
6.	24	12,31	20	10,26	44	22,56
7.	25	12,82	24	12,31	49	25,13
8.	30	15,38	29	14,87	59	30,26
<b>Total</b>	106	54,36	89	45,65	195	100,00

## **b) Data Collection Tools**

In this research, the “Science Center Opinion Survey” was used to receive students’ opinions about the science center and experimental setups after the application.

### **Science center opinion survey**

The survey consists of a total of 10 items developed by the researchers and comprising open-ended questions to receive middle school students’ views about the science center and experimental setups at the center after the application.

In order to ensure the internal validity of the measurement tool, the questionnaire was given to two expert and the final forms of the questions in the questionnaire were prepared by making necessary corrections with the opinions of the expert. Later, the survey was pre-applied. The data obtained after the preliminary application were examined by experts to determine whether the questions were clear and understandable, whether the responses reflected the answers to the questions asked, and the survey was given the final form. In this way, the internal validity of the questionnaire was provided. It was concluded that the open-ended questions provided the desired data and the measurement tool was applied to the middle school students in the sample.

The questions and analyses on the survey are given in the findings section.

## **c) Data Collection-Application**

The process of data collection and application was conducted according to the following steps:

1. Middle school students were given the opportunity to participate in the applications of Bursa Science and Technology Center in company with instructors working at the center, on the basis of different classes at different times. The students have tried all of the experimental setups at the center first in company with the instructors and then on their own.
2. The “Science Center Opinion Survey” was conducted as a final test in order to assess the middle school students’ views and impressions about the science center, the experimental setups, and the relevant scientific concepts.

## **d) Data Analysis**

The data obtained from the Science Center Opinion Survey were analyzed using frequency (f) and percentage (%) distributions in addition to descriptive analysis. In the descriptive analysis, the findings are presented to the reader in an organized and interpreted way. In this analysis method, the data are described systematically and explicitly, these descriptions are explained and interpreted, cause-effect relationships are examined, and certain results are obtained. The results can be correlated and interpreted in terms of themes, and predictions can be made (Yıldırım and Şimşek, 2005: 224). Within the scope of the study, the data obtained from the answers given to the research questions were analyzed by forming a frame, processing the data according to the thematic framework, identifying and interpreting the findings. The second research question formed the most general frame for data analysis in the process of creating a framework for descriptive analysis. In the course of processing the data according to the thematic framework, the questions in the Science Center Opinion Survey were accepted as themes for the data within the determined frame, and these data are organized and presented under the aforesaid themes. In the identification and interpretation phase of the findings, the data obtained in line with the determined theme were analyzed and arranged. Then, the arranged data were defined and the findings were interpreted on these

themes. Briefly, at this stage, students' answers were examined one by one, and the expressions stated in the evaluations were grouped. Thus, the data were coded and categorized by the researchers.

In this context, the qualitative data were evaluated separately by two different researchers, and codes and categories were finalized after the co-evaluation of the different results.

## FINDINGS

The research questions of this study are as follows: "What are middle school students' views and impressions about the practices, activities and experimental setups at the science center?", and "Do they differ by grade levels?". Accordingly, the answers given by 5th-, 6th-, 7th-, and 8th-grade students to the Science Center Opinion Survey after the application were analyzed through descriptive analysis. The findings obtained from this survey are presented below.

In this study, the students were first asked to answer the following questions: "Would you like to come back to the science center? Why?". The results of the research were as follows: the fifth (f=43, 100%), sixth (f=44, 100%), seventh (f=49, 100%) and eighth grade (f=59, 100%) students stated that they would like to come back to this center, which meant that all of the students wanted to visit the center again. The table given below (Table 2) shows the reasons for desire to revisit the center, as stated by the fifth graders (f=43, 100%), the sixth graders (f = 41, 93.2%), the seventh graders (f = 48, 98%) and the eighth graders (f=56, 95%) in total.

**Table 2.** Reasons for the desire to revisit the Science Center according to the grade levels

Grades	Reasons for the desire to revisit the science center	Yes	
		f	%
5 <sup>th</sup> -Grade	Because I get new information/ I learn with experiments/by experience/because it is very educational.	17	39.5
	Because I like it very much /I appreciate it very much.	16	37.2
	Because it is so entertaining/I had fun/it is enjoyable.	16	37.2
	Because the experimental setups were interesting./There are interesting things./There are interesting experimental setups.	7	16.3
	Because I have not seen an experimental setup before./I have never seen it in the daily life.	2	4.7
	Because I wanted to share this information with others	1	2.3
	Because I did not explore the science center well enough.	1	2.3
	6 <sup>th</sup> -Grade	Because I like it very much/I appreciate it very much.	18
Because it's an entertaining place./ Because it is so entertaining/I had fun.		12	29.3
Because I get new information / try new experiments/ Because it is very educational.		10	24.4
Because the experimental setups were interesting. There are interesting things. There are interesting setups.		8	19.5
Because I want to see test the experimental setups again.		3	7.3
Because I learn new things through experiments / I like making experiments.		1	2.4
7 <sup>th</sup> -Grade	Because it's an entertaining place. Because it is so entertaining/I had fun.	28	58.3
	Because I get new information / try new experiments/ Because it is very educational.	20	41.7
	Because the experimental setups were interesting. There are interesting things. There are interesting experimental setups.	15	31.2
	Because it was fun /it was very entertaining/I had a lot of fun /I am satisfied.	7	14.6
	Because I learn new things through experiments/I like making experiments.	5	10.4
8 <sup>th</sup> -Grade	Because it's an entertaining place. Because it is so entertaining/I had fun.	18	32.1
	Because I get new information / try new experiments./ Because it is very educational.	18	32.1
	Because it is a beautiful place./ I liked it./ I am satisfied.	17	30.4
	Because the experimental setups were interesting. There are interesting things. There are interesting experimental setups.	8	14.3
	Because I learn new things through experiments./ I like making experiments.	3	5.4



In the analyses that were carried out, 39.5% ( $f = 17$ ) of 5th-grade students stated that they learned new things by making experiments and by means of the activities performed at the science center. Moreover, 16 students (37.2%) said that they liked the science center and wanted to revisit it because they had fun there.

The sixth, seventh and eighth-grade students expressed their opinions which are similar to the ones of the fifth graders, and they remarked that the center of science was an entertaining, enjoyable place, that they liked it very much. In addition, they emphasized that they obtained new information and tried new experiments.

Considering the responses of the fifth graders to the question “*Has your interest in sciences increased?*” (Table 3), the majority of the students participating in the research (35 students-81.4%) gave positive responses to the question. However, few students (1 student-2.3%) answered the question negatively while some students (7 students-16.3%) remained hesitant. Similarly, the majority of the sixth grade-students gave positive responses (36 students-81.8%) while the responses of 2 students (4.6%) were negative. Some of the students (6 students-13.6%) stated that they were hesitant. Among the seventh and eighth grade students who participated in the survey, 45 seventh graders (91.8%) and 47 eighth graders (80%) also reported that their interests in science increased after the visit, which was a similar result to those obtained in other grades.

**Table 3.** *The perceived increase in students' interests in science after their visit to the science center*

Grade	Yes		No		Hesitant	
	f	%	f	%	f	%
5	35	81.4	1	2,3	7	16.3
6	36	81.8	2	4.6	6	13.6
7	45	91.8	-	-	4	8.2
8	47	80	-	-	12	20

The students' responses to the third question “*Would you tell your immediate surroundings ((friends, family, etc.) about your impressions and observations at the science center? Why?*” were analyzed. Accordingly, the majority of the students (42 5<sup>th</sup>-grade students- 97.7% and 39 6<sup>th</sup>-grade students-88.6%) stated that they would like to share their experiences and observations with their surroundings (Table 4). The rate of the desire to tell about their trip was found 91.8% for 7<sup>th</sup>-grade students (45 students), while the rate was 81.14% for 8<sup>th</sup>-grade students (52 students).

**Table 4.** *The Desire to Tell the Immediate Surroundings about Impressions and Acquisitions at the science center*

Grade	Yes		No		Hesitant	
	f	%	f	%	f	%
5	42	97.7	-	-	1	2.3
6	39	88.6	4	9.1	1	2.3
7	45	91.8	2	4.1	2	4.1
8	52	88.14	1	1.7	6	10.2

Table 5 below includes the statements of 41 (95.3%) 5<sup>th</sup>-grade students reporting that they told their immediate surroundings about their science center trip. A considerable number of 5<sup>th</sup>-grade students (21 students-51.2%) stated that they would also like their relatives and friends to learn, see, know, benefit and be informed of what they learned at the science center. Similarly, 7 students (17.1%) reported that they would tell about their trip because the center is a good place; 5 students (12.2%) would tell because their family and friend also wonder

and love the center and because the center would attract their family's and friends' attention. 5 students (12.2%) stated that they had a lot of fun; therefore, they would tell their family and friends about their trip.

**Table 5.** 5<sup>th</sup>-Grade Students' Reasons for Telling About the Trip to Their Immediate Surroundings

	Yes	
	f	%
I would also like them to learn/learn through trial/ benefit/know/be informed of what I learned.	21	51.2
I had a lot of fun. /It is fun/enjoyable.	7	17.1
My family also wonders./It attracts their attention./They also like it.	5	12.2
I liked/loved here.	5	12.2
It is an educative place./I would tell I learned new information.	4	9.8
I would also like them to come.	3	7.3
There are interesting things./It is an interesting place.	1	2.4

Table 6 includes the statements of 31 (70.5%) 6<sup>th</sup>-grade students about their reasons for telling about their science center trip to their immediate surroundings.

**Table 6.** 6<sup>th</sup>-Grade Students' Reasons for Telling About the Trip to Their Immediate Surroundings

	Yes	
	f	%
I would also like them to learn/learn through trial/ benefit/know/be informed of what I learned.	16	51.6
I would also like them to go to/come to the science center.	7	22.6
My family also wonders./It attracts their attention./They also like it.	5	16.1
It is an educative place./I would tell I learned new information.	3	9.7
I had a lot of fun. /It is a fun/an enjoyable place.	3	9.7
It is very good.	2	6.5
I would tell as I would like to come again.	2	6.5
There are interesting things./It is an interesting place.	1	3.2

A considerable number of 6<sup>th</sup>-grade students (16 students-51.6%) stated that they would also like their relatives and friends to learn, see, know, benefit and be informed of what they learned at the science center. Similarly, 7 students (22.6%) would also like their relatives and friends to come; 5 students (16.1%) reported that their family would wonder and the science center would attract their family's attention. 3 students (9.7%) highlighted the educative aspect of the science center and that they learned new information.

Table 7 includes the statements of 43 (87.8%) 7<sup>th</sup>-grade students reporting that they told their immediate surroundings about their science center trip. One of the two (4.1%) students who answered no to the question gave the following reason for not telling about the trip: "We saw much, I would forget."

**Table 7.** 7<sup>th</sup>-Grade Students' Reasons for Telling About the Trip to Their Immediate Surroundings

	Yes	
	f	%
I would also like them to learn/learn through trial/ benefit/know/be informed of what I learned.	19	44.2
I would also like them to go to/see the science center.	10	23.3
I had a lot of fun. /It is fun/enjoyable.	5	11.6
I liked/loved here./It aroused my interest/I would like to come again.	4	9.3
I like to tell.	3	6.9
There are interesting things./It is an interesting place.	2	4.7
My family also wonders./It attracts their attention./They also like it.	2	4.7

19 7<sup>th</sup>-grade students (44.2%) reported that they would also like their relatives and friends to learn, see, know, benefit and be informed of what they learned at the science center. Similarly, the students would tell about their trip because they would also like their relatives and friends to go to the science center (10 students-23.3%) and they liked the center and would like to come again (4 students-9.3%). 3 students (6.9%) stated that they would tell about their trip because they like to tell.

Table 8 includes the statements of 46 (78%) 8<sup>th</sup>-grade students reporting that they told their immediate surroundings about their science center trip.

**Table 8.** 8<sup>th</sup>-Grade Students' Reasons for Telling About the Trip to Their Immediate Surroundings

	Yes	
	f	%
I would also like them to learn/learn through trial/ benefit/know/be informed of what I learned.	21	45.7
I would also like them to go to/see the science center.	10	21.7
I had a lot of fun. /It is fun/enjoyable.	6	13
It is useful./It is useful/beneficial for science.	5	10.9
I liked/loved here./It aroused my interest/I would like to come again.	5	10.9
My family also wonders./It attracts their attention./They also like it.	4	8.7
I would like to come again.	3	6.5
To help increase the importance that people give to science.	1	2.2
There are technological tools.	1	2.2
I would like to share.	1	2.2

21 8<sup>th</sup>-grade students (45.7%) reported that they would also like their relatives and friends to learn, see, know, benefit and be informed of what they learned at the science center. Similarly, 10 students (21.7%) would tell about their trip because they would also like their relatives and friends to go to the science center; 6 students (13%) would tell because they had a lot of fun and the science center was fun and enjoyable. One 8<sup>th</sup>-grade student (2.2%) reported that he would tell "in order to help increase the importance that people give to science".

Considering 5<sup>th</sup>-grade students' responses to the fourth question in the Science Center Opinion Survey "Do you think that the experimental setups at the science and technology center are related to the subjects taught at school? Please explain why giving an example.", 65.1% (28) of the students think that the experimental setups at the science center are related to the subjects taught at school, while 27.9% (12) students think that they are not related. 3 students (6.98%) did not comment on this topic. Table 9 includes the statements of 5<sup>th</sup>-grade students (40 students-93.02%) expressing their opinion about the relevance/irrelevance of the experimental setups at the science center to the school subjects.

**Table 9.** 5<sup>th</sup>-grade Students' Views about the Relevance of the Experimental Setups to the School Subjects

		f	%
Relevance	Because such studies/experiments are done at school (Seasons, Moon and Sun; the spread of sound in a vacuum, Shadow, Electricity, Light Sources, Force)	21	49.5
	Because they think the subjects taught at the science center are more detailed and advanced than those taught at school.	5	12.5
Irrelevance	Because they think there is not enough material at school.	2	5
	Because they think that the experiments at the science center are more different/distinct/good.	4	10
	Because they think that the experiments at the science center are more fun.	1	2.5
	Because they think they did not make the science center experimental setups at school.	1	2.5
	Because they think they are not relevant.	2	5
	Because they did more experiments at the science center	2	5

As seen in Table 9, 49.5% of 5<sup>th</sup>-grade students think that the experimental setups at the science center are relevant to the school subjects as they do such studies/experiments at school. According to the opinions of 4 students (10%) thinking that the experimental setups are irrelevant to the school subjects, the experimental setups at the science center are better, more distinct, and more different.

Considering the responses of 6<sup>th</sup>-grade students to the fourth question, a significant number (18 students-62.1%) of the students reporting their views think that the experimental setups at the science center are relevant to the school subjects, while 11 students (37.9%) think that they are irrelevant. 15 students (34.1%) did not comment on this topic. Table 10 includes the statements of 6<sup>th</sup>-grade students (29 students-65.9%) expressing their opinion about the relevance/irrelevance of the experimental setups at the science center to the school subjects.

**Table 10.** *6<sup>th</sup>-grade Students' Views about the Relevance of the Experimental Setups to the School Subjects*

		f	%
Relevance	Because studies/experiments/subjects about some experimental setups are covered/discussed at school/in science classes (Force, bulb brightness, body capacitance, electricity)	16	55.2
Irrelevance	Because they do/ they themselves do experiments at the science center.	3	10.3
	Because they think that the experiments at the science center are more different/distinct/good.	2	6.9
	Because they think they did not make the science center experimental setups at school.	2	6.9
	Because they think that the experiments at the science center are more fun.	1	3.3

Considering the responses of 7<sup>th</sup>-grade students to the fourth question, 69.4% (34) of the students think that the experimental setups at the science center are relevant to the school subjects, while 16.3% (8) think they are irrelevant. 7 students (14.3%) did not comment on this topic. Table 11 includes the statements of 7<sup>th</sup>-grade students (42 students-85.7%) expressing their opinion about the relevance/irrelevance of the experimental setups at the science center to the school subjects.

**Table 11.** *7<sup>th</sup>-grade Students' Views about the Relevance of the Experimental Setups to the School Subjects*

		f	%
Relevance	Because such studies/experiments are done at school/in science classes (electric, electric circuit, magnet, magnetic field, series and parallel circuits, pressure, air)	27	64.3
	Because they think the subjects taught at the science center are more detailed and advanced than those taught at school	5	11.9
	Because they have some commonness.	2	4.8
Irrelevance	Because they think that the experiments at the science center are more different/distinct/good.	4	9.6
	Because they think that they are irrelevant.	2	4.8
	Because they think they did not make the science center experimental setups at school	1	2.4
	Because they did more experiments at the science center.	1	2.4

Considering the responses of 8<sup>th</sup>-grade students to the fourth question, a great majority (48 students-81.4%) think that the experimental setups at the science center are relevant to the school subjects, while 3 students (5.1%) think that they are irrelevant. 1 student (1.7%) remained hesitant. 7 students (11.9%) did not comment on this topic. Table 11 includes the

statements of 8<sup>th</sup>-grade students (38 students-64.4%) expressing their opinion about the relevance/irrelevance of the experimental setups at the science center to the school subjects.

**Table 12.** *8<sup>th</sup>-grade Students' Views about the Relevance of the Experimental Setups to the School Subjects*

		f	%
Relevance	Because such studies/experiments are done at school (Balloon explosion test, renewable energy, voltmeter, parallel connected circuit, states of matter, hydraulic press, sound, vacuum bell-shaped glass jar, condensation, pressure-related devices)	35	92.1
	Because they think the subjects taught at the science center are more detailed and advanced than those taught at school	1	2.6
Irrelevance	Because they think that the experiments at the science center are more different/distinct/good.	2	5.2

The following three questions were asked to determine what behaviors the participating students exhibited during their visit to the science center: “Did you ask instructors questions during the visit?”, “Did you take notes in your notebook during the visit?”, and “Did you practice every experimental setup by yourself?”. Table 13 includes students' responses to these questions according to grade level.

**Table 13.** *The Percentage of Some Behaviors Students Exhibited at the Science and Technology Center According to Grade Level*

	5 <sup>th</sup> -grade		6 <sup>th</sup> -grade		7 <sup>th</sup> -grade		8 <sup>th</sup> -grade									
	Yes		No		Yes		No									
	f	%	f	%	f	%	f	%								
1 Did you ask instructors questions?	29	67,4	14	32.6	23	52.3	21	47.7	37	75.5	12	24.5	41	69.5	18	30.5
2 Did you take notes in your notebook?	12	27.9	31	72.1	5	11.4	39	88.6	8	16.3	41	83.7	2	3.4	57	96,6
3 Did you practice every experimental setup by yourself?	30	69.8	13	30.2	32	72.7	12	27.3	41	83.7	8	16.3	47	79.7	12	20.3

Considering the responses of 5<sup>th</sup>-, 7<sup>th</sup>-, and 8<sup>th</sup>-grade students, a great number asked the instructors questions. As seen in Table 13, 6<sup>th</sup>-grade students asked instructors fewer questions (47.7%) compared to other grade levels. It is noteworthy that 5<sup>th</sup>-, 6<sup>th</sup>-, 7<sup>th</sup>-, and 8<sup>th</sup>-grade students did not take notes in their notebooks. Additionally, a significant number of students of all grade levels practices and used the experimental setups at the science center by themselves.

The participating students were also asked “What are your favorite three experimental setups at the science center? Please write the relevant concepts”. Table 14 includes the responses of 5<sup>th</sup>-grade students. The names of experimental setups are given as the students expressed.

**Table 14.** 5<sup>th</sup>-grade Students' Favorite Experimental Setups and the Concepts They Think Relevant

Name of the Experimental Setup	f	Concepts and Frequencies
Vortex Tunnel	8	Space (f=2), Universe (f=2), Milky Way (f=1), Effect (f=1)
Tornado Formation/Air Tornado/ Air Smoke	13	Electricity (f=1), Natural disaster (f=2), Air (f=1), Steam (f=2), Wind (f=1), Pressure (f=4), Water (f=3), Atmosphere (f=1), Smoke (f=1),
Water pressure/water match/water ball	6	Water pressure (f=5), Water Movement (f=1)
Mirror flying/Mirrors/Flying mirror	7	Gravity (f=1), Electricity (f=1)
Water waves /Tsunami	5	Waves (f=1), Water (f=1), Water pressure (f=1), Electricity (f=2)
Wind energy/Solar energy/Electricity energy	6	Electricity (f=4), Solar energy (f=1), Force (f=1),
Electric current/Electric circuits /Electricity	5	Electricity (f=2), Electricity shock (f=1),
Harp	4	Finger Detection (f=1), Laser (f=2)
Water Purification Plant	3	Water purification (f=1), Su (f=1), Purification (f=1),
Green Screen/ Green Curtain	4	Photograph (f=2)
Solar System/Solar Eclipse/Lunar Eclipse	5	Sun (f=1), Ay (f=1), Earth (f=1),
Thermal power station	3	Air (f=1), Electricity (f=2)
Reflexmeter	3	Electricity (f=3),
Formation of colors	1	Colors (f=1)
Submarine	1	Pressure (f=1)
Magnet	1	Magnet (f=1)
Fan	1	Electricity (f=1)
Tide	2	Pressure (f=1)
Eye delusion	2	Eye delusion (f=1), Rotation (f=1)
Solar panels	2	Solar energy (f=2)
Ship Game	2	Wind (f=1), Intelligence (f=1)
Jacob's Ladder/Lightning strike	1	Condensation(f=1),
Water Vortex	3	Water (f=1), Pressure (f=2)

As seen in Table 14, for the 5<sup>th</sup>-grade students, the three most favorite experimental setups at the science center include “tornado formation”, “vortex tunnel”, and “mirrors”. Considering the scientific concepts relevant to these three experimental setups, the students associated the setup of “tornado formation” with concepts such as electricity, natural disaster, air, steam, wind, pressure, water, atmosphere, and smoke. They associated “vortex tunnel” with space, universe, the Milky Way and effect. They used gravity and electricity with respect to “mirrors”. They reported that they also liked the experimental setups “wind energy/solar energy/electricity energy”, “water ball”, “water waves”, “Solar system”, and “electric circuits”.

For the 6<sup>th</sup>-grade students, the three most favorite experimental setups at the science center include “vortex tunnel”, “body capacitance setup”, and “playground”. Considering the scientific concepts relevant to these three experimental setups, the students associated “vortex tunnel” with concepts such as dizziness, rotation, picture rotation, later rotation (f=8), electricity (f=2), and eye delusion (f=2). They used only electricity (f=10) to define the experimental setup “body capacitance”.

**Table 15.** 6<sup>th</sup>-grade Students' Favorite Experimental Setups and the Concepts They Think Relevant

Name of the Experimental Setup	f	Concepts Reported by Students
Electricity Generation	4	Electricity (f=2)
Body Capacitance	18	Electricity (f=10)
Bobbin	5	Electricity (f=5)
Vortex Tunnel	33	Electricity (f=2), Dizziness/Rotation/Picture Rotation/Later Rotation (f=8), Pressure (f=1), Circuits (f=1), Eye delusion (f=2), Light (f=1)
Mirrors	2	
Tornado	4	Steam (f=1), Isı (f=1), Cold (f=1), Nature (f=1)
Water Match/Water Ball	3	Electricity (f=1)
Airbag	4	Pressure (f=1)
Jacob's Ladder	1	Electricity in the void (f=1)
Newton's Balls	2	
Water Purification	4	Water (f=1)
Playground	5	Pressure (f=1), Air Pressure (f=1)
Drums playing with heart rhythm	2	
Submarine	1	Pressure (f=1)

Table 16 includes 7<sup>th</sup>-grade students favorite experimental setups at the science center and their views about the scientific concepts related to these setups. For the 7<sup>th</sup>-grade students, the three most favorite experimental setups at the science center include “vortex tunnel”, “tornado”, and “electric circuits”. Considering the related concepts reported by the students, they associated the experimental setup “vortex tunnel” with electricity (f=1), rotation (f=6), dizziness (f=5), eye delusion (f=5), hallucination (f=1), and balance (f=1). For the experimental setup “tornado”, they used electricity (f=2), water (f=5), air pressure (f=2), evaporation (f=3), pressure (f=2), and air (f=1).

**Table 16.** 7<sup>th</sup>-grade Students' Favorite Experimental Setups and the Concepts They Think Relevant

Name of the Experimental Setup	f	Concepts Reported by Students
Harp	7	Laser (f=2), Electricity (f=1), Sound (f=2)
Water purification	4	Electricity (f=1), Water purification (f=1), Pressure (f=1)
Tornado	16	Electricity (f=2), Su (f=5), Air pressure (f=2), Evaporation (f=3), Pressure (f=2), Air (f=1)
Bridge	1	Water (f=1), Wind (f=1), Sun (f=1)
Body Capacitance	3	Electricity (f=1), Electric current (f=1)
Electric circuits	9	Electricity (f=8)
Vortex Tunnel	44	Electricity (f=1), Rotation (f=6), Dizziness (f=5), Eye delusion (f=5), Hallucination (f=1), Balance (f=1)
Water pressure	2	Water (f=1)
Reflexmeter	2	
Water ball/water football	4	Water (f=1)
Lever	1	
Bouncing balls	1	
Airbag/Trampoline	8	Air pressure (f=2), Pressure (f=1), Bouncing (f=1)
Mirrors	6	Reflection (f=2)
Magnet-magnetic field	1	
Submarine	8	Water pressure (f=2), Air (f=1), Water (f=1), Electricity (f=1)
Playground	3	Fun (f=1)
Power plants	1	Electricity (f=1), Pressure (f=1)
Hypnotizing circles	1	Eye delusion (f=1)
Jacob's Ladder	1	Electricity (f=1), Lightning (f=1)
Newton's Balls	1	Pressure (f=1)
Green screen-bicycle	1	
Solar panels	1	Electricity (f=1)
Electricity generation by wave	1	Electricity generation (f=1)

Table 17 includes 8<sup>th</sup>-grade students favorite experimental setups at the science center and their views about the scientific concepts related to these setups. For the 8<sup>th</sup>-grade students, the three most favorite experimental setups at Bursa Science and Technology Center include “vortex tunnel”, “tornado formation”, and “water purification plant model”. Considering the related concepts reported by the students, they associated the experimental setup “vortex tunnel” with such concepts as electricity (f=6), dizziness (f=2), eye delusion (f=6), balance (f=1), error/illusion (f=7), pressure (f=1), and rotation (f=2). They associated the setup “tornado” with evaporation (f=1), states of matter (f=3), pressure (f=9), and heat (f=1). For the experimental setup “water purification plant model”, they used such concepts as water energy (f=2), water clarity (f=1), water hardness (f=1), water (f=2), and pressure (f=1).

**Table 17.** 8<sup>th</sup>-grade Students’ Favorite Experimental Setups and the Concepts They Think Relevant

Name of the Experimental Setup	f	Concepts Reported by Students
Vortex Tunnel	37	Electricity (f=6), Dizziness (f=2), Eye Delusion (f=6), Balance (f=1), Error/Illusion f=7, Pressure (f=1), Rotation (f=2),
Electric circuits	1	
Power plants / thermal	6	Electricity (f=6)
Body Capacitance	5	Electricity (f=2)
Playground / Airbag	1	
Magnetic balls/magnet	5	Aspects of transmission (f=1), Force of attraction (f=1), Poles (f=1), Electricity (f=1), Electrification (f=1)
Water Purification Plant	11	Water energy (f=2), Water clarity (f=1), Water hardness (f=1), Water (f=2), Pressure (f=1)
Tornado Formation/Air Tornado	19	Evaporation (f=1), States of matter (f=3), Pressure (f=9), Heat (f=1)
Mirror flying / Mirrors	2	Sight (f=1)
Mirror-cartoon machines	1	Mirror (f=1)
Vocal cords	1	Vibration (f=1), Sound (f=1)
Newton’s balls	10	Pressure (f=6)
Water pressure/water match/water ball	1	
Voltmeter	1	
Wave Energy/wind energy/solar energy/electric energy	1	Pressure (f=1)
Submarine	6	States of matter (f=1), Pressure (f=1), Lift force (f=1), Air pressure (f=1), Water exchange (f=1)
Telephone communication model	1	Electricity (f=1)
Green screen	1	Electricity (f=1)
Reflexmeter	10	
Calulator model	4	Electricity (f=3), Intelligence (f=1)
Infinite space/infinite mirrors	3	Reflection (f=2), Mirrors (f=1)
Model for container shape and water level	1	Pressure (f=1)

The students of all grade levels were asked to write their reasons why they liked their favorite experimental setups at the science center. Table 18 shows the relevant data. According the table, 43.5% of 23 5<sup>th</sup>-grade students responding the question reported the following: “Because it is fun/enjoyable”, “Because it is good/interesting/impressive/attractive”, and “Because it is educative”, and “Because it attracted my attention” (Table 18). 31.3% of 16 5<sup>th</sup>-grade students responding the question stated the following with respect to their favorite experimental setups: “Because it is fun/enjoyable”, “Because it is good/interesting/impressive”, and “Because it is educative”. Additionally, 9 7<sup>th</sup>-grade and 21 8<sup>th</sup>-grade students reporting their views on this question gave similar responses 6<sup>th</sup>-grade students.



**Table 18.** Students Reasons for Liking the Experimental Setups

	5 <sup>th</sup> -grade		6 <sup>th</sup> -grade		7 <sup>th</sup> -grade		8 <sup>th</sup> -grade	
	f	%	f	%	f	%	f	%
Because it is fun/enjoyable	10	43.5	5	31.3	4	44.4	12	61.9
Because it attracted my attention/I liked it	2	8.7	4	25	3	33.3	3	14.3
Because it is good/interesting/impressive	6	26.1	5	31.3	1	11.1	2	9.5
Because I would like to see again.	1	4.4	1	6.3				
Because I have never seen before	1	4.4					1	4.8
Because I learned new information/things					1	11.1	2	9.5
Because it is educative			4	25	3	33.3	1	4.8
Because it is related to electricity							1	4.8

The participating students were lastly asked “*Is there any experimental setup that you do not like? If any, which one/ones? Please explain why*”. Table 19 includes students’ responses to this question. Accordingly, a great majority of 5<sup>th</sup>-grade students (33 students) stated no experimental setup they did not like, while 10 students reported the experimental setups listed in Table 19. Concerning their reasons for disliking these setups, they stated the following: “It made me feel dizzy” (f=4), “I do not like/love/It did not arouse my interest” (f=5), “it is too simple” (f=1), “it is related to sound” (f=2), and “it is an experiment I already know” (Figure 2).

**Table 19.** Experimental Setups Students Disliked

	5 <sup>th</sup> -grade		6 <sup>th</sup> -grade		7 <sup>th</sup> -grade		8 <sup>th</sup> -grade	
	f	%	f	%	f	%	f	%
Tornado Formation	1	10			1	7.1	3	23.1
Water pressure/Water ball	2	20			1	7.1		23.1
Green Screen/curtain/green screen-bicycle	2	20			2	14.3		
Vortex tunnel	2	20			3	21.4	3	23.1
Windmills	1	10						
Eye delusion	4	40						
Submarine	1	10					1	7.7
Sound in the void/bell-shaped glass jar	3	30						
Mirrors			1	12.5	4	28.6	5	38.5
Newton’s balls			3	12.5	2	14.3		
Drum			3	37.5	1	7.1	2	15.3
Water purification					2	14.3	2	15.3
Phone model					1	7.1		
Serial circuit					1	7.1		
Drum making using pipes					1	7.1		
Science show					1	7.1		
The earth-sun-moon model							1	7.7
Water waves							3	23.1
Jacob’s Ladder							1	7.7

Considering 6<sup>th</sup>-grade students’ responses to the same question, a great majority of them (36 students-81.8%) reported no experimental setup they did not like, while 8 students (18.2%) indicated the experimental setups listed in Table 19. 6<sup>th</sup>-grade students did not like the setups mirrors, Newton’s balls, and drum. They reported the following reasons: “I do not like/love/It did not arouse my interest” (f=4), and “it is too simple/basic” (f=1). 71.4% of 7<sup>th</sup>-grade students (f=35) reported no experimental setup they did not like, while 14 students (28.6%) responding the question stated the following reasons: “it is simple” (f=3), “it is complicated and I could not understand” (f=3), and “I have seen the same setup before” (f=7). Additionally, a great majority of 8<sup>th</sup>-grade students (46 students-78%) also reported no

experimental setup they did not like. 11 students did not like the experimental setups because they did not like the setup (f=3), the setups were simple and boring (f=6), and they were not fun (f=3).

## DISCUSSION and CONCLUSION

This study was conducted to evaluate middle school students' views and impression about the science center as an out-of-school learning environment and presented the results obtained from the "Science Center Opinion Survey".

According to the research results, the application performed at the science center created a positive impact on students of all grade levels. In other words, it is clear from the research results that students were impressed by, liked and enjoyed the science center and the setups there and they would like to revisit the center. This result is true for all grade levels. The survey also asked the question "*Would you like to come back to the science center*" and all participating students of all grade levels stated that they would like to revisit the center. This result indicated that all the students liked the science center and found it interesting. When the students were asked their reasons for the desire to revisit, the most common responses for all grade levels include "I had a lot of fun and it was very enjoyable", "It is very good", and "I learned new information".

Considering the students statements such as "the place is good", and "there are funny experimental setups", it seems that the majority of the students perceive the science center as more a place of entertainment than a science center. Thus, for students, learning remained in the background. At the end of their trip, the students were also asked the question "*Has your interest in sciences increased?*". An increase was observed in the responses of students who remained hesitant and responded no. This increase was similarly detected in all grade levels. Thus, this result is another indication that learning remained in the background.

Throughout the world, students are known to be impressed by out-of-school settings like science centers. In Turkey, Bozdoğan (2007) reported that preservice teachers described a science center as an enjoyable and interesting place; thus, they would like to revisit the science center. In other words, preservice teachers were impressed by such settings. Çıgırık (2016) found the same results in the doctoral dissertation. Rennie and McClafferty (1996) also examined visitors' reasons for visiting interactive exhibits and investigated whether visitors intended to learn concepts in such exhibits or to have fun. Research also argued that the entertainment aspects of science centers outweighed their educational aspect (Ertaş, Şen & Parmaksızoğlu, 2011; Rennie & McClafferty, 1996). This research result is consistent with that of the present study indicating that students found the experimental setups at the science center impressive and enjoyable. Eshach (2007) also claimed that education was missed when entertainment was foregrounded, and further noted that when education and entertainment were brought under the same roof, education would lose.

In order for education to be realized through planned activities in out-of-school learning environments and in order to help students acquire specific goals and behaviors, teachers should clarify their goals and take precautions, if necessary, according to the nature of such visits.

In this study, the participating students were asked a set of questions to determine their behaviors during the visit to the science center. Among these questions, the question "*Did you ask instructors questions during the visit?*" was answered yes slightly above the average. Considering the students' responses to the question "*Did you practice every experimental setup by yourself?*", it was answered yes in a fashion increasing from lower grades to higher grades.

When the students were asked whether the experimental setups at the science center were relevant to the topics taught at school, approximately 50%-65% of fifth, sixth and

seventh-grade students reported that there were relevant. The rate was 92% for the eighth graders. Considering the students' responses to the question “*What are your favorite three experimental setups at the Science Center?*”, the two most favored experimental setups at Bursa Science and Technology Center were tornado formation for all grade levels, and vortex tunnel for sixth, seventh and eighth-grade levels. The reason why these experimental setups were found interesting at every grade level can be the fact that they practiced themselves, there were different visual elements (Vortex Tunnel), or they confronted an unexpected situation (Tornado Formation).

In Champagne's (1975) research, a total of six hours visit to the science museum was made and this situation was described as “having fun but not being satisfied”. Champagne highlighted the point where the true meaning became obscured. In this study, the students were asked to write the names of experimental setups that they liked. However, when they were asked to report the underlying concepts, the majority of students failed to express. Although the experimental setups consistent with curriculum acquisitions were also practiced within the scope of this study, different teaching methods and techniques were not used to support learning. Accordingly, for the accurate description of concepts related to the experimental setups or in other words, for the effective association of these concepts with everyday life as cited in the literature (Bozdoğan, 2007; DeWitt & Osborne, 2007; Erten & Taşçı, 2016), it can be helpful when teachers plan such trips in advance and repeat and when different teaching methods and techniques applicable in out-of-school settings are used.

Science classes involve many phenomena and events that we encounter in everyday life. Research has shown that it is more meaningful and persistent for students to learn science subjects in relation to everyday life, that is, to learn by watching, touching, researching materials in the natural environment (Tatar & Bağrıyanık, 2012). Based on the research results, out-of-school learning environments should not be planned only as trips, activities to be conducted in such environments should be associated with science curricula, and thus, students are helped to have several acquisitions, to better understand subjects, and to conceptualize new concepts in concrete terms. Under this perspective, science centers seem to contribute to the association of science with everyday life.

### **Suggestions**

1. The most favored experimental setups at science centers can be identified for all grade levels, and they can be used as a focus of interest when students become less interested during visits.
2. Students can be informed by science centers about their operation.

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## Studies Conducted on Entrepreneurship in Science Education: Thematic Review of Research

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### ABSTRACT

In recent years in many educational curriculums, entrepreneurship has attracted much attention as a concept, from primary education to higher education. In this sense, attention is given to the concept of entrepreneurship that is included in both national and international science education curriculums. In this research, the aim was to investigate studies conducted on entrepreneurship in science education in terms of their general characteristics (publication year, number of authors, publication type) and characteristics of their content (purpose, method, data collection tool, sample type, conclusion and suggestions). As a result of the research, it is noteworthy that studies have been published in recent years in general. On the other hand, it was identified that there are studies much more published as literature review, document analysis, theoretical. In some research, it was seen that the teaching model, curriculum and modules are developed and integrated within science education to promote entrepreneurship. In addition, it is observed that in most of the studies have been reached positive results about the concept of entrepreneurship should be integrated with science education. Depending on the results, it should be said that teaching curriculums can be designed and implemented that are likely to improve students' entrepreneurial skills in science courses.

**Keywords:** Entrepreneurship, science education, thematic review.

### INTRODUCTION

Entrepreneurship is among a number of skills that students should consider to gain, and the concept of entrepreneurship is mentioned in the majority of teaching curriculums. Therefore, the knowledge and skills of teachers concerning entrepreneurship is seen as important. Entrepreneurship has special significance in terms of science education. Because the concept of entrepreneurship is one of the concepts frequently pronounced in science education, especially in recent years.

When definitions are considered in the field of business and economics, for example, according to Schumpeter, the entrepreneurship is defined the new combination of existing factors (Schumpeter, 1934). Also, Knight (1921) stated that entrepreneurship is related to uncertainty. Gartner (1988) expressed that entrepreneurship is the process of creating new ventures. When definitions are considered in the field of education, it was seen that



entrepreneurship is attributed to an individual's ability to transform ideas into action (European Commission, 2011). On the other hand, it has been stated that entrepreneurship in education is about students improving the characteristics and mentality that enables them to transform creative ideas into entrepreneurial action (European Commission, 2016). In this sense, the basic competencies in science education are ranked as collaboration, listening to the ideas of others, critical thinking, being creative and taking the initiative, solving problems and taking risks, and making decisions (European Commission, 2015). Therefore, it can be said that entrepreneurship and science education have some common aims.

It is emphasized that the links between science, innovation, creativity and entrepreneurship are important (European Commission, 2015). It was noted that entrepreneurship has an important implementation area in terms of education in physics, chemistry and biology (Agommuoh & Akanwa, 2014; Ejilibe, 2012; Ezeudu, Ofoegbu & Anyaegbunnam, 2013; Hilario, 2015). Also, the concept of scientific entrepreneurship is mentioned. It seems that scientific entrepreneurship means the process of producing innovative, science-based products based on the ability to forecast a new product that is not on the market (Peter & Anne, 2000). In addition, it is stated that students can gain entrepreneurial characteristics through science laboratories, workshop practices, in-class and extracurricular activities (Adeyemo, 2009). Table 1 briefly summarizes some studies carried out in the field of science education.

**Table 1.** *Related literature in science education*

The scope of the research	Studies conducted in literature
Investigating the opinions of students, prospective teachers, teachers and educators	Agommuoh & Akanwa, 2014; Buang, Halim, & Meerah, 2009; Bolaji, 2012; Deveci & Çepni, 2015b; Deveci, 2016b; Deveci & Seikkula-Leino 2016; Habila-Nuhu-Clark & Pahalsan, 2014; Pan & Akay, 2015; Çelik, Gürpınar, Başer & Erdoğan, 2015
Informative literature review and theoretical research.	Abdu, 2011; Achor & Wilfred-Bonse, 2013; Adeyemo, 2009; Bacanak, 2013; Erarslan, 2011; Ejilibe, 2012; Nwakaego & Kabiru, 2015
Suggestions of entrepreneurial activity, enterprising education module and (hands-on) laboratory kits.	Deveci, Zengin & Çepni, 2015; Hsiao, 2010; Young, 1991
Examination of curriculum (for example, acquisitions, activities).	Güven, 2009; Güven, 2010
Experimental studies on characteristics of taking risks	Çelik, 2010; Yıldız, 2012
Examination of teaching practices.	Koehler, 2013; Hsiao, 2010;

As seen in Table 1, most research regarding entrepreneurship in science education has examined the perceptions and opinions of students, prospective teachers, teachers and educators. It can be said many literature reviews and theoretical research studies have been performed to improve the understanding of entrepreneurship in science education. Some studies have introduced training modules and investigated hands-on lab kits as examples of entrepreneurial activity based on entrepreneurship. Also, experimental studies have been conducted to determine the effects of project-based learning and problem-based learning on students' characteristics of taking risk. It is possible to come across qualitative studies that directly examine teachers' practices. However, no thematic review conducted on entrepreneurship in science education has been encountered. Therefore, this research will contribute to the literature in different ways.

First, we will attempt to understand the studies conducted on entrepreneurship in science education, and their point of view. Second, we will identify the methods and data collection tools used in studies on entrepreneurship. Third, we will determine which dimensions have deficiencies. Finally, we will have an idea what teachers or educators think about integrating entrepreneurship into a science curriculum. The aim of this study is to investigate studies conducted on entrepreneurship in the literature of science education. Therefore, the questions that arise are as follows:

- What is the distribution of studies according to their general characteristics (year, author, publication type)?
- What is the distribution of studies according to the characteristics of their contents (aims, methods, data collection tools, results, and suggestions)?

## METHODS

In this research, the studies on entrepreneurship in science education were examined thematically through content analysis. For this, in much research, a matrix was used as a guide (Çalık, Ayas & Ebenezer, 2005; Kurnaz & Çalık, 2009; Unal, Çalık, Ayas & Coll, 2006; Yücel-Toy, 2015). Content analysis is divided into three groups: “meta-analysis, meta-synthesis (thematic content analysis) and descriptive content analysis”. It has been stated that meta-synthesis (thematic content analysis) means synthesized and evaluated studies carried out on a specific subject using a matrix created by researchers (Çalık & Sözbilir, 2014). The matrix generally contains the themes, such as the aims, methods, data collection tools, important findings, and important results. Each study was examined separately using this matrix (Table 2). The general trends in the studies were identified in this way.

### a) Data Collection

Databases were scanned using the following keywords to identify publications: "enterprise" or "entrepreneur" or "entrepreneurship" or "entrepreneurship education" and "teacher education" or "teacher" or "elementary school" or "secondary school" or “biology education” or “chemistry education” or “physics education”, and were written in English, provided that the concept of "science education" was fixed. A total 38 publications were retrieved from the databases according to matrix in Table 2. These publications are marked with “\*” in the reference section (for example, \*Chigozie, 2014).

The databases included the Education Resources Information Center (ERIC), Education Research Complete, Academic Search Premier (EBSCO), ScienceDirect, PsycArticles (ProQuest), Social Science Citation Index, Taylor & Francis Online Journals, Emerald Journals and Theses Database, Web of Science – SocINDEX With Full Text, Wiley Online Library, Bibliography of Asian Studies, First World War Portal, Sage Research Methods Online, Springer LINK Contemporary, PROQUEST Dissertations and Theses Full Text, Council of Higher Education Thesis Center, and TUBITAK ULAKBIM.

**Table 2. Matrix**

Themes	Codes	Explanations
General Characteristics	Years of publication	Year of published study
	Number of authors	Number of authors in the study
	Type of publication	Group of publication (articles, congress, thesis, etc.)
Content Characteristics	Aims	Aim of the study
	Methods	Qualitative (case study, phenomenology etc.)
		Quantitative (survey, experimental, etc.)
	Data collection tools	Tools used in obtaining the data (observation, interview, Likert scale, etc.)
Results	Basic results of study	



**b) Data Analysis**

The above matrix was used to analyse the studies accessed from the databases. At first, codes were prepared to correspond to each category. For example, each study is categorized according to year of publication and number of authors. Then, the aims of the studies were coded. Studies with common objectives are grouped under the same code. Studies with a similar general purpose have been named under the theme name by combining codes. For example, as seen Table 4, studies aiming to determine the perceptions and opinions of participants about entrepreneurship are shown under the theme named as perceptions and opinions. Similar processes were followed in the creation of other codes and themes.

**c) Reliability of Study**

The use of data collection tool in many research shows it is reliability tool (Çalık et al., 2005; Kurnaz & Çalık, 2009; Unal et al., 2006; Yücel-Toy, 2015). On the other hand, the codes and the themes created by a different researcher are used to provide reliability. And then, these codes and themes created researcher author and a different researcher who is specialist in science education were compared. The percentages of codes and themes agreed on by researcher author and a different researcher was 84. The codes and themes re-examined by researcher author and a different researcher that cannot be agreed on. Finally, both researchers accepted the codes agreed upon by arguing.

**d) Limitation of the Study**

This research is limited to publications such as articles, theses and conference papers available using databases. National and international reports prepared in the context of science education are excluded. Also, this research is limited to studies carried out about entrepreneurship in science education. In addition, this research is limited to the databases mentioned above within the scope of this research. For research ethics, the coding process was overseen by a researcher other than the research authors. It is aimed at reducing the prejudices in this way.

**FINDINGS**

This section contains findings about the general characteristics and characteristics of the content of the studies under investigation. Table 3 contains findings related to the general characteristics of the studies.

**Table 3.** General information about the studies

Themes	Codes	f	Total
Years of publication	1999 and before	1	38
	2000-2003	2	
	2004-2007	1	
	2008-2011	8	
	2012-2016	26	
Number of authors	1	20	38
	2	12	
	3	5	
	4	1	
Type of publication	Article	29	38
	Conference/seminar/congress/symposium	2	
	Thesis	7	

When the studies' general characteristics were examined, it was seen that most of the studies were conducted from 2012 to 2016. With regards to number of authors, studies with one or two authors are far more common, while in terms of publication type scientific articles are more preferred. Table 4 shows the distribution of studies according to their aims.

**Table 4.** Distribution of studies according to aims

Themes	Codes	f	Total
Perceptions and opinions	Determination of prospective teachers' perceptions and competences related to entrepreneurship.	2	6
	Examining the opinions of science teacher educators about the process of entrepreneurship education.	2	
	Investigation of physics teachers' perceptions about entrepreneurial characteristics.	1	
	Exploring the thoughts of entrepreneurial scientists who have developed innovative products on their own initiative.	1	
	Examination of science teachers' perspectives on integrating entrepreneurship education with science curriculum.	1	
	Investigation of the views of teachers about the effects of science courses on the entrepreneurial characteristics of students.	1	
	Examination of the level entrepreneurial characteristics acquired by students through a physics education curriculum.	1	
	Examining prospective teachers' views on the necessity of an entrepreneurial education.	1	
	Examining the level of productivity of chemistry students for entrepreneurship.	1	
	Determination of how science teachers perceive entrepreneurship in education.	1	
	Determining the levels of entrepreneurial characteristics of prospective teachers.	1	
	Investigating the entrepreneurial characteristics of prospective teachers in terms of some variables.	1	
	Examining the views of science teachers about the entrepreneurial characteristics of the students.	1	
	Examining the learning styles of students according to their entrepreneurial characteristics.	1	
The importance	Provide better understanding of the basic concepts related to the	6	

of the concept of entrepreneurship	<p>concepts of entrepreneurship.</p> <p>Provide an understanding of the problems and challenges faced by entrepreneurship in chemistry education.</p> <p>Clarification of the importance of entrepreneurship in biology education.</p> <p>Shed light on the teaching of entrepreneurship in a primary education life science curriculum.</p> <p>Discussion of the great gap between creating job opportunities and education in terms of science and technology education.</p> <p>Emphasize the need to develop the entrepreneurial characteristics of chemistry graduates from the view point of entrepreneurship in education.</p>	
Applied studies	<p>Providing training to teachers on being inventive and innovative, and becoming entrepreneurs.</p> <p>Explaining what engineering is in a science curriculum with the definition of science teachers, and explaining the development process of hands-on laboratory kits.</p> <p>An examination of two science teachers who created entrepreneurial learning opportunities for students going beyond classroom practices in science education.</p> <p>Development of entrepreneurial characteristics of scientists in the field of science at universities.</p> <p>Identification of the difficulties faced by prospective teachers in the entrepreneur project development process.</p> <p>Development, implementation and evaluation of a science-based enterprise training module in middle school science courses.</p>	6
Experimental studies	<p>Investigation of the effect of a problem-based learning approach on students' higher-order thinking skills and the level of academic risk-taking.</p> <p>Examination of the effect of a problem-based learning approach on students' attitude towards the science and technology course and the effects of their academic risk-taking.</p> <p>Determination of the effect of a project based learning approach on students' problem-solving skills and the effects of their academic risk-taking.</p>	3
Structuring the teaching curriculum	<p>Discussion on the need to restructure science, technology and mathematics education in terms of entrepreneurship.</p> <p>Attention is drawn to the fact that an education curriculum for science teachers should be restructured in terms of entrepreneurial education.</p>	2
Teaching curriculum	<p>Investigating the acquisitions of a science curriculum in terms of entrepreneurial characteristics.</p> <p>Investigation of the Primary Education Life Science teaching curriculum in terms of entrepreneurial characteristics.</p>	2
Scale development	<p>Developing an entrepreneurship scale for prospective science teachers.</p> <p>Development of a science laboratory entrepreneurship scale.</p>	2
Other	Suggest ideas and activities that will enable students to take risks.	1

When the aims of the studies are examined, it seems that a large number of studies aim to determine the perceptions or competencies of educators, teachers, prospective teachers and students (15). On the other hand, in some research, emphasis is placed on the importance of the concept of entrepreneurship and entrepreneurial characteristics (6). In addition to these aims, variables affecting academic risk taking have been investigated

using experimental investigations (3). Furthermore, studies have been encountered that were aimed at restructuring a science teaching curriculum in terms of entrepreneurship (2); aimed at examining a science teaching curriculums in terms of acquisitions, workbook activities and textbook activities (2); aimed at developing a scale (2); and aimed at suggesting ideas and activities that will enable students to take risks (1). Table 5 shows the distribution of studies in terms of preferred methods.

**Table 5.** *Distribution of studies according to preferred methods*

Research approach	Methods	f	Total
Quantitative research	Survey research	9	12
	Experimental research	3	
	Phenomenological research	7	
Qualitative research	Case studies	2	13
	Stated that only qualitative research	4	
	Literature review / Theoretical research	8	
Other	Unspecified	5	13

When table 4 is examined, it was seen that the survey research method was preferred in some studies (9), and the experimental research method was preferred by other studies (3) in the quantitative research category. According to the qualitative research category, it was determined that some studies used a phenomenological research method (6); two studies preferred the case study method, and some researchers simply explained that they used a “qualitative method” (4). Additionally, some research was carried out as a literature review and theoretical research (8), whereas in other research it was observed that there was no statement about the method of study (5).

**Table 6.** *Distribution of studies according to preferred data collection tools*

Data Collection Tools	f
Likert scales / Graduated scales	13
Interviews	12
Open ended questions	4
Documents / Archives (workbook, textbook, learning outcomes etc..)	3
Observations	2
Field notes	1
Unspecified	9

As seen in Table 6, researchers preferred Likert type scales to obtain data (13) - this was followed by collecting data through interviews (12). In addition, it was observed that open-ended questions (4) are also used to gather data. Moreover, it has also been found that studies benefit from observations (2) and field notes (1). Distribution of the studies according to preferred sample groups is given below.

**Table 7.** *Distribution of the studies according to preferred sample groups*

Participants / Sample	Level	f	Total
Educator / Teacher	Primary school	1	17
	Middle school	8	
	High school	5	
	University (academic-lecturer)	4	
Student	Primary school	0	13
	Middle school	3	
	High school	3	
Unspecified	University (prospective teachers)	7	11

When the preferred sample groups in Table 7 are looked at, it can be seen that some research preferred educators who were working at primary school level (1), working at middle school level (8), working at high school level (5), and working at university level (4). Moreover, it was observed that other research preferred students who received training in middle schools (3), students who received training in high schools (3), and prospective teachers who received training at university (7). On the other hand, it was determined that there was no expression concerning sampling in the rest of the studies (11). Findings obtained from the research results are given below.

**Table 8.** *Distribution of studies according to obtained results*

Themes	Codes	f
Educators	Teachers have enough knowledge about the concept of creativity and entrepreneurship, and they have taken into account verbal expressions in order to gain entrepreneurial characteristics.	8
	It has been stated that teacher trainers focus on the risk taking characteristic of students, they include cooperative learning, and invite entrepreneurs into the classroom.	
	Teachers believe that they should have entrepreneurial characteristics, such as effective communication, effective planning, competitiveness and risk taking.	
	Teachers are informed about entrepreneurship in education, and they have become more conscious about the possibilities and meanings of entrepreneurial education.	
	It is stated that teachers' entrepreneurial activities create an innovative learning field; for students, educational opportunities are supported by external society.	
	It is concluded that entrepreneurial scientists could evaluate candidates in various positions for science-based innovation.	
Students and prospective teachers	It has been determined that teacher trainers are involved techniques like teamwork and brainstorming in their classes, and they focused on characteristics of creativity and risk taking for students.	6
	It has been pointed out that the entrepreneurial characteristics of teachers influence the development of the entrepreneurial characteristics of students.	
	It is stated that prospective teachers find entrepreneurial education very important in terms of it being in their educational curriculum.	
	It is stated that prospective science teachers have many more entrepreneurial characteristics than among the teacher education departments of Turkish, Science, Mathematics, English, Primary School, and Pre-school.	
	It is stated that men are better than women in terms of taking risks and being innovative, and that senior prospective science teachers have more innovative characteristics than other grade levels.	
	It was determined that students with a kinaesthetic learning style were more effective in their entrepreneurial characteristics.	
Integration of entrepreneurship with	It was determined that science-based, entrepreneurial education modules positively reflected students' awareness on entrepreneurship.	6
	It is stated that this situation reflects positively on the scientific process skills of students when their entrepreneurial characteristics are increased.	
	The result is that science teachers have a positive perception about integrating entrepreneurship with science education.	

science education	<p>In terms of entrepreneurship, it is stated that the curricula of chemistry teaching should be reviewed and changed.</p> <p>It is stated that entrepreneurship training has to be included in chemistry education.</p> <p>One of the steps in the process of change in science and technology education is to create an entrepreneurial environment.</p> <p>In order to increase entrepreneurship in biology education, biology has played an important role in enhancing national development.</p> <p>It is stated that an entrepreneurial education should be a part of teacher education curriculums, especially in the field of chemistry education.</p>	
Curriculum	<p>It has been determined that acquisitions in the primary school curriculum do not meet a majority of entrepreneurial characteristics.</p> <p>In terms of entrepreneurial characteristic, the acquisitions of the 2005 Life Science Curriculum have become more prominent, but not sufficient, in comparison to previous years.</p> <p>Emphasis is on the appropriateness of the acquisitions of the curriculum to the student level, and the preparation of the learning and teaching environments supporting the entrepreneurship of the teachers.</p> <p>It was emphasized that entrepreneurship should be included among the purposes of teachers' education curriculum.</p> <p>It has been suggested that a learning model composed of 5-steps can be used in a science curriculums</p> <p>Risk taking levels are divided into 5 categories and sample activities are introduced.</p>	6
Experimental Results	<p>It is concluded that the project-based learning approach has a positive effect on the risk taking characteristics of students.</p> <p>It has been determined that the probing-based learning approach has a positive effect on the level of taking risks of students.</p> <p>It has been determined that the probing-based learning approach has no effect on the level of taking risks of students.</p>	3
Development of scale	<p>It appears that a scale consisting of taking risks, being innovative, self-confidence, seeing opportunities and emotional intelligence has been developed.</p> <p>It appears that a scale consisting of communication, self-efficacy, taking risks, the need for success and creativity has been developed.</p>	2
Deficiencies	Students	It has been stated that physics students have low entrepreneurial characteristics.
	Prospective teachers	<p>It has been stated that no courses in teacher education will increase the understanding of innovation and entrepreneurship of prospective teachers.</p> <p>It has been determined that prospective teachers have a limited and insufficient understanding of entrepreneurship.</p> <p>It has been determined that prospective teachers have difficulty in creating innovative ideas and foreseeing unexpected situations.</p>
	Teachers	<p>It is stated that the teachers do not have enough knowledge about engineering, and they do not consider important elements about engineering.</p> <p>It is stated that teachers do not have the necessary knowledge about entrepreneurship.</p>

Table 8 shows that the results for educators obtained in the studies are much higher (8). Also, it has been reached the results about the integration of entrepreneurship into the science curriculum (6). It is seen that the results related to the acquisitions, goals and activities of the teaching curriculums have also been reached (6). Moreover, results related to deficiencies or difficulties faced, in terms of students, teachers, and prospective teachers, have also been reached (6). Some of the studies have been reached the positive results about students and prospective teachers (6). In the studies composed taking into account experimental design, researchers focused on characteristics of taking risk (3). In addition to, it is seen that there are studies towards Likert type scale development in the literature (2). Table 9 below gives the distribution of studies according to suggestions.

**Table 9.** *Distribution of studies according to suggestions*

Themes	Codes	f
Suggestions for Teacher Education	(4) Science teachers must be educated through in-service education, continuing education or seminars.	13
	Duties ensuring prospective teachers communicate with different institutions or organizations should be increased.	
	Entrepreneurship in education should be an integral part of science teachers' curriculums and integrated into all disciplines.	
	Entrepreneurship in education should be integrated into science teachers' curriculums. Also, it should be integrated into science subjects in particular.	
	Educational content should be given that will increase prospective teachers' knowledge and experience related to entrepreneurship in science education.	
	Seminars and workshops related to entrepreneurship must be arranged that allow the participation of prospective teachers.	
	Entrepreneurship in education should be made part of teacher education in terms of chemistry education.	
	Teachers should try to understand the problems students face in the process of improving their entrepreneurial characteristics.	
	Entrepreneurial scientists should establish an effective communication network.	
	Entrepreneurship in education among teachers should be emphasized, and a suitable environment for this education should be provided.	
Suggestions for approach, strategy, method, technique and learning environments	Minor projects should be carried out using accessible materials for entrepreneurial teaching in chemistry education in schools.	9
	Science educators should benefit from additional methods and techniques in entrepreneurial education, such as probing-based learning, collaborative learning, creative problem-solving techniques, a learning diary and project-based learning.	
	Interactive demonstrations should be made using an innovative laboratory kit related to entrepreneurship and engineering for 9-12 grade level.	
	Strategies, methods, techniques, models and course content will positively affect entrepreneurial characteristics, and should be prepared by increasing the number of applied studies.	
	For students, visits must be organized to various industries, zoos and fields related to biology.	
	In order to support entrepreneurship, appropriate learning-teaching environments should be prepared that are open to teachers.	
	Activities should be created to improve the entrepreneurial characteristics of students.	
	Training environments should be equipped with more human resources in parallel with developments over time.	
Students should be supported by student-centred learning approaches to ensure that they can take risks		
Suggestions for curriculum	Entrepreneurial acquisitions should be added to the curriculum at each grade level of primary education according to the development of the individual.	7
	Acquisitions that can benefit entrepreneurial characteristics should be given more prominence in future studies on life science, curriculum development.	
	An entrepreneurial education, and concepts related to this education, should be	

	included in all educational curriculums.	
	Entrepreneurial characteristics and creativity must be gained to students at an early age.	
	Entrepreneurial characteristics must be integrated with scientific process skills.	
	Science, technology and mathematics curriculums must be restructured to include entrepreneurship.	
	Chemistry students' productivity skills should be further supported.	
Suggestions for applied studies	Applied studies on entrepreneurship in science education should take into account variables of participants' gender, work experience, reward and grade level.	
	The training modules that are most effective in developing entrepreneurial characteristics should be determined.	
	A learning model called "entrepreneurial scientific thinking" has been proposed.	6
	Different methods should be tried to improve students' high-order thinking skills, and to develop risk taking.	
Suggestions for survey study	The levels of entrepreneurial characteristics acquired by students in private schools should also be studied, and in different science subjects.	
	For students with kinaesthetic and visual learning styles, students should be directed to entrepreneurship by preparing appropriate learning environments.	
	Survey studies should be carried out using laboratory entrepreneurship scales, developed according to different variables.	2
Unspecified	Comparative studies should be conducted using a developed entrepreneurship scale.	1

As seen Table 9, a large majority of the suggestions are stated towards teacher education (13). There are also suggestions on approach, strategy, method, technique and learning environments to realize entrepreneurship in science education (9). Moreover, it seems that there are suggestions regarding the structure of a science teaching curriculum in terms of acquisitions, concepts related to entrepreneurship, and entrepreneurial characteristics (7). On the other hand, it is also possible to see suggestions for applied studies (6), and for survey studies (2).

## DISCUSSION and CONCLUSION

### a) General Characteristics

When the general characteristics are examined, it is apparent that in recent years an increasing number of studies have been published on entrepreneurship in science education; this shows that interest in, and the importance of, entrepreneurship is growing. This situation can be attributed to the concept of entrepreneurship that has become more pronounced in the field of science education in recent years, consequently this concept began to take place in the science curriculum. For example, in a European Commission report on science education, it was emphasized that the links between science, creativity, entrepreneurship and innovation must be strengthened (European Commission, 2015). As a result, this has been included the concept of "entrepreneurship" among the life skills in the 2013 and 2017 science curriculum for grades 5-8 in Turkey (Ministry of Education, 2013; 2017). Therefore, it can be said that entrepreneurship is integrated with the science curriculum in Turkey. On the other hand, Finland, which has a broad education strategy concerning entrepreneurship in its latest five-year development plan for education and research (2011-2016), has aimed to develop entrepreneurship at all levels (Audiovisual and Culture Executive Agency, 2012). These developments, both internationally and nationally, may have led to the search for entrepreneurship in science education in scientific research.

Moreover, in the current study, according to author numbers, it appears that articles with a small number of authors were published. This situation can be attributed to the fact



that there are no projects or cooperative work in this area, because entrepreneurship is a new research topic in science education. We know that when publications emerge from projects or collaborative research they can have multiple authors. However, in the coming years it could be possible to see publications by multiple authors in this area. Finally, it was observed that in terms of publication type, publications are mostly printed as articles. It was also determined that there are few conference presentations and theses.

#### **b) Aims**

When the distribution of publications is examined according to their aims, it is noteworthy that they aim at getting participants' opinions, perceptions and qualifications about entrepreneurship in science education (Armstrong & Tomes; 2000; Bolaji, 2012; Çelik, Gürpınar, Başer & Erdoğan, 2015; Deveci, 2016b; Deveci & Seikkula-Leino, 2016). Furthermore, it seems that studies whose aims are theoretical, or are a literature review on entrepreneurship in science education, seem to be more numerous (Deveci & Çepni, 2014; Ezeudu, Ofoegbu & Anyaegbunnam, 2013; Nwakaego & Kabiru, 2015). This can be attributed to giving priority to studies designed as theoretical or literature reviews, which is informative in this respect as entrepreneurship is a new research topic in science education. Therefore, when an original research problem is defined, the current situation should be determined first, then educational dimensions about the related concept should be discussed.

It can also be seen that the number of studies aiming at developing the education module (the curriculum and the teaching process related to entrepreneurship), seems to be quite high (Kleppe, 2002). The cause of this situation can be attributed to researchers progressively focussing on the practice dimension about entrepreneurship in science education. This is because how entrepreneurship is integrated into science education is a subject of curiosity in the literature.

On the other hand, experimental studies examining the impact of different variables on the ability to take risks were also found in the literature (Çelik, 2010; Çınar, 2007; Yıldız, 2012). It is noteworthy that these research studies especially focused on the characteristic of taking risks. This situation is normally acceptable because the most emphasized characteristics in an entrepreneurial education is the characteristic of risk taking. Thus, risk taking is an accepted prerequisite for success (European Commission, 2014). In this sense, a researcher suggested activities for developing the characteristics of risk taking (Young, 1991).

Moreover, it is also possible to see studies that intend to focus on the restructuring of science teaching curriculums in terms of entrepreneurship (e.g. Ezeudu et al., 2013), and some studies aim to examine learning outcomes in terms of entrepreneurship (Güven, 2009; Güven; 2010). In this instance, the question that arises is to what extent the structure of teaching curriculums are appropriate to gain entrepreneurial characteristics. As expected, it seems that some researchers intend to solve this problem using both curriculum construction and current acquisitions. In addition, some researchers developed scales about entrepreneurship in science education (Çelik, Bacanak & Çakır, 2015; Deveci & Çepni, 2015a). It can be said that Likert type scales are needed to observe the development of some entrepreneurial characteristics in students or prospective teachers.

#### **c) Method**

When the studies were examined in terms of method, it was observed that many more used a survey or phenomenological research. The fact that the survey research method is too high indicates that studies about the opinions of participants about entrepreneurship are weighted. Therefore, these findings can be interpreted in that most researchers first try to

determine the opinions of educators, students or teachers who have encountered new concepts, such as the concept of entrepreneurship. We know that the survey research method could be used to obtain some aspects or properties of a particular group on a topic, e.g. abilities, opinions, attitudes, beliefs, and/or knowledge (Fraenkel & Wallen, 2006). Similarly, the reason why the phenomenological research method is preferred can be attributed to researchers who want to determine the perceptions of educators, students or teachers about their knowledge and experiences regarding entrepreneurship.

It was stated that an experience has a different meaning for different people (Ary, Jacobs, Sorensen & Razavieh, 2010). It was seen that there are many more literature reviews and theoretical research about entrepreneurship in the science education literature (Adeyemo, 2009; Deveci & Çepni, 2014; Ejilibe, 2012). Actually, it can be said that the educational dimension of entrepreneurship has not become widespread in the literature of science education until recently, therefore in recent years researchers have tried to clarify what this means. For example, Ezeudu et al., (2013) shed light on the importance of entrepreneurship in chemistry education. Similarly, Ejilibe (2012) draws attention to the importance of entrepreneurship in biology education. On the other hand, Deveci and Çepni (2014) draw attention to the importance of dimensions like environment, pedagogy, educator, school, administrator, business world, and science teacher education. Accordingly, it may be said that the number of literature reviews and theoretical research regarding the importance of the educational dimension of entrepreneurship in science education will increase in the coming years.

#### **d) Data Collection Tools**

In the studies under investigation it was noted that the most preferred data collection tools were Likert type scales and interviews (Agommuoh & Akanwa, 2014; Boloji, 2012; Deveci & Çepni, 2015b; Deveci, 2016b). The preference of Likert type scales indicates that more studies were conducted on large sample groups. On the other hand, the preference of interview method showing that there are the studies was conducted on small sample groups. Therefore, it can be said that both Likert type scales and interviews are preferred at approximately the same rate in the literature. However, some of the data collection tools are not preferred, e.g. observations and field notes.

#### **e) Sample Group**

The research preferred educators as participants (Deveci & Seikkula-Leino, 2016; Hsiao, 2010; Koehler, 2013; Habila-Nuhu-Clark & Pahalson, 2014). In fact, it is a matter of curiosity as to what kind of practices educators do related to entrepreneurship, and what the educators think about it. For this reason, it can be said that many more studies are conducted on educators. In parallel with this situation, it was also observed that many more studies are conducted on students (Çınar, 2007; Deveci, Zengin, & Çepni, 2015; Yıldız, 2012). Therefore, it appears that studies are widely used to determine what variables influence the entrepreneurial characteristics of students, e.g. risk taking (Çelik, 2010; Çınar, 2007; Yıldız, 2012). Moreover, research carried out on prospective teachers is also quite high (Çelik, Bacanak & Çakır, 2015; Deveci, 2016b; Deveci & Çepni, 2015b). This situation indicates that the dimension of teacher education of entrepreneurship should not be ignored. This is because it is crucial that prospective teachers, who are the practitioners of teaching curriculums, understand the educational dimension of entrepreneurship.

#### **f) Results**

It is noteworthy that there are much more the results reached about educators in investigated studies (Agommuoh & Akanwa, 2014; Bacanak, 2013; Deveci, 2016b; Deveci

& Seikkula-Leino, 2016; Kleppe, 2002). In this sense, it could be said that science teachers or educators, who have great responsibility as practitioners of a new concept like entrepreneurship in science education, play an important role. Thus, it is seen that the most emphasized dimension for entrepreneurship from an educational perspective in the European Commission reports is teacher education (European Commission, 2011; European Commission, 2013).

In the research, it is seen that researchers have tried to clarify subjects, such as what entrepreneurial characteristics teachers should have, what methods and techniques teachers should use, what activities teachers should undertake outside school, what entrepreneurial characteristics of students teachers should develop, and what knowledge and experience teachers should have about entrepreneurship.

Another point highlighted from the research results is that entrepreneurship must be integrated with science education (Abdu, 2011; Achor & Wilfred-Bonse, 2013; Deveci & Çepni, 2014; Ugwu, Laah & Olotu, 2013). This situation can be attributed to the fact that entrepreneurship and science education have common goals. As a matter of fact, it has been emphasized that the concept of entrepreneurship can easily find applications in areas of physics, chemistry and biology (Abdu, 2011, Agommuoh & Akanwa, 2014; Ezeudu et al., 2013; Ejilibe, 2012; Nwakaego & Kabiru, 2015).

Another point, drawn from the research results, is that of teaching curriculums. Some studies examined the aims and acquisitions of science curriculums (Güven, 2009; Güven 2010). Other studies make recommendations for activities and a learning model (Buang & Halim, 2007; Young, 1991). In fact, it can be said that research, which examines entrepreneurial characteristics in science teaching curriculums, has an important role in developing science curriculums. Therefore, the number of such studies is expected to increase in the coming years.

On the other hand, another factor that attracts attention in the research results is that of deficiencies for entrepreneurship. There are some shortcomings in terms of students, teachers and prospective teachers. For example, some studies indicated that teachers do not have sufficient knowledge and experience about engineering and entrepreneurship (Bacanak, 2013; Hsiao, 2010). It is also stated that prospective teachers' knowledge and experience about entrepreneurship is inadequate (Deveci, 2016b). It can be said that these results are very important for science teacher education. It is possible to prepare action plans that identify deficiencies in developing entrepreneurship within science teacher education.

#### **g) Recommendations**

In many studies, it is recommended that entrepreneurship must be part of science teachers' education (Hilario, 2015; Achor & Wilfred-Bonse, 2013; Nwakaego & Kabiru, 2015). In fact, this suggestion may seem right. This is because entrepreneurship has not yet become fully widespread in science teacher education. Thus, teacher training curriculums do not have adequate training in entrepreneurship (Seikkula-Leino, Ruskovaara, Hannula & Saarivirta, 2012). In this sense, attention is drawn to the need for good teacher education in order to benefit from entrepreneurial training in the field of education (European Commission, 2013). In the suggestions of some studies should be given in the educational process that allows prospective teachers to gain knowledge, skills and experience about entrepreneurship (Deveci, 2016a; Deveci, 2016b; Pan & Akay, 2015). It could be said that these suggestions reveal a lack of science teacher education in terms of entrepreneurship in education.

The recommendations of some studies seem to be related to the methods and techniques approach, strategy, method, technique and learning environments (Abdu, 2011;

Hsiao, 2010). These suggestions show that teachers have difficulty regarding the implementation of entrepreneurship. It was stated that they have problems in finding methods and content for entrepreneurship in the educational process (Seikkula-Leino, 2008; Solomon, 2007). In this sense, it appears that there are considerably more suggestions for a science curriculum related to entrepreneurial characteristics (Güven, 2010; Kleppe 2002; Buang & Halim, 2007). These suggestions can be generally be interpreted to mean that a science curriculum is not sufficiently developing the entrepreneurial characteristics of students. This is because it is known that science curriculums are not prepared taking into account the concept of entrepreneurship. In some studies, it is recommended that applied studies and survey studies should be carried out (Buang et al., 2009; Çınar, 2007; Deveci & Çepni, 2015a; Nwoye, 2012).

Finally, it is noteworthy that studies on entrepreneurship have been published at all in recent years. Also, most of the studies' aims were to determine perceptions, opinions and competences about entrepreneurship. Moreover, in terms of method, survey research, literature review, theoretical research and phenomenological research were preferred by most studies. In terms of data collection tools, most studies preferred Likert type scales and interviews. Furthermore, in terms of sample groups, most studies preferred middle school science teachers and prospective science teachers. In the most of the studies were reached the results for educators/teachers. Most of the suggestions has been stated for science teacher education.

#### **h) Recommendations of current research**

The following proposals can be made about conducting studies on entrepreneurship in science education:

- In terms of methods for future research, experimental design, action research and a case study may be preferred.
- It can be said that, in terms of sample groups, the number of studies conducted on primary school teachers and middle school students can be increased.
- In future research, studies could be conducted related to entrepreneurship in pre-school science education.

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## Instructor's Use of Student-Generated Annotated Concept Sketches in Formative Assessment in General Science

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### ABSTRACT

Student-generated annotated concept sketches provide an alternative approach for instructors to formatively assess students' understanding of environmental topics, such as photochemical smog and ozone layer depletion. The sketches are external representations of students' cognitive models. Results obtained from a group of 150 female students using an action research methodology, suggest that this method is effective in enhancing students' engagement and communication among peers. This further helps students to reinforce scientific theories and concepts. Furthermore, the data gathered also revealed alternative conceptions, misconceptions, and knowledge gaps in students' understanding and provides an opportunity for easy and immediate feedback. In this study, misconceptions define ideas that are in direct contrast with the accepted scientific conceptions, whereas alternative conceptions describe ideas that are incompatible but unconflicting with the accepted scientific conceptions. Students were actively engaged and showed the ability to express their knowledge in ways other than writing, which is especially useful in English Language Learner (ELL) friendly environments. Students were required to participate in the lecture by paying special attention to the source of pollution, environmental impact, and solutions to issues related to air pollution. The representational annotated concept sketches were completed individually or in groups of two to three students. Feedback was provided orally, and/or using a rubric designed to identify and highlight understanding, misconceptions, and knowledge gaps.

**Keywords:** Concept Sketches; Formative assessment; Active learning Strategies; Cognitive models; English Language Learner Friendly Environment

### INTRODUCTION

Many undergraduate programmes require that students complete a general education component. Usually, general science is integral to the core-curriculum. General science education modules are aimed at fostering critical thinking and increasing students' global and local awareness of scientific issues (McConnell, Steer, & Owens, 2003; Solas & Wilson, 2015). However, students especially non-science majors, find it difficult to understand scientific material because of the inclusion of specialized jargon and abstract concepts (Ajaja, 2013). Within an English Language Learner (ELL) friendly environment, the complexities in terms of understanding increase, because the capacity of the mental working space of students





reportedly reduce by up to 25%, owing to translation activities (Johnstone & Selepeng, 2001). Other studies, conducted from the point of view of teaching within the Arabic English Language Learning (AELL) classrooms, have outlined the difficulties faced by not only students but also native English-speaking faculty in the Middle East (Jewels & Albon, 2012; Wilson, Copeland-Solas, & Guthrie-Dixon, 2016). As such, countries that teach science in non-native languages should be aware of the implications of reduced critical thinking among language learners (Johnstone & Selepeng, 2001).

Within the general science classroom, it is imperative that instructors are able to gain insight into students' cognitive models to regulate and adapt their teaching to meet students' learning needs. Studies have shown that an effective formative assessment results in significant learning gains especially for low achievers (Black & Wiliam, 2010). Time constraints, language barriers, and lack of useful techniques result in a paucity of useful information to fulfill the exigencies of deep learning in classrooms.

### ***Formative Assessment***

Traditionally formative assessments are grouped into areas of questioning, providing assessment criteria (e.g., rubrics), feedback through written comments, peer and self-assessment, as well as summative assessment (Black & Wiliam, 2009). However, many of these methods are time consuming and burdensome for the teacher and do not fulfill the needs of deep learning, which is the main focus of formative assessment (assessment for learning). There is still a pressing need for assessment techniques which allow teachers to gain an insight into the cognitive models of learners to establish levels of comprehension, knowledge gaps, and misconceptions in learners. Information gained from such assessments would be extremely useful in increasing the learning levels of the students. According to David Ausubel, as reported by Wiliam (2011), understanding what a student knows, bears a significant influence on future learning as it provides the teacher with the tools to adapt the teaching methodology as per the student's needs. A few researchers have revealed that, despite similar instruction, students have different cognitive models for understanding concepts based on their prior learning experiences. Some researchers are even of the view that these existing cognitive models are mainly unaffected by instruction (Chandrasegaran, Treagust, & Mocerino, 2007; Howard, Brown, Chung, Jobson, & VanReken, 2013). It is therefore crucial that teachers understand these cognitive models to be able to affect change positively.

### ***Drawing in Science Teaching and Learning***

The merits of drawing to student learning in science have been well-documented (Ainsworth, Prain, & Tytler, 2011; Davidowitz, Chittleborough, & Murray, 2010; Johnson & Reynolds, 2005; Leopold & Leutner, 2012; Mason, Lowe, & Tornatora, 2013; Nyachwaya et al., 2011; Schwamborn, Mayer, Thillmann, Leopold, & Leutner, 2010; Van Meter, Aleksic, Schwartz, & Garner, 2006; Van Meter & Garner, 2005; Zhang & Linn, 2011). In their study, *Drawing to Learn in Science*, Ainsworth, Prain, & Tytler (2011) suggest that science teachers use student drawings inside classrooms to enhance student engagement, foster reasoning, and increase communication among themselves. Leopold and Leutner (2012) state that the drawings of students provide external representations of their cognitive models and therefore exposes the comprehension level of students. Johnson and Reynolds (2005) have successfully used student-drawings in geology to stimulate thinking and practice the selection of the main ideas. In chemistry, drawings have been used to provide instructors with external representations of students' cognitive models of chemical structures at the submicro level (Davidowitz et al., 2010; Kern, Wood, Roehrig, & Nyachwaya, 2010; Nyachwaya et al., 2011). From the sketches, instructors have been able to recognize students' prior

understanding, knowledge gaps, and misconceptions, which were not obvious with traditional methods of using chemical symbols to represent reactions. It is also suggested that the discipline of having students create external representations of concepts forces them to actively arrive at main ideas, relevant connections, and the best ways to summarize and represent the information gained (Schwamborn et al., 2010). These claims have also been supported by Naylor and Keogh (2013). They proposed that concept cartoons are a valuable tool in helping learners to develop their ideas.

Generally learners readily engage in discussion when Concept Cartoons are used, and as they attempt to justify their ideas, this exposes their views to the possibility of challenge by their peers. In looking for evidence and constructing suitable arguments to justify their ideas, learners often come to recognize for themselves that their understanding is limited and that there are more productive ways of understanding the situation. (p. 7)

These actions eliminate tendencies toward superficial learning though some researchers caution that if the mechanics of drawing are too demanding they may interfere with the capacity of learners to focus on generative activity, which in turn facilitates deep learning (Schwamborn et al., 2010).

This study describes the use of student-generated sketches as a formative assessment tool in environmental science. We describe how students, when using this strategy, provide teachers with external representations of cognitive models thereby allowing teachers to adapt their teaching methodology to improve student learning, which results in deep learning.

## **METHODOLOGY**

### ***Participants***

The study used a convenience sample of N = 150 female students of a core-curriculum science course. The sample selected was based only on the classes assigned to the investigators. All students were Arabic English Language Learners. The sketches were collected over two semesters. Students either did individual sketches or were part of a group of two to three students. All students had previously taken a basic science course, which introduced them to the scientific process. Students were in their third semester or higher of their university programme.

### ***Study Design and Data Collection***

An action research methodology was the approach taken for this investigation. Action research can be defined as a process of inquiry conducted by individuals performing the action (Sagor, 2000). It focuses on instructors gaining a better understanding of their practice to inform how the practice itself can further be improved (Carr & Kemmis, 2005). The investigators mainly sought to assess how effective the use of concept sketches would be as a pedagogic strategy geared toward improving the learning experience of these language learners.

Students were taught lessons on topics related to air pollution including ozone layer depletion (OLD) and photochemical smog (PCS). At the start of each lesson, students were encouraged to note the names of air pollutants, sources of pollutants, effects on humans and the environment, and solutions to the environmental problems. Each topic was explained using a variety of methods: power point slides, anthropomorphism, videos, and animations. The explanations of the topics were repeated with emphasis being laid on the main ideas.

Students were then asked to brainstorm relevant ideas among themselves and jot down relevant information on how their ideas would be presented either individually or in groups. They were then asked to represent their understanding of the topic of study through a drawing. Drawings should include each of the main ideas emphasized and the significant relationships between the ideas. The students were also encouraged to discuss their sketches with other groups/individuals to foster communication and build each other's knowledge by listening and critiquing each other's work.

Sketches collected on photochemical smog included 36 group sketches and 54 individual sketches. A total of 68 individual sketches were collected for ozone layer depletion.

### **Data Analysis**

The data was analyzed using a phenomenographic approach (Marton, 1986). Marton defines phenomenography as studies focused on qualitatively mapping the ways students perceive concepts differently within their environment (Marton, 1986). A qualitative study was conducted on the sketches produced by students on the environmental science topics. Sketches were assessed for representation of main ideas, correct portrayal of important relationships, conceptual errors and misconceptions, knowledge gaps, alternative conceptions, sketch and label details. Misconceptions was used to define ideas that are in direct contrast to the accepted scientific conceptions, whereas alternative conceptions describe ideas that are incompatible but are unconflicting with the accepted scientific conceptions (Abimbola & Baba, 1996). Feedback to students was given either orally and/or using a rubric, which was adapted from Johnson and Reynolds (2005). Four instructors from the science department examined and analyzed the sketches based on the rubric although no grades were assigned. Information gathered from the sketches were compared, wherever applicable, to that from other studies to analyze similar issues using other techniques, such as questionnaires and interviews (Cordero, 2000; Howard et al., 2013; Papadimitriou, 2004) .

**Table 1. Rubric for Concept Sketch**

<b>Category</b>	<b>General Rubric</b>		
<b>Content</b>	All essential concepts shown	Most concepts and relationships correctly shown	Essential concepts left out
	Important relationships portrayed correctly	Some aspects left out	Relationships not portrayed correctly
	No conceptual errors or evidence of misunderstanding	Minor conceptual errors or misunderstandings	Major conceptual errors or misunderstandings
<b>Detail and Presentation</b>	Sketch detailed and clearly drawn and labeled	Sketch lacking some detail	Sketch lacking detail or is illegible
		Not clearly drawn or labeled	Sketch is difficult to interpret

Content should include the following topics: causes, effects, important pollutants, solutions, and correct relationships between pollutants and processes.

## RESULTS and DISCUSSION

The general observations showed that students spent more time on the task during this activity than that spent on traditional worksheets; further, they seemed genuinely more engaged and motivated. Students could be seen comparing their sketches with each other and frequently amended their sketches wherein they believed that their key points were omitted. Students could be heard using scientific jargon when they were brainstorming with their peers and they were seen explaining their ideas to their peers, who needed further clarification.

Administration of the drawing technique and providing feedback to students was immediate and easy. Students appreciated the timely feedback and were very actively engaged in the process. It was heartening to see students engrossing themselves to an extent that they were even oblivious of the time as they worked on their sketches. The themes that emerged from the sketches were used as diagnostic tools to frame further instruction. The sketches of the students detailed out almost all the information on the concept thereby revealing the knowledge gaps, misconceptions, and alternative conceptions that were influenced by prior learning experiences. A quick assessment on the quality of the sketches revealed that more details were added when sketches were performed in groups versus those done individually. As was observed by Ozuro et al. and reported by Leopold and Leutner (2012), students submitting high quality sketches generally had higher levels of understanding. This was evident based on the higher test scores of these students.

### *Emerging Themes from Sketches on the Formation of Photochemical Smog*

A total of 90 sketches were assessed on photochemical smog (54 individual sketches and 36 group sketches). The sketches revealed that most students understood the principle behind the formation of smog and its effects on the environment (see Figure 1). Some students found it difficult to remember the names of primary and secondary pollutants. Other misunderstandings and knowledge gaps included incorrect relationships between primary and secondary pollutants; a belief that all primary pollutants, including carbon monoxide, resulted in the formation of photochemical smog, and that photochemical smog was destroying the ozone layer. It was interesting to see student sketches, including that on the ozone layer, in the drawing of photochemical smog. This is because, though ozone layer depletion is included in the syllabus, students were not yet given instruction on the topic. This confirms that students' preexisting knowledge inside the classroom and fit knowledge gained within the lesson into their prior cognitive schema, which may lead to incorrect cognitive models if not addressed (Osborne & Wittrock, 1985) We believe in this case that students confused tropospheric ozone, formed as a part of photochemical smog, with their prior knowledge on the destruction of stratospheric ozone.

A few sketches showed no relationships, pollutants, or effects; however, they showed only structures, such as buildings and cars. These sketches were usually produced by low achieving students and further revealed that their cognitive models missed relevant information on the concept. In a few instances, it was noticed that students who were very artistic spent too much effort and time on the quality of the artwork, rather than on the generative activity. This issue was mentioned by Schwambon et al. (2010), as they cautioned users of the technique that this could occur. Figures 1–4 provide examples of student sketches on photochemical smog and some information that could be gathered from each of these sketches.

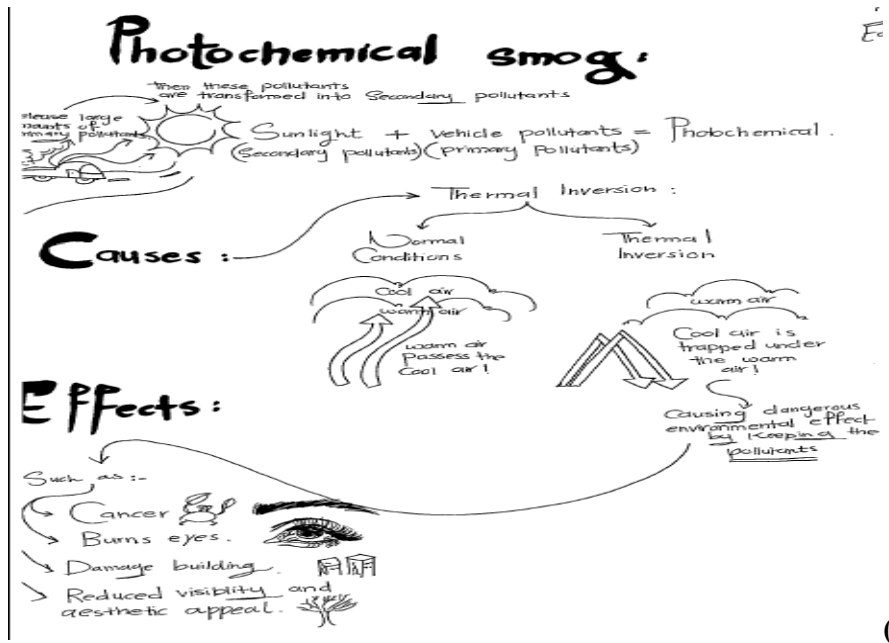
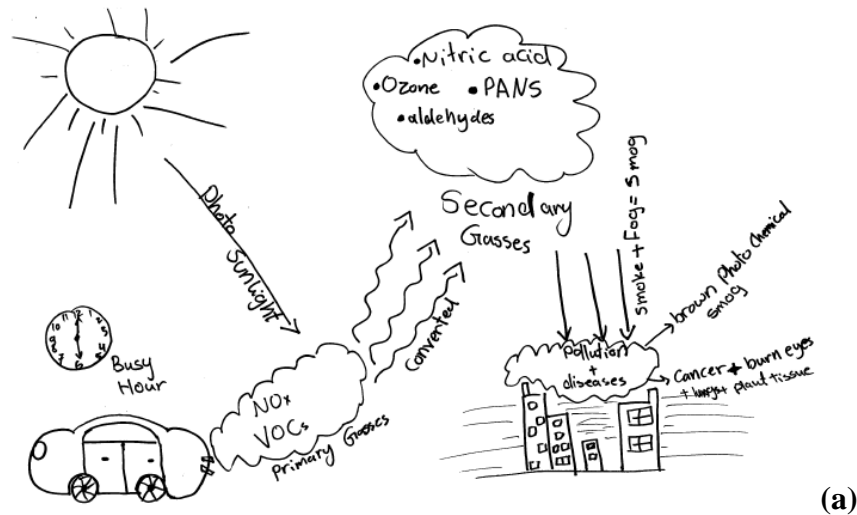


Figure 1. Two examples of student-generated group sketches on photochemical smog Findings

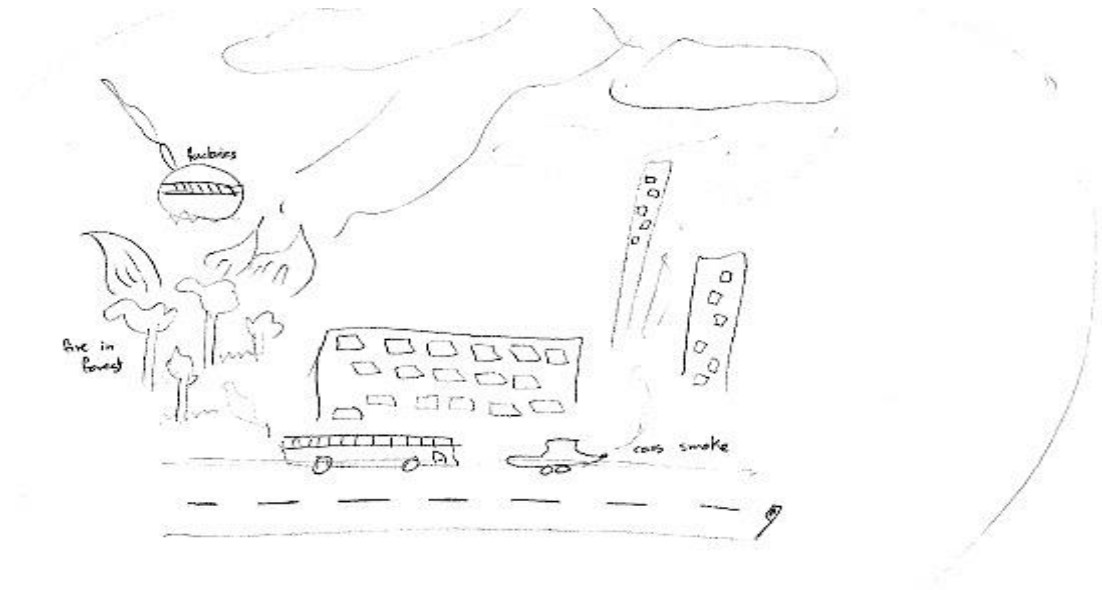
- o The sketches shown in Figure 1 provide all details on the concept thereby providing the names of pollutants, their sources, and the health as well as environmental effects of PCS.



**Figure 2.** A student-generated sketch on PCS showing the misconception that carbon dioxide is involved in all problems related to air pollution

### Findings

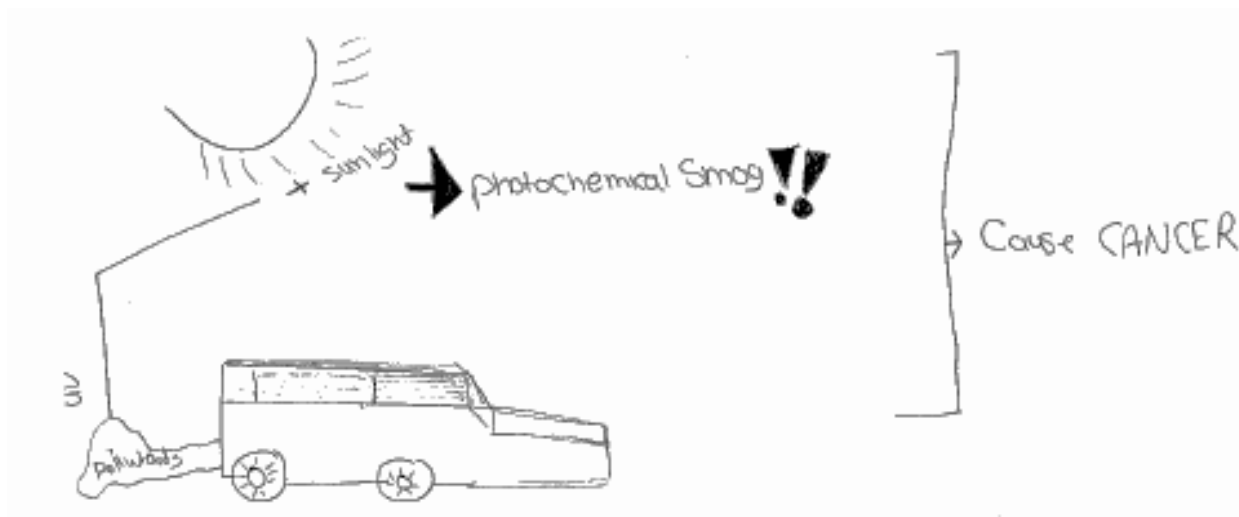
- This sketch reveals that the student understands that factories and vehicles lead to air pollution.
- The catalytic converter is called a filter on the car to indicate its “cleaning” effect on pollutant gases.
- The student understands the role of sunlight acting on oxides of nitrogen and hydrocarbons to form photochemical smog; however, he/she has failed to indicate the names of secondary pollutants.
- The student has used an increase in the number of trees to remedy the problem related to air pollution. Here, a knowledge of carbon dioxide as a pollutant is introduced; however, its involvement in photochemical smog is misplaced.



**Figure 3.** A student-generated sketch on PCS revealing knowledge gaps

### *Findings*

- The student seems unsure of how exactly photochemical smog is formed; however, he/she knows that it is a form of air pollution.
- No specific pollutants are mentioned. However, motor vehicles, factories, and burning are identified as being the contributing factors to this problem.
- The effects of and solutions to solve the problem of photochemical smog are missing from the sketch.



**Figure 4.** A sketch showing the basic idea of PCS with some knowledge gaps

#### Findings

- The names of all pollutants are missing.
- The student has a general idea of the formation of photochemical smog (PCS)—and further understands the role of sunlight in the conversion of primary to secondary pollutants; further, he/she realizes that PCS is dangerous as it causes cancer.
- Vehicles have been identified as a source of primary pollution.

Group sketches were generally more detailed and showed fewer misconceptions and knowledge gaps. This is one advantage that resulted from students' learning from each other and supports social constructivism (Powell & Kalina, 2009). In these instances, students with different knowledge levels and strengths motivate and support each other (Solas & Wilson, 2015).

#### *Emerging themes from sketches on Ozone Layer Depletion*

A total of sixty-eight (68) individual sketches from female students, depicting ozone layer depletion, were analyzed. The concept of Ozone layer depletion is taught after the concept of photochemical smog is taught; therefore, students are already familiar with the formative assessment through the drawing task. In this course, the main emphasis is on the concept of chlorofluorocarbons (CFCs) being the primary ozone depleting pollutant; further, the effects of ozone layer depletion on human health, animal health, and physical environment are explored. The mechanistic details of ozone formation and destruction are not emphasized as this course is a general science curriculum module, and most students have minimal science backgrounds. The mechanism of formation and destruction of stratospheric ozone is however demonstrated through a short video to help with further clarification on the topic and satisfy the curiosity of those students who want to know more.

Several teaching methods and tools were utilized in explaining the OLD concept to students. These include caricaturing/cartooning (to show the difference between stratospheric and tropospheric ozone), drawing pictures, framing object lessons, videos, highlighting focal points, and providing cues at the start of the lesson.

An examination of the literature reveals that students commonly have alternative conceptions, misconceptions, and knowledge gaps about ozone layer depletion. A summary of issues identified from student's work, reported by other researchers, is provided in Table 2 (Howard et al., 2013; Papadimitriou, 2004). In particular, issues 8, 9, and 10, mentioned in

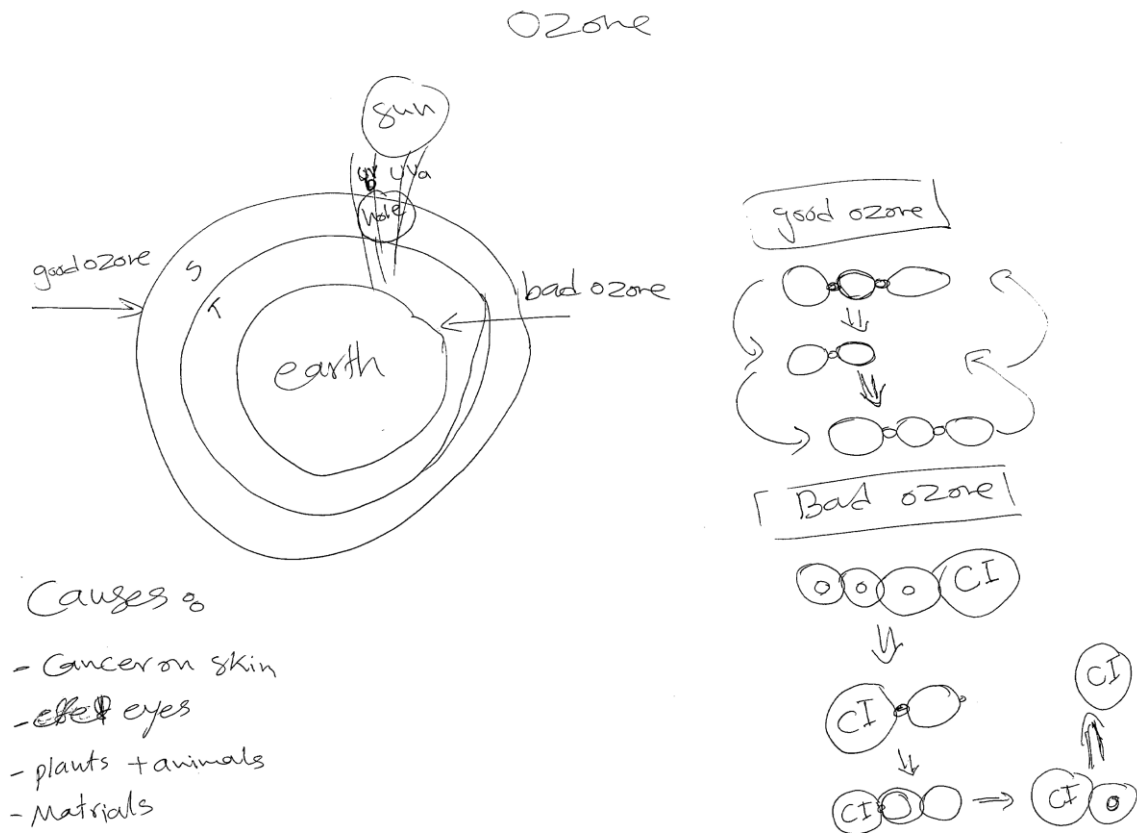


Table 2, were the most common misconceptions observed by the authors in the sketches that students generated.

**Table 2.** Misconceptions, alternative conceptions, and knowledge gaps regarding ozone layer depletion (Howard et al., 2013; Papadimitriou, 2004)

	<b>Misconceptions, alternative conceptions, and knowledge gaps as seen from students' sketches</b>	<b>Comments</b>
1	The concerns regarding ozone is due to its role as a greenhouse gas.	Its protective function in the atmosphere is not considered.
2	The students believed that stratospheric ozone was formed from oxides of nitrogen (NO <sub>x</sub> ) and volatile organic compounds (VOCs).	This shows that students confuse between stratospheric and tropospheric ozone and the mechanism of the formation of each.
3	Ozone acts as a filter to remove harmful UV rays.	Alternative conceptions regarding the mechanism used to prevent harmful UV rays from reaching the earth.
4	The hole in the ozone makes the radiation vertical and therefore harmful.	This supposition stems from sunrays being more direct and therefore more potent.
5	The ozone layer is made of many compounds.	Other compounds excluding ozone form the ozone layer.
6	Pollutants dissolve the ozone layer.	Alternative conception of how stratospheric ozone is destroyed.
7	Ozone is contaminated by pollutants from the earth.	Alternative conception of how stratospheric ozone is destroyed.
8	Carbon dioxide is responsible for the depletion of ozone layer.	The students show confusion regarding the role of carbon dioxide in the process of environmental degradation.
9	Individual names for pollutants are omitted in favor of general terms such as aerosols, industry emissions, cars, and spray.	Some students have trouble recalling the names of pollutants, preferring instead to indicate the sources.
10	Cars and industry emissions are responsible for the depletion of the ozone layer.	The students are unclear regarding the roles of cars and industry emissions in air pollution.

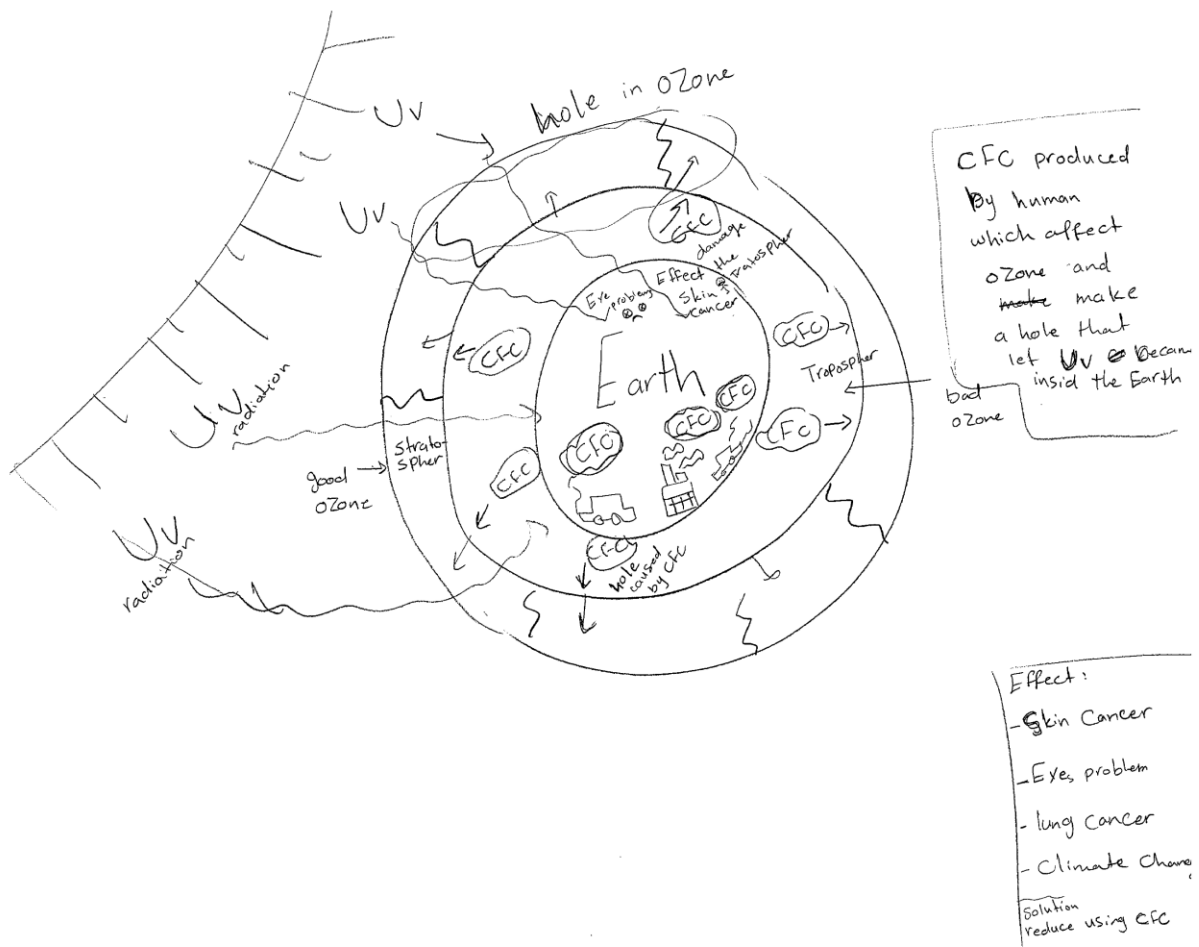
An analysis of the sketches (see Figures 5–8) revealed that most students understood the position of the stratosphere in relation to the troposphere and earth. Though some students were not able to recall the name of the primary ozone depleting pollutant, most were able to recall CFCs as the agent of destruction for stratospheric ozone.



**Figure 5.** A sketch that reveals the misconception on why ozone is beneficial in the stratosphere and detrimental to the troposphere

### Findings

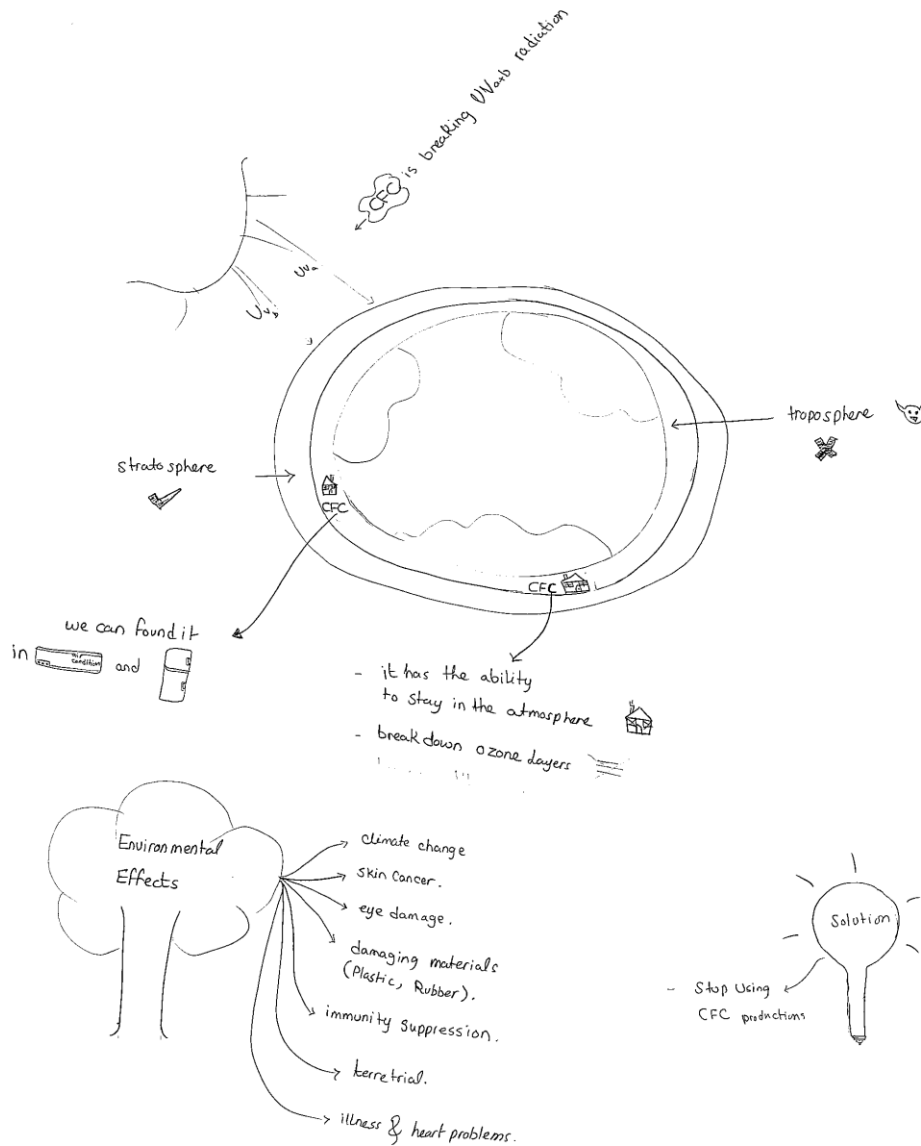
- The sketch reveals an understanding of the positions of stratospheric ozone and tropospheric ozone relative to the earth's surface.
- One glaring misconception revealed is that ozone is "bad" because it reacts with the CFCs; however, it is good if it breaks and re-forms as ozone.
- The sketch indicates an awareness of problems, such as skin cancer, eye problems, associated with the ozone layer depletion.



**Figure 6.** A student-generated sketch showing that motor vehicles and factories are incorrectly implicated in CFC production

### Findings

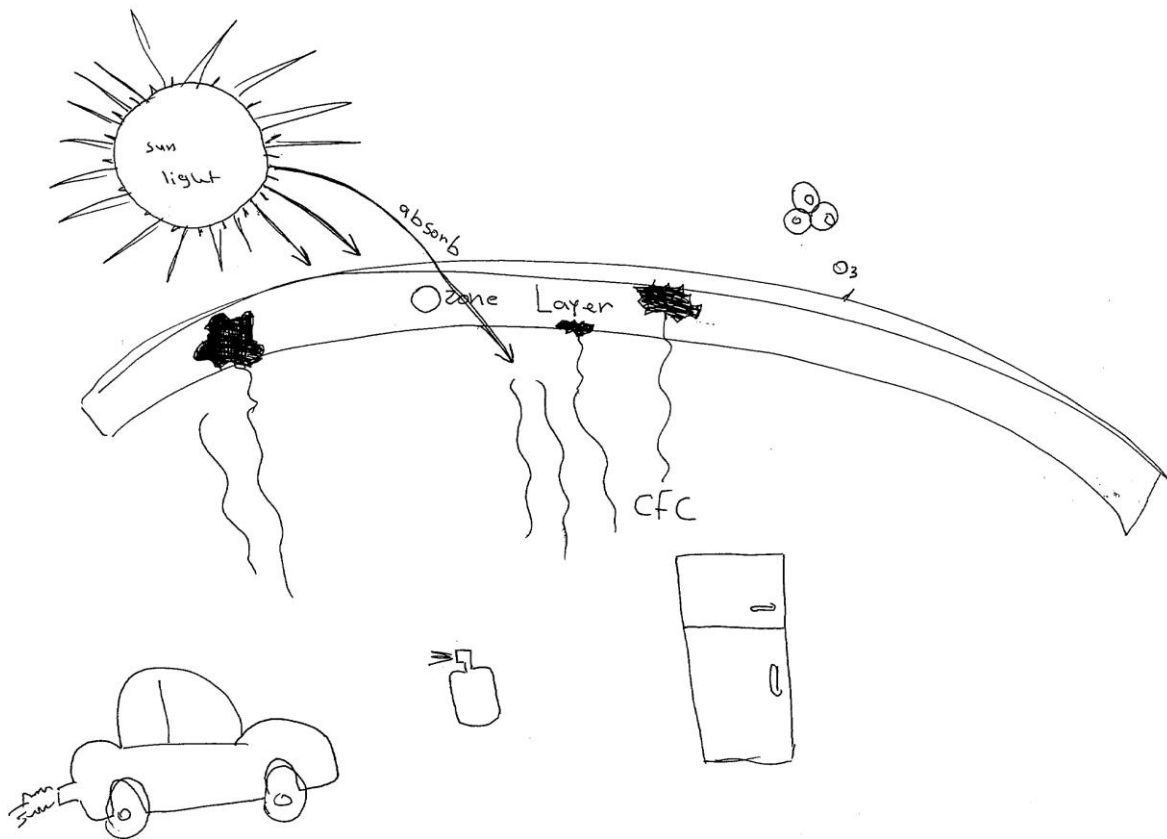
- The above sketch reveals an understanding of CFCs as a manmade pollutant, the effect of CFCs on the ozone layer, and the harmful effects of UV radiation on the earth due to ozone layer depletion.
- It is easy to see that this student, as shown in this sample, has a deeper understanding of the concept than the one shown in Figure 5.



**Figure 7.** A student-generated drawing showing that CFC is “breaking UV radiation,” illustrating a knowledge gap

### Findings

- This sketch correctly implicates CFCs as a cause of ozone layer depletion. Here, the student gives the following message as a solution to the problem: stop producing CFC.
- The student lists several effects associated with OLD.
- No distinction is made between direct and indirect effects, which makes the instructor wonder if the student understood the distinction between the two or just wrote down every effect that had ever been mentioned in the class.



**Figure 8.** Motor vehicles are erroneously implicated in Ozone Layer Depletion

### *Finding*

- This sketch reveals an understanding of the function of the ozone layer and the role of the CFCs in its depletion. However, the presence of an automobile indicates that the student believes that burning of fossil fuel is harmful to the ozone layer.

## **CONCLUSION**

The results of the study show that student-generated annotated sketches are an excellent formative assessment tool. Formative assessments can be considered as activities that contribute to students' learning by providing information about their performance (Yorke, 2003) and those that inform student learning during the actual learning process (Bell & Cowie, 2001). This is a useful tool for both learners and educators. Having students create concept sketches allows them to make external representations of their cognitive schema thereby providing instructors with tools to assess and adjust their teaching accordingly. An effective formative assessment is crucial when teaching science to second language learners and this is considered to be an important aspect of an efficient teaching practice (Chickering & Gamson, 1987; ÇÝMER, 2007).

The literature documents reduction in the critical thinking skills and science academic achievements among English Language learners (ELLs) (Johnstone & Selepeng, 2001; Solas & Wilson, 2015). These inadequacies can only be addressed when instructors are aware of the cognitive abilities of students in a classroom situation. The ease of execution, opportunity for main idea selection and organization, prompt teacher evaluation of sketches, and revelatory glimpses of students' cognitive schema makes the technique useful and relevant inside an ELL classroom wherein students are more reliant on instructor feedback to determine their

progress and the traditional methods of communication are inadequate due to language barriers.

It should also be noted that this study provides evidence that the use of sketches as a pedagogic strategy for teaching science may have significant implications in language learning environments. Activities such as sketching, facilitate the reduction of cognitive load and the ability to communicate knowledge without “filler” words, which was particularly useful for our students (Wilson et al., 2016). Another complementary aspect of using sketches in classroom situations was to give students freedom of individual expression and creativity. These features are highly beneficial in the context of our language learners as this strategy helps students to feel relaxed, creating a productive environment for the learning process. It also allows for diverse learning styles and creativity within the classroom (Eppler, 2006).

The study is also significant as the sketching technique is transferable to other pure science subjects, such as chemistry, physics, and biology. Although some researchers have used sketching to understand students’ cognitive models of particulate matter and chemical reactions (Kern et al., 2010; Nyachwaya et al., 2011), student sketches may also be quite revealing on other concepts, such as bonding in chemistry; this is a topic that has been shown to be a challenge for many students due to the abstract nature of the concept (Suat, Coştu, & Alipaşa, 2010; Taber, 2011). For example, students may be asked to sketch what happens to water molecules when water boils. Sketches would reveal the understanding and misconceptions on intermolecular and intramolecular bonding (H-bonds vs covalent bonds). This information would not necessarily be revealed through traditional assessment. Teachers would then have a powerful tool to influence students’ cognitive models through the adaptation of classroom instruction as per the students’ needs.

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The last issue of Volume 14 includes ten articles from Turkey, Indonesia, Philippines and United Arab Emirates. This is a promising indicator of our journal's reputation in international science education. We believe that their conclusions will not only make a significant contribution to science education but also shape its future context. We will concisely summarize the studies in this issue as follows:

Cepni, Ulger and Ormanci, who elicit prospective science teachers' views of the process 'associating science subjects with everyday life', found that prospective science teachers mainly focused on knowledge transfer rather than feeling, seeing or understanding scientific events they encounter in everyday life. Ata Akturk, Demircan, Senyurt and Cetin, who examined the Turkish early childhood education curriculum prepared for 36–72 month children relative to science, technology, engineering, and mathematics (STEM) education, revealed that the curriculum and teacher activity book contained most of the characteristics of STEM education. Haristiani, Aryanti, Nandiyanto and Sofiani, who investigated Indonesian students' constructed knowledge of solar eclipse, reported that students' belief on mystical stories decreased along with increases in age and grade. Castro and Morales, who determined the challenges and difficulties by science-oriented students in performing GIL activities in biology, addressed that these features (background knowledge; performance of laboratory procedure; managing extended activities; designing an experiment; and writing a laboratory report) fell into a fair difficulty level. Kocagul-Saglam and Sahin, who investigated the effect of inquiry-based professional development training on science teachers' beliefs and self-efficacy about inquiry-based teaching and science process skills, professional development training was effective in improving teachers' beliefs, self-efficacy, and process skills. Zubaidah, Fuad, Mahanal and Suarsini, who determined the effects of three different science learning models on male and female students' creative thinking skills, found a significant difference between their creative thinking skills. Sinaga, Kaniawati and Setiawan, who assessed science textbook design and development procedures to increase secondary school students' scientific literacy, implied that the science textbooks had high readability for main ideas and appropriate quality purposing to achieve scientific literacy. Zeren Ozer and Gungor, who evaluated middle school students' views of science centers, identified that a vast majority of the students had difficulty in identifying related science concepts. Deveci and Cepni, who examined the entrepreneurship studies in science education, found that teaching model, curriculum and modules were developed to promote the entrepreneurship in science education. Copeland and Solas, who went over student-generated annotated concept sketches to formatively assess students' understanding of environmental topics, indicated that this alternative pedagogical approach is an excellent formative assessment tool.

These studies reveal that the *Journal of Turkish Science Education* is a correct platform to globally discuss, disseminate and improve science education. As a matter of fact, well-known databases/indexes have still been tracking the journal. In 2018, we expect to get good news from our ongoing applications to new indexes/abstracts. We would like to thank our reviewers and editorial board members for their invaluable efforts and constructive feedbacks. We appreciate their kind performances in improving the quality of the published papers and journal. We wish new year brings healthy, wealthy and fruitful days for you.

Happy reading!

On behalf of Editorial Board Members Prof. Dr. Muammer CALIK Associate Editor