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Rectifying Analogy-Based Instruction to Enhance Immediate and Postponed Science Achievement

Maymoona AL-HINAI[1], Sulaiman AL-BALUSHI[2]

[1] Science Supervisor, Ministry of Education, OMAN
[2] Assoc. Prof., Sultan Qaboos University, College of Education, Muscat-OMAN

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ABSTRACT

The aim of this study was to examine the impact of analogy-based instruction on immediate and postponed science achievement. More specifically, the focus of the current study was on the retention of students at three cognitive levels: knowledge, comprehension and application. Two classes of 63 ninth grade female students in Oman participated in the study. These classes were randomly assigned to an experimental group (N=32) which used analogy-based instruction and a control group (N=31) which used the traditional method. An achievement test was designed at the three cognitive levels and was administered to both groups immediately after the conclusion of the study which lasted for five weeks and once again two weeks later. In the immediate administration of the test, the findings indicated that the experimental group significantly outperformed the control group in terms of two cognitive levels, comprehension and application, and also in the overall score of the test. In the postponed test, the experimental group outperformed the control group in all three levels and in the overall score. Also, there was a substantial decline in control group students' scores in the three cognitive levels and in the overall test score. This was not the case for the students in the experimental group. We have listed several justifications for these findings, recommendations for science teachers and textbook writers, limitations of the study and ideas for further research in the section headed "Conclusions and recommendations" below.

Keywords: Analogy-Based Instruction; Application; Comprehension; Immediate Achievement; Knowledge, Oman; Postponed Achievement.

INTRODUCTION

An epistemological difficulty that many students face with a considerable number of scientific concepts is the high level of abstractness associated with these concepts (Al-Balushi, 2011; Harrison & Treagust, 2000; Şekercioğlu & Kocakülah, 2008). Consequently, some students start to question the credibility of scientific models that represent natural entities and phenomena. Some doubt the ability of scientists to construct reliable models for highly abstract entities. The high level of spatial relations involved in some of these abstract entities and phenomena makes some low spatial ability students deny the existence of these entities and phenomena (Al-Balushi, 2011, 2012). Therefore, this high level of abstractness needs to be loosened so that students become able to visualise what scientists mean by the

Corresponding author e-mail: sbalushi@squ.edu.om

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models they construct to make us better understand and predict the world around us. One way to do so is using pedagogical analogical models (Harrison & Treagust, 2000), or what are commonly known as analogies. It is a process of establishing similarities between a familiar concept (analogue) and a new concept (target) (Dilber & Duzgun, 2008).

Along with scientific models, analogies have played a crucial role in the development of meaning in science and its progress and have been an essential element of scientific theories and explanations (Guerra-Ramos, 2011; Harrison & Treagust, 1993; Marcelos & Nagem, 2010). The work of Boyle, Carnot, Darwin, Faraday, Kepler and Maxwell, for instance, reflects an extensive use of analogies in the construction of scientific models and theories. Besides their role in the construction of knolwedge, analogies facilitate the organisation, examination and communication of knowledge (Yilmaz & Eryilmaz, 2010). Marcelos and Nagem (2010) lists a number of classifications of analogies compiled by researchers; among which, structural and functional analogies are the most common.

Gentner et al. (1997) argue that using analogies is an everyday practice of science and, in doing that, successful conceptual change takes place and creativity is fostered. Analogies enable students to reconstruct their understandings (Nashon, 2004). Analogies enhance the visualisation of abstract concepts by learners, making them more tangible (Thiele & Treagust, 1994). If introduced effectively, analogies present scientific knowledge as plausible and intelligible and make abstract concepts more comprehensible and visualisable (Dilber & Duzgun, 2008; Marcelos & Nagem, 2010; Paris & Glynn, 2004). These are some conditions for conceptual change to take place as proposed by Posner and colleagues (cited in Khourey-Bowers, 2011).

Studies have shown that analogy-based instruction has a positive impact on students' learning of science (Guerra-Ramos, 2011; Harrison & Treagust, 1993; Sarantopoulos & Tsaparlis, 2004). This is, in most part, due to the fact that everyday entities and situations are frequent sources for analogies (Sarantopoulos & Tsaparlis, 2004). Learners' familiarity with these everyday entities and situations makes analogies more effective in bridging the gap between a familiar and concrete domain (analogue) and an unfamiliar and abstract domain (target). The process of finding the correspondences between the two systems, which is called mapping or matching, is what makes analogies an effective mental tool that loosens the abstractness of the newly introduced scientific entities and phenomena. They facilitate bridging between abstract and concrete learning experiences and provide students with an easy-to-imagine mental model. Thus, teachers use analogies to integrate previous knowledge into the new learning experience by activating related schemata and to help explain complex phenomena or processes (Clement, 2003). Their power lies in their ability to embrace a whole system of relations and features within the target phenomenon.

Analogies also act as a memory aid which promotes retention of new abstract target concepts (Glynn & Takahashi, 1998; Guerra-Ramos, 2011; Paris & Glynn, 2004). They enhance students' intrinsic motivations (Dilber & Duzgun, 2008) by building up their confidence in their ability to tackle difficult concepts (Guerra-Ramos, 2011). In addition, using carefully crafted analogies helps overcome students' misconceptions (Yilmaz & Eryilmaz, 2010). It has been reported that lower cognitive development (concrete) students benefit more from analogies than higher cognitive development (formal) students (Glynn & Takahashi, 1998; Sarantopoulos & Tsaparlis, 2004). Analogies also attract curious students, who are more actively engaged in exploratory activities than formal passive classroom settings (Sarantopoulos & Tsaparlis, 2004).

Analogies could be enhanced more to support students' construction of scientific knowledge by associating them with pictorial representations that resemble the analogy and facilitate the comparisons between the analogue and the target concept. Accompanying analogies with pictorial representations takes advantage of the role imagery plays in learning and assists students to create a visual mental model for the concept under study. This mental process supports the systematic mapping of verbal and visual shared features between the analogue and the target concept, that is, between what is already known to students and what is new for them (Paris & Glynn, 2004). It is worthy of note that research indicates that static analogies, which are sketched analogies, work as effectively as dynamic analogies, which are animated computerised sketched analogies, in promoting students' understanding (Chiu & Chen, 2005).

Analogies might be brought up by the teacher or students. They might be self-designed or adopted from external sources such as related literature or expert recommendations; with the former, the process of self-generation is likely to be more difficult (Clement, 1998, 2003). Individuals exercise their analogical reasoning when they are involved in self-generation and evaluation of analogies (Marcelos & Nagem, 2010). For some, experts or students, generation of analogies is a natural reasoning strategy. Interestingly, eighth graders, who are more abstract thinkers, have been reported to generate more analogies in their explanations of the target phenomena than sixth graders who are more concrete thinkers. These self-generated and spontaneous analogies are based on concepts in students' everyday lives (Glynn & Takahashi, 1998). Compared to ready-made and teacher-provided analogies, self-generated analogies promote deeper relational structures (Haglund & Jeppsson, 2012).

Given that analogies are sometimes spontaneously generated during the teaching-learning and problem solving settings, an evaluation mechanism should be in place to evaluate the validity of these analogies. Experts tend to take considerably more time to evaluate the validity of an analogy (Clement, 1998). Students might be encouraged to use analogies to evaluate their learning of a target concept by training them how to map features of the analogue to the shared features of the target concept (Paris & Glynn, 2004). Some science teachers think that analogies are "shortcuts" that save time and lead to the desired conceptual change in one "magic" step. They underestimate the size of the conceptual change needed and the fact that students need time to evaluate the provided analogy and reflect on its usefulness and applicability to the undertaken scientific concept or phenomenon. As a result, students with misconceptions, might spend more time than expected to comprehend an analogy and change their existing conceptions (Clement, 1998).

We need to admit that using analogies in teaching has not been always successful. Proposed analogies are sometimes complex by themselves and require a high level of thinking to be comprehended. Thus, students are not able to conceptualise both the anchor analogue and the target concept (Clement, 1998; Guerra-Ramos, 2011; Podolefsky & Finkelstein, 2007). Also, sometimes when teachers use an anchor analogue to explain the relations within a target phenomenon, students focus on the comparisons between the anchor and the target in terms of physical attributes such as colour, size and rigidity instead (Podolefsky & Finkelstein, 2007). Students might judge some unrelated attributes as valid. As a result, they start to form alternative conceptions and thus, conceptualise the analogy differently from the manner the teacher intends (Harrison & Treagust, 1993). Also, science teachers themselves might not be familiar as to where a particular analogy breaks down (Guerra-Ramos, 2011).

The process of misunderstanding starts when the comparison process considers detailed features in order to identify the similarities and dissimilarities between the analogue and the target (Guerra-Ramos, 2011). It also occurs when students are not warned of the limitations of the undertaken analogy and not given guidance on whether they should focus on the physical features or the functional attributes. There is sometimes a whole range of physical and functional attributes presented in one analogy-target comparison. Thus, classroom discussion of an analogy should lead students to explicitly identify the key related attribute(s) and the unshared ones within the given range of attributes (Guerra-Ramos, 2011; Harrison & Treagust, 1993; Marcelos & Nagem, 2010). For instance, the spiral staircase is used as an analogy to resemble the structure of DNA. Although this analogy focuses on a structural attribute, the shape of NA, other physical attributes such as the rigidity of the staircase should be excluded. In addition, an important step in analogy-based instruction should be that once the analogy job to explain the target phenomenon is complete, the target should be separated from the analogy and extended by providing more examples and clarifications (Nashon, 2004).

Also, superficial delivery and discussion of analogies without explicit elaboration and systematic mapping of target attributes verbally and visually lead to possible failure of analogy-based instruction (Paris & Glynn, 2004). In this respect, there is an underestimation of the role of visual imagery in learning science with analogies (Glynn & Takahashi, 1998) in both comprehension and retention of knowledge. Unfortunately, literature shows that explicit elaboration of the similarities and dissimilarities between analogues and target concepts is not a frequent classroom practice and science teachers underestimate the difficulty that students might face when introduced to an analogy (Guerra-Ramos, 2011).

There is another failure of the analogy-based instruction. Given that analogies are easier to remember than the target concepts because of their familiarity to students, some students remember the concrete attributes of the analogy and not the abstract attributes of the target scientific concept. Therefore, students come up with alternative conceptions regarding the target phenomena based on their knowledge of their anchored analogue (Dilber & Duzgun, 2008). By the same token, self-generated analogies might lead to personal explanations that are not in line with scientific consensus. Students assume ownership of their self-generated analogies and, consequently, they might over-generalise them to suit inapplicable contexts and omit the points of breakdown (Haglund & Jeppsson, 2012). Also, young students such as those in high school might not be capable of generating analogies that lead to successful conceptual change. They lack the ability to consistently maintain a well-developed analogy (Hagans, 2003; Harrison & Treagust, 2006).

For complex and highly abstract concepts and processes, it might be useful to use multiple analogies to compensate for the deficiencies in single analogies. Previous works emphasise the role of multiple representations in fostering students' comprehension of complex scientific concepts (Nichols, Ranasinghe, & Hanan, 2012). If a phenomenon is complicated, one analogy might work for one of its aspects and another analogy might be designed to explain another aspect of this phenomenon (Harrison & Treagust, 2006; Podolefsky & Finkelstein, 2007). For instance, while the water circuit analogy works well to explain the concept of batteries within the electric circuit, the moving-objects analogy works better to explain the concept of resistors (Podolefsky & Finkelstein, 2007). Also, multiple analogies allow students to select the most appropriate bridging method that links scientific concepts to everyday physical phenomena (Chiu & Lin, 2005).

However, the analogies to be involved in the multiple-analogies approach should be carefully chosen as research indicates that multiple analogies might sometimes cause cognitive difficulties. It happens that the second analogy, when poorly chosen, contradicts with the first one and consequently wipes out the positive accomplishment of the first analogy (Harrison & Treagust, 1993). Also, students sometimes are not keen on using several analogies. One type of explanation is usually preferred by most students (Yilmaz & Eryilmaz, 2010). It becomes difficult to some students to conceptualise the core abstract themes that regulate multiple representations of natural phenomena or entities (Al-Balushi, 2012; Gericke & Hagberg, 2007). This happens to students who believe in only one correct answer to each problem. Thus, they become confused when the teacher presents more than one analogy or explanation to the undertaken phenomenon (Harrison & Treagust, 2006).

The above review of previous works indicates that explicit discussion of shared attributes between analogies and target concepts is an effective mental tool that helps students recall, visualise and comprehend scientific concepts. Nonetheless, there is little empirical evidence available to date regarding whether the impact of analogy-based instruction lasts longer than traditional teaching. The work of Glynn and Takahashi (1998) is one of the exceptions in this regard. Their study indicates that analogy-enhanced text has greater immediate and postponed (two-week) retention as compared to a control text. The differences between the current study and that of Glynn and Takahashi are: 1) the current study examined the impact of analogy-based instruction instead of analogy-enhanced text only, 2) the treatment in the current study lasted for five weeks with six periods in each week (a total of 30 periods including the reviewing lessons) while it was a one-time administration of the treatment (25 minutes) in Glynn and Takahashi's study, and 3) the impact in the current study was measured according to different cognitive levels, recall, application and reasoning, and not only recall as Glynn and Takahashi did. Another study by Paris and Glynn (2004) divided the impact in terms of two different cognitive levels: retention and inferential. However, they tested the impact of one-time administration of an analogy-enhanced text and not the impact of analogy-based instruction for a whole science unit in the same manner that the present study did. Also, they did not measure the retention after a period of time as was recorded in the current study and in that of Glynn and Takahashi's. They only measured the achievement immediately after students' exposure to analogy-based text.

Because analogy-based instruction has not always been successful (Clement, 1998; Guerra-Ramos, 2011; Harrison & Treagust, 1993; Podolefsky & Finkelstein, 2007), we examined the implementation of some recommendations and advice given by previous researchers to avoid the pitfalls of analogy-based instruction. Examples of this advice are: elaborative discussion of the similarities and differences between the analogue and the target (Glynn & Takahashi, 1998; Paris & Glynn, 2004); ensuring students' familiarity with the analogy (Clement, 2003; Sarantopoulos & Tsaparlis, 2004); the importance of identifying where the analogy breaks down and emphasising the positive role of visualisation (Chiu & Chen, 2005; Paris & Glynn, 2004); and the careful use of self-generation strategy (Haglund & Jeppsson, 2012). By integrating these research-based recommendations into the design of analogy-based instruction, we hope that we provide science teachers and text writers with a working and rectified model for the use of analogies in science teaching.

PURPOSE OF STUDY

The current study examined the impact of analogy-based instruction on immediate and postponed retention at three cognitive levels: knowledge, comprehension and application related to electric energy and its technical applications.

METHODOLOGY

a) Participants

The participants were 63 ninth grade female students studying in two classrooms in a school in Al-Dakheliah province in Oman. The school was chosen based on the willingness of the school administration to host the study and the presence of an experienced teacher who expressed the interest to teach both groups of the study. We randomly assigned the two classrooms to an experimental group (32 students) and a control group (31 students).

b) Design of Study

A control group quasi-experimental design was used in the current study. The experimental group studied a unit called "Electric Energy and Its Technical Applications" using an analogy-based instruction while the control group used the traditional teaching method to study the same unit. We used results of students' science achievement in the first semester of the school year to test whether both groups were equivalent before the beginning of the study. The achievement scores of the students in the first semester were based on formative evaluation (40%) and summative evaluation (60%). The formative evaluation score was obtained by short quizzes, classroom participation and a mini project. The summative evaluation was in the form of a final written achievement test. Table 1 illustrates that both groups were equivalent and had no significant differences between them.

Table 1. *Independent samples t-test results of the comparisons between the two groups on students' science achievement before the beginning of the study*

Group	N	mean*	SD	df	t	p
Control	31	12.22	3.22	61	0.84	0.16
Experimental	32	12.29	3.72			

*Maximum mark = 20

We asked a cooperative teacher to teach both groups. She had eight years of teaching experience. Before the beginning of the study, the second author conducted a workshop for the teacher regarding the analogy-based instruction. The workshop lasted for two days comprising three and a half hours each day. The workshop was composed of three parts: the theoretical aspects of analogy-based instruction, the use of the teachers' manual and illustration of a sample lesson using the strategy. Since the teacher had significant teaching experience, we thought two days' training would be enough. She had studied analogy-based techniques in her teacher preparation programme and used analogies in her teaching before being chosen for the current study. Therefore, she did not have any difficulties in comprehending the topics presented in the workshop.

The study lasted for five weeks with six lessons during each week. The second author attended all the lessons taught in the experimental groups and most of the lessons taught in the control group. After the completion of the study, an achievement test was immediately administered to both groups. The same test was administered again after two weeks to measure the retention of both groups.

The teacher's control group was subjected to her regular teaching methods. Examples of these methods were lecturing, classroom discussion, discovery and hands-on activities, some guided inquiry activities and cooperative learning. The same instructional methods were used in the experimental group. Instead of presenting the scientific topics through regular classroom discussion, however, the teacher used the analogy-based model. She was instructed not to use any analogies when teaching the control group.

c) Materials

We designed a teacher manual to be used in the experimental group. The manual was designed around the "Electric Energy and Its Technical Applications" unit found in the ninth grade science textbook. This unit included topics such as electric charges, static electricity, electric circuits, transformations of electric energy, electrochemistry, electromagnetism and electric efficiency. Also in this unit, students learned about various devices and technical applications that accompanied different topics.

We adopted the Teaching With Analogy (TWA) model which has been widely reported in different literatures (Guerra-Ramos, 2011; Harrison & Treagust, 1993; Marcelos & Nagem, 2010). Below are the general steps in the TWA model:

1. Introduce the target (scientific) concept
2. Introduce the analogue
3. Identify the shared key features between the target and the analogue

4. Illustrate the similarities using a chart or a sketch
5. Identify the limitations of the analogy
6. Infer the conclusion(s)
7. Self-generate your own analogy

We added step no. 7 to encourage students to self-generate their own analogies especially in the homework with emphasis that students needed to list the limitations of their self-generated analogies.

The teacher manual has the following sections:

- An introduction
- The theoretical framework for analogy-based instruction which includes a description of the modified TWA model
- Instructions to the teacher
- Learning outcomes
- The unit plan
- The lesson plans and their related worksheets
- We included in the teacher manual different well-known analogies related to electricity. Table 2 illustrates examples of these analogies.

Table 2. *Examples of different analogies used in the current study*

Target concept	Analogue	no. of lessons
electric discharge	a water circuit which included: a water tower, pipes and water basins	2
moving charges	train	2
electric current	a water circuit which included: straight pipes, zigzag pipes, water pump, valves	2
potential difference	water tower, pipes, water wheel and water basins	2
resistance	a cat prevents a group of mice from reaching a piece of cheese	4
series connection	series water valves in a water circuit	3
parallel connection	parallel water valves in a water circuit	3
chemical batteries	food and human body	2
alternating current	ocean waves	3

As noted above, academic texts (Dilber & Duzgun, 2008; Glynn & Takahashi, 1998; Marcelos & Nagem, 2010; Paris & Glynn, 2004; Thiele & Treagust, 1994) emphasise the importance of using both the verbal and visual features of the analogies to promote students' learning of the target scientific concept. Therefore, activities in the teacher manual are designed to help the learners to create verbal and visual connections between the analogue and target concepts. To do so, we designed an activity worksheet for each analogy that accompanied each lesson. The worksheet presented a photograph or sketch (the *visual element*) for both the target concept and the analogy. Then, a comparison table was presented beneath these illustrations. In that table, students were asked to write similarities and differences (the *verbal element*) between the target concept and the analogy. Both the visual representations and the table worked as graphic organisers that students used to summarise and organise the information they discussed and inferred. Previous works considered graphic organisers as useful learning techniques that foster the comprehension of newly-learned information (Trowbridge & Wandersee, 1998). Appendix 1 shows an example of the worksheets used in the study.

We asked a panel of 13 science educators to review the teacher manual. The panel included three science education professors working in two different universities in Oman, seven physics supervisors working in the Ministry of Education and three physics teachers working in different public schools. We asked the panel to focus on the complexity level of each analogy and whether it was appropriate to grade nine students. They also checked the scientific content presented in the manual. Based on the comments of the panel, we made some modifications to the manual such as simplifying certain analogies, clarifying some others and re-phrasing several linguistic structures.

d) Achievement Test

We developed an achievement test to measure participants' achievement in the "electric energy and its technical applications" unit. Three cognitive levels were incorporated in the test: knowledge, comprehension and application. The test encompassed 27 items: 20 multiple-choice items and seven open-ended items. There were eight knowledge items (29.63%), five comprehension items (18.52%) and 14 application items (51.85%). The reason for having more application items was because of the nature of the unit used which focused on the applications of electric concepts. To ensure the test items were fair for both groups of students, all items were based on the content found in student textbooks.

The same panel that reviewed the teacher manual also judged the validity of the achievement test. The panel checked the appropriateness of the test for the purpose of the study, its scientific accuracy, its readability, its alignment with the content in the student text, its appropriateness for grade nine students and whether each item measured its assigned cognitive level. The panel suggested re-phrasing for some items and the clarification of certain figures.

We piloted the achievement test on a classroom of 31 female grade nine students who finished studying the "electric energy and its technical applications" unit. They were not from the same school that hosted the study. The aim of this process was to check the readability of the test items, measure the appropriate test time and calculate the reliability coefficient. The second author administered the test and asked the students to point out any ambiguous words or phrases. Thus, some minor modifications were made to the test items. The number of items remained the same. The estimated test time was 80 minutes (approximately two periods) and Cronbach's alpha coefficient was 0.83.

RESULTS AND DISCUSSIONS

The purpose of the present study was to assess the impact of analogy-based instruction on immediate and postponed students' retention in terms of three cognitive levels: knowledge, comprehension and application. Table 3 illustrates the results of independent samples t-test analysis of the immediate administration of the achievement test. The findings showed that there were significant differences between the two groups of the study in terms of two cognitive levels: comprehension and application. The mean differences between the two groups in these two levels indicated that the differences came in favour of the experimental group (effect size $r=0.71$ & $r=0.50$ respectively). Also, the experimental group outperformed the control group in the overall total score of the immediate administration of the achievement test (effect size $r=0.55$). However, there was no significant difference between the two groups in terms of the knowledge cognitive level.

Table 4 illustrates the results of independent samples t-test analysis of the postponed administration of the achievement test. The experimental group significantly outperformed the control group in the three cognitive levels (effect size $r=0.57$, $r=0.80$ & $r=0.62$ respectively) and in the overall score of the test (effect size $r=0.71$). Also, as shown in Table 5, a comparison of the immediate and postponed administrations of the test shows that students' scores in the control group declined significantly in all three cognitive levels and in the overall score of the test. On the other hand, there were no significant differences between the immediate and postponed administrations of the test in terms of the experimental students' scores in the three cognitive levels and in the overall score of the test. It is worthy to note that in the immediate administration of the test there was no significant difference between the two groups in terms of the knowledge level. Then, the score of the students in the control group declined significantly. Nevertheless, students' score in this cognitive level in the experimental group did not change significantly. In summary, it is plausible to conclude that students' retention in the experimental group was significantly higher than their retention in the control group in all three cognitive levels: knowledge, comprehension and application.

Table 3. *Means, standard deviations and independent samples t-test results for immediate achievement test*

Cognitive level	maximum mark	group	no	mean (Mi)	SD	df	t	p
Knowledge	9	control	31	6.48	1.09	61	0.92	0.36
		experimental	32	6.75	1.19			
Comprehension	6	control	31	2.81	1.08	61	8.12	0.001
		experimental	32	4.88	0.94			
Application	15	control	31	6.52	3.28	61	4.62	0.001
		experimental	32	9.94	2.55			
Overall test	30	control	31	15.81	4.88	61	5.22	0.001
		experimental	32	21.56	3.81			

Table 4. *Means, standard deviations and independent samples t-test results for postponed achievement test*

Cognitive level	maximum mark	group	no	mean (Mp)	SD	df	t	p
Knowledge	9	control	31	5.26	1.03	61	5.55	0.001
		experimental	32	6.94	1.34			
Comprehension	6	control	31	2.19	0.98	61	10.38	0.001
		experimental	32	4.91	1.08			
Application	15	control	31	5.42	2.91	61	6.31	0.001
		experimental	32	9.78	2.56			
Overall test	30	control	31	12.84	4.30	61	7.98	0.001
		experimental	32	21.47	4.28			

Table 5. *Mean differences and paired samples t-test results for immediate/postponed achievement test*

Cognitive level	group	decline (Mi-Mp)*	df	t	p
Knowledge	control	1.22	30	8.08	0.001
	experimental	-0.19	31	2.25	0.32
Comprehension	control	0.62	30	3.34	0.002
	experimental	-0.03	31	0.30	0.77
Application	control	1.10	30	3.72	0.001
	experimental	0.16	31	0.63	0.53
Overall test	control	2.97	30	6.84	0.001
	experimental	0.09	31	0.29	0.77

*Mi: Mean of the *immediate* achievement test; Mp: Mean of the *postponed* achievement test

This capacity of analogy-based instruction to help students in their comprehension and application of scientific concepts has been emphasised in the literature (Dilber & Duzgun, 2008; Guerra-Ramos, 2011; Harrison & Treagust, 1993; Marcelos & Nagem, 2010; Paris & Glynn, 2004; Sarantopoulos & Tsaparlis, 2004). In the current study, students in the experimental group had the opportunity to study visual representations that symbolise both the analogue and the target. The purpose was to infer the similarities and differences between the two. This incorporation of visual inspection in the learning of science concepts is responsible for reducing the level of abstractness associated with many science concepts and phenomena (Thiele & Treagust, 1994). Thus, science learning becomes more plausible and comprehensible (Dilber & Duzgun, 2008; Marcelos & Nagem, 2010; Paris & Glynn, 2004).

Also, students in the experimental group were actively engaged in their small groups when they were trying to complete the worksheets and negotiate the possible connections between the analogy and the target. This minds-on active learning process of student-student dialogue allowed for the sharing of ideas and negotiation of meaning in a social context. As students talk more about science and science concepts, they have more chance to develop and refine their science understanding (Khourey-Bowers, 2011).

The teacher in the experimental group would ask the students, as part of their homework, to think of an analogy to the concepts taught in the lesson. To avoid the formation of alternative conceptions, the teacher required students to also think of the limitations of the analogy they brought to the classroom. She encouraged them to think of one aspect at which the target and analogue intercepted. During the next lesson, students explained their analogies and the teacher would evaluate them and cautioned them on some limitations that they ignored. The authors noticed that students were eager to offer their own analogies. Some of them were preparing for the lesson by thinking of related analogies from their surroundings or examples from their previous experience. These efforts by students made learning more meaningful (Glynn & Takahashi, 1998). Compared with teacher-generated analogies, it is easier for students to map self-generated analogies (Harrison & Treagust, 2000).

Also, Haglund and Jeppsson (2012) argued that the process of self-generation of analogies by students seemed to align more logically with constructivism which emphasised the importance of involving students' pre-existing knowledge. When the teachers provide students with analogies, they assume that they know these analogies from their daily lives and previous experience. However, this assumption is not always correct. Some students might not know these examples or some of their details. On the other hand, when students generate their own analogies, the expectation that they are familiar with the analogy they bring and its details is higher. Also, we believe that this process of establishing associations with elements, events and processes in the environment helped students in the experimental group to expand their mental networks and recall the information longer than the control group. Previous studies indicated a positive impact of the use of analogies on students' recall and retention of scientific information (Glynn & Takahashi, 1998; Paris & Glynn, 2004).

The results of the immediate administration of the achievement test indicated that students in the control group were as good as their counterparts in the experimental group in terms of the recall of information (the knowledge cognitive level). This difference did not last for a long time. Two weeks later, the postponed administration of the test revealed a significant difference in favour of the experimental group. Paired samples t-test results showed a considerable decline in the control group's scores in the knowledge questions. This was not observed in the experimental group. The construction of visual associations and mental models during the analogy-based instruction should have played an essential role in helping students in the experimental group to preserve the information they learnt. This successful achievement in the current study was due partially to the realisation of the importance of visual imagery in analogy-based instruction (Glynn & Takahashi, 1998). Students in the experimental group were involved in explicit discussion of the verbal and visual mapping between the target and the analogy. This elaboration of the systematic mapping is considered a driving force in the success of teaching with analogy. In addition, the verbal and visual links made the target concept better represented in students' memories and therefore better enhancing their retention of information (Paris & Glynn, 2004).

The implementation of the analogy-based instruction in the current study emphasises the importance of discussing where the analogy broke down. Students were encouraged to talk about the limitations in their small groups, write them down on their worksheet and then present them to the whole class. As stressed in the literature (Glynn & Takahashi, 1998; Guerra-Ramos, 2011; Haglund & Jeppsson, 2012; Harrison & Treagust, 1993; Paris & Glynn, 2004), we believe that this important action helped students avoid being dragged into constructing alternative conceptions. Previous research indicated that when students were warned of the differences between the target and the analogue, no analogy-based alternative conceptions were reported (Glynn & Takahashi, 1998). Also, in the present study, this classroom practice made students conscious of the importance of always thinking of limitations for self-generated analogies while they were doing their homework and reported them when they presented their homework.

CONCLUSION AND RECOMMENDATIONS

The findings of the current study indicated that analogy-based instruction helped students to comprehend and apply scientific concepts at a level substantially higher than the traditional teaching methodology. Also, analogy-based instruction facilitated students' retention of scientific information at the three cognitive levels (knowledge, comprehension and application). On the other hand, there was a significant decline in the performance at the three cognitive levels for students who were taught by the traditional method. While there was no important difference between the two strategies in terms of the knowledge level (recall of information) in the immediate test, the experimental groups outperformed the control group in this particular level in the postponed test. This result is a new addition that the current study contributed to our knowledge of analogy-based instruction. We would like to emphasise the following conditions which we believe facilitated the positive impact of analogy-based instruction used in the current study:

1. *Familiarity:* the abstractness level of scientific concepts was reduced by using familiar everyday analogies.
2. *Elaboration:* the frequent mapping of the verbal and visual features between the analogue and the target.
3. *Limitations:* the emphasis on stating the limitations of each analogy to avoid forming alternative conceptions.
4. *Active-learning:* engaging learners in active learning discussions in their small groups and then as a whole class regarding different aspects of the undertaken analogy and target concepts.
5. *Graphic organising:* activity worksheets helped students to study a sketch used to infer similarities and differences between the analogue and the target and then organise them in a table. This graphic organising combination helped foster students' recall and comprehension of information.
6. *Self-generations:* encouraging students to come up with their own self-generated analogies that correspond to concepts under study with a clear caution about their possible limitations.
7. *Motivation:* the eagerness and high level of motivation noticed with the students in the experimental group had to come up with their own analogies.

To be successful, we recommend that any analogy-based instruction should take these conditions into consideration. Science teachers and text writers could benefit from these instructional ideas to design a learning environment that maximises the benefits from using analogies and, at the same time, overcomes their limitations.

The current research design was unique to this study. Exploration of retention at different cognitive levels has been rare in previous research that focused on analogy-based instruction. However, one limitation to the current study was the use of the same test in the immediate and postponed administration. There was a fear that students might remember the answers in the second administration of the test and this might turn responding to the application and comprehension question into mere recall of information. Nevertheless, it was not necessary that all students did care about the questions they were asked in the tests. Students did not receive any feedback to their answers in the immediate administration. No review sessions were conducted after the first administration. Also, we thought that a two week period would be long enough for most students to forget most test items. Add to this, the fact that we did not inform students about the second application of the test to avoid any attempt from them to remember the test items from the first application. We suggest that a future exploration might consider designing two compatible versions of the achievement test. Another limitation of the current study may be that its findings may not be generally applicable to fields other than physics which was the focus subject matter of the current study. Physics deals more with everyday objects and events compared to chemistry and biology. Therefore, it might be easier to find matching analogies to physics concepts than in other fields of science. A further study might use the same design but on another science field such as biology or chemistry.

REFERENCES

Al-Balushi, S. M. (2011). Students' evaluation of the credibility of scientific models that represent natural entities and phenomena. *International Journal of Science and Mathematics Education, 9*(3), 571-601. DOI:510.1007/s10763-10010-19209-10764.

Al-Balushi, S. M. (2012). The relationship between learners' distrust of scientific models, their spatial ability, and the vividness of their mental images. *International Journal of Science and Mathematics Education*, DOI: 10.1007/s10763-10012-19360-10761.

Chiu, M.-H., & Chen, I.-J. (2005, August). *Dynamic analogies promoting students' learning of behavior of gas particles.* Paper presented at the ESERA, Barcelona, Spain.

Chiu, M.-H., & Lin, J.-W. (2005). Promoting fourth graders' conceptual change of their understanding of electric current via multiple analogies. *Journal of Research in Science Teaching, 42*(4), 429-464.

Clement, J. (1998). Expert novice similarities and instruction using analogies. *International Journal of Science Education, 20*(10), 1271-1286.

Clement, J. (2003, March). *Abduction and analogy in scientific model construction.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Dilber, R., & Duzgun, B. (2008). Effectiveness of analogy on students' success and elimination of misconceptions. *Latin American Journal of Physics Education, 2*(3), 147-183.

Gentner, D., Brem, S., Ferguson, R., Markman, A., Levidow, B., Wolff, P., & Forbus, K. (1997). Analogical reasoning and conceptual change: A case study of Johannes Kepler. *The Journal of the Learning Sciences, 6*(1), 3-40.

Gericke, N. M., & Hagberg, M. (2007). Definition of historical models of gene function and their relation to students' understanding of genetics. *Science and Education, 16*, 849-881.

Glynn, S. M., & Takahashi, T. (1998). Learning from analogy-enhanced science text. *Journal of Research in Science Teaching, 35*(10), 1129-1149.

Guerra-Ramos, M. (2011). Analogies as tools for meaning making in elementary science education: How do they work in classroom settings? *Eurasia Journal of Mathematics, Science & Technology Education, 7*(11), 29-39.

Hagans, C. (2003). *An analysis of the effectiveness of teacher versus student-generated science analogies on comprehension in biology and chemistry*. Unpublished Master Thesis, Defiance College, Defiance, OH.

Haglund, J., & Jeppsson, F. (2012). Using self-generated analogies in teaching of thermodynamics. *Journal of Research in Science Teaching, 49*(7), 898-921.

Harrison, A. G., & Treagust, D. F. (1993). Teaching with analogies: A case study in grade-10 optics. *Journal of Research in Science Teaching, 30*(10), 1291-1307.

Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *International Journal of Science Education, 22*(9), 1011-1026.

Harrison, A. G., & Treagust, D. F. (2006). Teaching and learning with analogies. In P. Aubusson, A. G. Harrison & S. Ritchie (Eds.), *Metaphor and analogy in science education* (pp.11-24). Netherlands: Springer.

Khourey-Bowers, C. (2011, April/May). Active learning strategies: The top 10. *The Science Teacher, 78*, 38-42.

Marcelos, M., & Nagem, R. (2010). Comparative structural models of similarities and differences between vehicle and target in order to teach Darwinian evolution. *Science and Education, 19*, 599-623.

Nashon, S. (2004). The nature of analogical explanations: High school physics teachers use in Kenya. *Research in Science Education*, *34*, 475-502.

Nichols, K., Ranasinghe, M., & Hanan, J. (2012). Translating between representations in a social context: A study of undergraduate science students' representational fluency. *Instructional Science*, DOI 10.1007/s11251-11012-19253-11252.

Paris, N., & Glynn, S. M. (2004). Elaborate analogies in science text: Tools for enhancing preservice teachers' knowledge and attitudes. *Contemporary Educational Psychology*, *29*, 230-247.

Podolefsky, N., & Finkelstein, N. (2007). Analogical scaffolding and the learning of abstract ideas in physics: An example from electromagnetic waves. *Physical Review Special Topics-Physics Education Research, 3*(1), 010109.

Sarantopoulos, P., & Tsaparlis, G. (2004). Analogies in chemistry teaching as a means of attainment of cognitive and affective objectives: A longitudinal study in a naturalistic setting, using analogies with a strong social content. *Chemistry Education Research and Practice, 5*(1), 33-50.

Şekercioğlu, A & Kocakülah, M (2008). Grade 10 students' misconceptions about impulse and momentum. *Journal of Turkish Science Education, 5*(2), 47-59.

Thiele, R., & Treagust, D. F. (1994). An interpretive examination of high school chemistry teachers' analogical explanation. *Journal of Research in Science Teaching, 31*(3), 227-242.

Trowbridge, J., & Wandersee, J. H. (1998). Theory-driven graphic organizers. In J. J. Mintzes, J. H. Wandersee & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp.95-131). San Diego, CA: Academic Press.

Yilmaz, S., & Eryilmaz, A. (2010). Integrating gender and group differences into bridging strategy. *Journal of Science Education and Technology, 19*, 341-355.

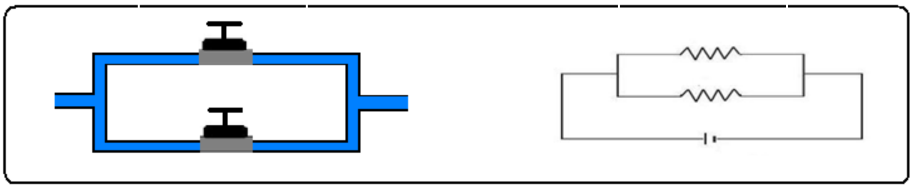
APPENDIX

A sample worksheet

Lesson 7: *parallel electric connections*

Study the sketches below to compare between the *analogue: parallel water valves in a water circuit* and *target: parallel electric connection*. Then, write the seminaries and differences between the analogue and the target.
Note that the differences are the limitations of the analogy used in this lesson.

Analogu **Target**



parallel water valves in a water circuit	parallel electric connection
Similarities	
------------------------------------	------------------------------------
------------------------------------	------------------------------------
------------------------------------	------------------------------------
------------------------------------	------------------------------------
------------------------------------	------------------------------------
------------------------------------	------------------------------------
Differences	
------------------------------------	------------------------------------
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List the characteristics of parallel electric connection:

Think of some applications of parallel electric connections around you. List them below:

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A Comparative Investigation of Sub-Components of the Environmental Literacy at the Secondary School Level

Gökhan SONTAY[1], Murat GÖKDERE[2], Erdoğan USTA[3]

[1] Science and Technology Teacher, Gediksaray Secondary School, Amasya-TURKEY
[2] Prof. Dr., Amasya University, Faculty of Education, Amasya-TURKEY
[3] Assist. Prof. Dr. Gaziosmanpasa Universtiy, Faculty of Education, Tokat-TURKEY

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ABSTRACT

The purpose of this research is to determine the correlation between "environmental knowledge", "environmental effect" and "environmental behavior" which are accepted as environmental literacy components. "Environmental Knowledge Test (EKT), "Environmental Affect Scale (EAS)" and "Environmental Behavior Scale (EBS), which have been prepared by the researchers and their validity and reliability ensured, have been used as the measurement tools. The research group is composed of 364 students from 6 different secondary schools in the center of Amasya city providing education in the school year of 2011-2012. Correlational research method was used in the study. The Pearson Correlation Test has been used for analysis of the data. As a result of the research; it was found that there was a positive and *high* correlation at 0,858 strength between the "environmental knowledge" component and "environmental affect" component; a positive and *low* correlation at 0,426 strength between the "environmental knowledge" component and "environmental behavior" component; a positive *medium level* correlation at 0,502 strength between the "environmental affect" variable and "environmental behavior" variable. The results obtained from the investigation are of great importance in terms of shedding light on the issue for determination of how environmental literacy components affect each other.

Keywords: Environmental Literacy; Environmental Knowledge; Environmental Affect; Environmental Behavior.

INTRODUCTION

Humankind confronts with many environmental problems due to an increasing population in our country and in the world depending on industrialization, urbanization and technologic advances. The view about education is necessary for the prevention of environmental problems and they have been a main concern of many national or international studies, at some important environmental organizations, declarations and conventions (Stockholm, 1972; UNESCO, 1978; Peyton, et al., 1995; Kiziroğlu, 2000; Bülbül, 2007). These kind of conferences and meetings were held in order to enhance environmental consciousness among people across the world and it has been embodied in the concept of "environmental literacy" (Kibert, 2000). The concept of environmental literacy was defined as

Corresponding author e-mail: gokhansontay@gmail.com

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“environmental knowledge and awareness level of an individual” in an article by Charles Roth the first time (Roth, 1968). Disinger and Roth (1992) have interpreted environmental literacy as “the capacity for being able to perform appropriate actions in order to perceive the relative health of the environmental systems, to interpret, to protect the health of these systems, to re-gain health to them or to develop these systems” by improving further this definition. Therefore, the people who are environmentally literate should be able to exhibit positive attitudes and behaviors in order to develop these environmental systems after becoming aware of the environmental systems.

It has been put forth by some researchers that environmental literacy was not only cognitive, but also related with affective and psychomotor aspects (Roth, 1992; Schneider, 1997). In other words, it can be said that an environmentally literate person is a human not only having knowledge about the environment, but also having affective characteristics as well, such as responsibility towards environment, sensitivity and perception. Such a person can acquire these characteristics as behaviors. It is required to take into account of environmental literacy components in determination of whether environmentally literate individuals can be raised/grown in a society (Altınöz, 2010). The environmental literacy components, which were recognized mostly in environmental education literature, have been defined by Disinger and Roth (1992), supported by Hsu (1997) and used in some studies through application. (Chu, Shin & Lee, 2006; McBeth, Hungerford, Marcinkowski, Volk & Meyers, 2008; Kışoğlu, 2009; Öztürk, 2009; Altınöz, 2010; Meuth, 2010; McBeth, & Volk, 2010; Karatekin, 2011; Kışoğlu, Gürbüz, Sülün & Alaş, 2011; Karatekin & Aksoy, 2012). The main components constituting the environmental literacy adopted by Disinger and Roth (1992) are four as being *knowledge, affective area, skill and behavior.* Investigation of whether there is any correlation between each of “knowledge”, “affect” and “behavior” towards the environment among these components is the subject of this study.

Environmental literacy is a broad concept encompassing not only an individual’s environmental knowledge or environmental attitude but also the environmental behavior and problem solving skills towards the environment (Roth, 1992; Hsu, 1997; McBeth et al., 2008). Generally in our country, although studies have been made like environmental knowledge, environmental affect (attitude), environmental behavior, no research has been encountered towards *secondary school 6., 7. and 8. grade students* wherein the correlation between each of these three important variables under the name of “environmental literacy”. Meanwhile Erdoğan (2009) has examined the correlation between each of these three components in a study made towards *secondary school 5th grade students.* In studies across our country, it has been encountered that mostly the correlation between environmental knowledge and environmental attitude (affect) (Atasoy, 2005; Atasoy & Ertürk, 2008; Ökesli, 2008; Varışlı, 2009; Teksöz, Şahin & Ertepınar, 2010) was investigated. Therefore, this study is very important in order to learn whether there is any correlation between *environmental knowledge, affective tendency towards the environment and environmental behavior* possessed by secondary school students. Besides, if there is any correlation between these sub-components, it is particularly important for correcting the deficiency in the literature upon finding out this at what direction (positive or negative) and at which level (low, medium and high). Thus, it is being thought that this will give an opinion to similar researches to be carried out in the field of environmental education and organizations performing activities related with the environment and to other researchers.

The main goal of this investigation is to determine whether there is any correlation between the “environmental knowledge”, “environmental effect” and “environmental behavior” components which are placed in the environmental literacy components.

The main problem of this research is whether there is any relationship between subcomponents of environmental literacy **(**environmental knowledge, environmental effect and environmental behavior) that secondary school students have, or nat. In addition, if any, it is also research subject which level this relationship is at.

METHODOLOGY

This part contains information about the model of research, working group, data collection tools and the analysis of data.

a) Model of the Research

Correlational research method was used in the study. This study is a correlational study that carried on to determine cause and effect and relations between two or more variables (Büyüköztürk, Çakmak, Akgün, Karadeniz & Demirel, 2010).

b) Working Group

The sample of the research is composed of 364 students at 6th, 7th, 8th grades from six different secondary schools in the center of Amasya city in the 2011-2012 academic year.

c) Data Collection Tool

In this study, Environmental Knowledge Test (EKT) composed of 19 questions, 5 point likert type Environmental Affect Scale (EAS) composed of 15 clauses, 7 point likert type Environmental Behavior Scale (EBS) composed of 12 clauses which were prepared by researchers as a data collection tool have been used. The pilot implementation, conducted at the stage of development of data collection tools, has been applied by the researcher himself to 258 8th grades students attending four schools selected randomly from the Amasya city in the 2011-2012 school year.

Environmental Knowledge Test (EKT)

The Environmental Knowledge Test is composed of 19 multiple-choice questions prepared in accordance with cognitive levels of students by taking into account of acquisitions with respect to the environment in science and technology lesson at 4th, 5th, 6th, 7th, 8th grades. The value of each question in the test is 1, and while the highest score to be obtained from the test is 19, the lowest score is 0.

The EKT, which had 20 questions prior to the pilot implementation, decreased to 19 questions by discarding one question after the pilot implementation. KR-20 (Kudher Richardson) formula has been used for ensuring the reliability of EKT. According to this analysis, the reliability of EKT was found to be 0,807. Additionally, an item analysis has been carried out of the EKT. As a result of the item analysis, item distinctiveness index of the 4th item was found as negative, this item was discarded from the test. The average difficulty of the test was identified as 0,545 (Arithmetic average of the scores=10,91)/(The possible highest score in the test=20). Even though the difficulty levels of each items in a test are different, it is a desirable situation for being around 0,50 of the test’s average difficulty that to be found by averaging them (Çepni et al., 2008). Average difficulty value after the fourth item discarded from the test has been found to be 0,542 and the average difficulty of the test has not changed much.

Six lecturers and twelve science and technology teachers having expertise in their fields have been consulted for the scope and face validity of EKT. The test was taken its final form by considering necessary suggestions.

Environmental Affect Scale (EAS)

The Environmental Affect Scale is composed of 15 items and in 5 point likert type. The items associated with the gains of students by scrutinizing the acquisitions related to the environment issue and suitable to the affective level of students while preparing the scale items. Prior to giving answers to the scale items, students were told that scale items are not correct and wrong and therefore each individual were asked to reflect own thought and to what extent they agree or not agree with these items. The answers given to the scale items were rated as 5 point likert type in the form of absolutely disagree, disagree, agree a little, agree and absolutely agree. Scoring of the scale was calculated as “absolutely disagree” 1 point, “disagree,” 2 points, “agree a little” 3 points, “agree” 4 points and “absolutely agree” 5 points. While the possible lowest score in EAS is 15, the highest score is 75.

Six lecturers and twelve science and technology teachers having expertise in their fields have been consulted for the scope and face validity of EAS. The test took its final form by considering necessary suggestions. Cronbach’s alpha reliability coefficient was observed for ensuring the reliability of EAS and this value has been found to be 0,860. Cronbach Alpha coefficient is often used in the cases where particularly responses are obtained from the rating scale (Büyüköztürk, Çakmak, Akgün, Karadeniz & Demirel, 2010). In Büyüköztürk’s opinion, it is adequate for being 0,70 and above of the reliability coefficient. Accordingly, the reliability analysis result of the scale is sufficient for the actual application.

The factor analysis has been observed for the structure validity. According to this analysis, Environmental Affect Scale has been separated into 3 factors as being *environmental responsibility, environmental sensitivity, environmental perception.* Reliability values of sub-dimensions of EAS which was constituted as a result of the factor analysis was given in the following Table 1.

Table 1. *Factor and Reliability Analysis Result of Environmental Affect Scale*

Factors	Scale İtems	Rotated Component Matrix	Cumulative (%)	Reliability
Environmental Responsibility	1	,812	21,935	,867
	9	,808		
	10	,778		
	13	,763		
	14	,743		
Environmental Sensitivity	2	,785	19,180	,807
	6	,758		
	7	,746		
	11	,704		
	15	,683		
Environmental Perception	3	,786	17,959	,784
	4	,716		
	5	,715		
	8	,668		
	12	,633		
Total			59,075	,860
			Kaiser-Meyer-Olkin Measure of Sampling Adequacy	,858
			Bartlett's Test of Sphericity	1470,588
			Sd	105
			P value	,000

Acceptable lower limit of KMO sampling sufficiency is 0,50 and the KMO value is considered excellent for 0,80 and above (Durmuş, Yurtkoru & Çinko, 2011). The data set was considered suitable for factor analysis due to KMO value is over 0,80 (KMO=0,858) and Barlett test is significant at the 0,05 significance level ($\chi^2_{\text{Barlett test}}$=1470,588, p= 0,000).

Environmental Behavior Scale (EBS)

The Environmental Behavior Scale is composed of twelve items and in seven point likert type. The answers given to scale items have been rated as seven point likert type in the form of *never, 1 time, 2 times, 3 times, 4 times, 5 times and more than 5 times.* The scale grading has been calculated in the form of “never” 0 points, “1 time” 1 point, “2 times” 2 points, “3 times” 3 points, “4 times” 4 points, “5 times” 5 points, “more than 5 times” 6 points. While the possible lowest score in EBS is 0, the highest score is 72.

Content validity and construct validity was watched for identification of the validity of environmental behavior scale; and Cronbach Alpha (α) internal consistency coefficient was for its reliability. It was applied to the expert opinion for content validity, and to the factor analysis for construct validity. The EBS, which had 15 items prior to the pilot implementation, has taken its final shape as being 12 items by discarding two questions as a result of factor analysis after the pilot implementation, and one question depending on the expert opinion before the pilot implementation. It has been determined that EBS has three factors according to the factor analysis. These are; *“the behavior protective of natural balance”, “societal behavior”* and *“top level cognitive behavior”.* The Cronbach Alpha (α) internal consistency coefficient has been calculated for reliability of the final status of this measurement tool and this value has been determined as 0,773.

The factor analysis and reliability analysis results of EBS calculated as a result of the pilot implementation are seen in Table 2.

Table 2. *Factor and Reliability Analysis Result of Environmental Behavior Scale*

Factors	Scale İtems	Rotated Component Matrix	Cumulative (%)	Reliability
The Behavior Protective of Natural Balance	6	,713	23,281	,774
	8	,691		
	9	,752		
	13	,670		
	14	,705		
Societal Behavior	1	,691	20,854	,743
	3	,651		
	10	,727		
	11	,772		
	15	,620		
Top Level Cognitive Behavior	2	,842	13,637	,708
	5	,838		
Total			57,772	,773
			Kaiser-Meyer-Olkin Measure of Sampling Adequacy	,764
			Bartlett's Test of Sphericity	819,730
			Sd	66
			P value	,000

d) Analysis of Data

SPSS 15 package program was used in analysis of data. Pearson Correlation Coefficient (Simple Correlation) was used to see the correlation between for each environmental literacy components. Pearson Correlation Coefficient, investigation of relation between variables, is carried out by utilizing statistical techniques depending on whether the correlation between them is linear (Büyüköztürk, 2011).

FINDINGS

In this part, the correlation between “Environmental Knowledge Test”, “Environmental Affect Scale” and “Environmental Behavior Scale” prepared by researchers have been examined; and the tables have been given from the obtained results of the survey and the findings of these tables have been included.

Frequency and Percentage Values of Independent Variables

In this section, the frequency and percentage values regarding to certain independent variables possessed by a number of students participated in the research were given.

The distribution of students participated in the research according to the "student group, gender and class level" variables is as follows.

Table 3. *The Distribution According To The Characteristics of Students Forming The Sample*

Variable	Characteristics	Frequency (F)	Percentage (%)
Gender	Girl	179	49,2
	Boy	185	50,8
Class level	6^{th} Class	121	33,2
	7^{th} Class	122	33,5
	8^{th} Class	121	33,2
	Total	364	100

According to the Table 3, gender distribution of students participated in the research is close to each other. 49,2% is (179) girl students, 50,8% (185) is boy students participated in the research. When the Table 3 is looked, 33,2% (121) is at 6^{th} grade, 33,5% (122) is at 7^{th} grade, 33,2% (121) is at 8^{th} grade.

Table 4. *Descriptive Statistics of Environmental Knowledge, Environmental Affect, Environmental Behavior Score Averages*

Test/Scale	N	Average	Standard Deviation	Standard Fault	Highest Score
Environmental Knowledge	364	10,16	3,69	,193	19
Environmental Affect	364	51,27	6,81	,357	75
Environmental Behavior	364	39,17	10,55	,553	72

When the Table 4 is examined, descriptive statistical values of total points average belonging to Environmental Knowledge Test, Environmental Affect Scale and Environmental Behavior Scale of the students.

The Correlation between Environmental Knowledge, Environmental Affect and Environmental Behavior Score Averages

Pearson Correlation Coefficient (Simple Correlation) was used to indicate the relationship between *environmental knowledge total score average, environmental affect total score average* and *environmental behavior total score average* possessed by secondary school students participated in the study. Pearson correlation coefficient values are ranging between (r) $-1 \leq r \leq +1$. Here the r coefficient shows the direction and strength of the correlation. While the strength of correlation increases as the r value approaches to +1, it indicates that the strength of correlation is less as it approaches to 0. In this respect, although there is no definite limitations, the correlation under 0,50 shows the weak, the correlation between 0,50 and 0,70 shows the medium, the correlation above 0,70 shows the strong relationship (Durmuş et al., 2011).

Table 5. *The Correlation between Environmental Knowledge, Environmental Affect and Environmental Behavior Score Averages*

		Environmental Knowledge	Environmental Affect	Environmental Behavior
Environmental Knowledge	r	1	,858**	,426**
	P		,000	,000
	N	364	364	364
Environmental Affect	r	,858**	1	,502**
	P	,000		,000
	N	364	364	364
Environmental Behavior	r	,426**	,502**	1
	P	,000	,000	
	N	364	364	364

** Correlation is significant at the 0.01 level

When Table 5 is examined, it is seen that there is a positive and at 0,858 strength high correlation between the environmental knowledge variable and environmental affect variable. It has been determined that there was a positive and at 0,426 strength low correlation between the environmental knowledge variable and environmental behavior variable. Meanwhile, it is seen that there is a positive and at 0,502 strength medium level correlation between the environmental affect variable and environmental behavior variable.

DISCUSSION

The aim of this study was to learn whether there was any correlation between the components of “environmental knowledge”, “environmental affect” and “environmental behavior” among the significant components of environmental literacy and to determine if there is a relation between them. The findings obtained were discussed in this section.

It is seen that the correlation (r=0,858) between the *environmental knowledge and environmental affect* is *a positive and high* relationship according to the correlation among environmental literacy components. This finding shows parallelism with the findings in the researches made by Bradley, Waliczek and Zajicek (1999); Teksöz, Şahin and Ertepınar (2010). However, while the correlation between the environmental knowledge and environmental affect is *positive and at medium level* according to the researches of Kibert (2000), Atasoy (2005) and Atasoy and Ertürk (2008), Ökesli (2008) and Erdoğan (2009) have determined that there was a *positive and low level* correlation between the *environmental knowledge* and *environmental attitude* (affective). Therefore according to the finding derived, the knowledge possessed by students towards the environment, at the same proportion, might be affecting positively their affective characteristics towards the environment. So it can be said that if a student has sufficient information about the environmental issues, he/she also has positive affective characteristics towards the environment.

The correlation (r=0,502) between the *environmental affective* and *environmental behavior*, which is another finding in our study, has been found to be *positive at medium level*. Many studies (Hines, Hungerford & Tomera, 1986; Kuhlemeier, Van Den Bergh & Lagerweij, 1999; Kaiser, Sybille & Urs, 1999), contain findings supporting this finding in our study, regarding the correlation between the *environmental attitude* and *environmental behavior* is at *medium level* and *positive*. So, it can be said that the students have tendencies to convert most of their affective tendencies towards the environment into a behavior at the medium level though they not acting in. Meanwhile in the study made by Erdogan (2009), as opposite to these findings, it has been found to be a negative correlation between the *environmental behavior* and *environmental affect* of the students.

The correlation (r=0,426) between the *environmental knowledge* and *environmental behavior*, which is another finding in our study, was determined as *positive* and *at low level*. The study made by Hines and colleagues (1986) and Erdogan (2009) seems to support this finding. This finding indicates that a student is not capable to change his knowledge about the environment into his behavior. For example, a student might know that the paper, glass or plastics should be thrown into the recycling boxes, but he/she might be not acting adequately.

In this study, which is researching whether there is a correlation between "environmental knowledge", "environmental affect" and "environmental behavior" among the environmental literacy components; it has been determined that the correlation between the *environmental knowledge* and *environmental affect* was a *positive* and *high* correlation, the correlation between *environmental affect* and *environmental behavior was positive* and *at medium level*, the correlation between the *environmental knowledge* and *environmental behavior* was *positive* and *environmental knowledge.*

SUGGESTIONS

The following suggestions can be presented with respect to this research based on these conclusions.

- ✓ By taking into consideration of the *high level relationship* between the increment of students' environmental knowledge level and affective characteristics towards the environment; it can be provided to enhance their affective characteristics towards the environment in parallel with this by enabling the students have sufficient knowledge about the environment.
- ✓ By taking into consideration of the *medium level* relationship between the students' environmental affect level increase and behavior characteristics towards the environment; it may be effective if the students' environmental curiosity; interest and sensitivity for the environment are united with acting in towards the environment in order to further enhance this relationship. Therefore if we can gain affective characteristics sufficiently to students towards the environment, we can expect more effective positive behaviors from students on environmental issues.
- ✓ By taking into consideration of the *low level* relationship between the students' environmental knowledge level increase and behavioral characteristics towards the environment; practical environmental spaces should be arranged in which different methods and techniques are implemented to enhance this relationship and their impact levels on students' behaviors should be examined.
- ✓ Observation technique should be included in the environmental education process given to students, these individuals' affective characteristics and behaviors towards environmental events should be observed.
- ✓ To increase the positive behaviours of students towards the environment, it should be necessary to focus on practical environmental education including the students' families.
- ✓ Secondary school students' desires on the environment should be satisfied by Science and Technology teachers through giving education on the "environment".
- ✓ Within scope of the environmental education, students should not only be provided with environmental education but also practical activities should be organized in order to improve their affective characteristics and to convert these into environmental behaviors.
- ✓ Projects with environmental subjects should be concentrated at schools and the students should be ensured to adopt responsible behaviors towards the environment by participating in these projects.

REFERENCES

Altınöz, N. (2010). *Fen bilgisi öğretmen adaylarının çevre okuryazarlık düzeyleri*. Yüksek Lisans Tezi, Sakarya Üniversitesi Fen Bilimleri Enstitüsü, Sakarya.

Atasoy, E. (2005). *Çevre için eğitim: ilköğretim öğrencilerinin çevresel tutum ve çevre bilgisi üzerine bir çalışma*. Yayınlanmamış Doktora Tezi. Bursa Uludağ Üniversitesi Sosyal Bilimler Enstitüsü.

Atasoy, E., & Ertürk, H. (2008). İlköğretim öğrencilerinin çevresel tutum ve çevre bilgisi üzerine bir alan araştırması. *Erzincan Eğitim Fakültesi Dergisi*, 10(1).

Bradley, J. C., Waliczek, T. M., & Zajicek, J. M. (1999). Relationship between environmental knowledge and environmental attitude of high school students. *Journal of Environmental Education*, 30(3), 17-21.

Bülbül, Y. (2007). *Ortaöğretim çevre ve insan dergisinde işbirlikli öğrenme yönteminin çevreye karşı tutumlara ve erişiye etkisi*. Yüksek Lisans Tezi, Çanakkale Onsekiz Mart Üniversitesi Sosyal Bilimler Enstitüsü. Çanakkale.

Büyüköztürk, Ş., Çakmak, E. K., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2010). *Bilimsel Araştırma Yöntemleri (6. baskı)*. Ankara: Pegem Akademi.

Büyüköztürk, Ş. (2011). *Sosyal Bilimler İçin Veri Analizi El Kitabı (14.baskı)*. Ankara: Pegem Akademi.

Çepni, S., Bayrakçeken, S., Yılmaz, A., Yücel, C., Semerci, Ç., Köse, E., Sezgin, F., Demircioğlu, G., & Gündoğdu, K. (2008). *Ölçme ve Değerlendirme*. Ankara: Pegem Akademi.

Chu, H. E., Shin, D. H., & Lee, M. N. (2006). Korean students' environmental literacy and variables affecting environmental literacy. In S. Wooltorton and D. Marinova (Eds.) Sharing Wisdom for Our Future: Environmental Education in Action. Proceedings of The 2006 Conference of the Australian Association for Environmental Education.

Disinger, J. F., & Roth, C. E. (1992) . Environmental literacy. Columbus, OH: ERIC/SMEAC Information Reference Center.

Durmuş, B., Yurtkoru E. S. ve Çinko, M. (2011). *Sosyal Bilimlerde SPSS'le Veri Analizi*. İstanbul: Beta Yayıncılık.

Erdoğan, M. (2009). *5. sınıf öğrencilerinin çevre okuryazarlığı ve bu öğrencilerin çevreye yönelik sorumlu davranışlarını etkileyen faktörle*r. Doktora Tezi, ODTÜ Sosyal Bilimler Enstitüsü, Ankara.

Hines, M. J., Hungerford, H. R., & Tomera, A., N. (1986). Analysis and synthesis of research on responsible environmental behavior: A Meta-analysis. *Journal of Environmental Education*, 18(2), 1-8.

Hsu, S. J. (1997). An assessment of environmental literacy and analysis of predictors of responsible environmental behavior held by secondary teachers in hualien country of Taiwan. Unpublished Doctoral Dissertation.

Karatekin, K. (2011). *Sosyal bilgiler öğretmen adaylarının çevre okuryazarlık düzeylerinin belirlenmesi*. Yayınlanmamış Yüksek Lisans Tezi, Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara.

Karatekin, K., & Aksoy, B. (2012). Sosyal bilgiler öğretmen adaylarının çevre okuryazarlık düzeylerinin çeşitli değişkenler açısından incelenmesi. *International Periodical For The Languages, Literature and History of Turkish or Turkic Volume*, 7(1), 1423-1438.

Kaiser, F., Sybille, W., & Urs F. (1999). Environmental attitude and ecological behavior. *Journal of Environmental Psychology*, 19, 1-19.

Kışoğlu, M. (2009). *Öğrenci merkezli öğretimin öğretmen adaylarının çevre okuryazarlığı düzeyine etkisinin araştırılması*. Doktora Tezi, Atatürk Üniversitesi Fen Bilimleri Enstitüsü, Erzurum.

Kışoğlu, M., Gürbüz, H., Sülün, A., & Alaş, A. (2011). Biyoloji öğretmeni adaylarının çevre okuryazarlıklarının farklı değişkenler açısından incelenmesi. *e-International Journal of Educational Research*, 2(1), 1-14.

Kibert, N. C. (2000). An analysis of the correlations between the attitude, behavior and knowledge components of environmental literacy in undergraduate university students. Master Dissertation, The Graduate School Of The University Of Florida, University Of Florida.

Kiziroğlu, İ. (2000). Türk eğitim sisteminde çevre eğitimi ve karşılaşılan sorunları. *V. Uluslararası Ekoloji ve Çevre Sorunları Sempozyumu*: Çevre Eğitimi, 1-2 Kasım, Ankara, Çevre Bakanlığı Yayını, 165-190.

Kuhlemeier, H., Van Den Bergh, H., & Lagerweij, N. (1999). Environmental knowledge, attitudes and behavior in dutch secondary education. *Journal of Environmental Education*, 30(2), 4-14.

McBeth, W., Hungerford, H., Marcinkowski, T., Volk, T., & Meyers, R. (2008). National Environmental Literacy Assessment Project: Year 1, National baseline study of middle grade students; final research report. Unpublished Project Report. Florida Institute of Technology, Melbourne, USA.

McBeth, B., & Volk, T. (2010). The National Environmental Literacy Project: A Baseline Studyof Middle Grade Students in the United States. University of Wisconsin-Platteville, Platteville, Wisconsin, USA Southern Illinois University-Carbondale, Carbondale, Illinois, USA.

Meuth, A. M. (2010). Environmental literacy of hispanic, urban, middle school students in Houston, Texas Ed. D., University of Houston.

Ökesli, T. F. (2008). Relationship between primary school students' environmental literacy and selected variables in bodrum. Unpublished Master's Thesis, Middle East Technical University, Ankara.

Öztürk, G. (2009). *Öğretmen adaylarının çevre okuryazarlıklarının epistemolojik inançları vasıtasıyla incelenmesi*. Yüksek Lisans Tezi, ODTÜ, Ankara.

Peyton, B., Campa, H., Peyton, M. D., & Peyton, J. V. (1995). Biological Diversity for Secondary Education. Environmental Education Module/ UNESCO - UNEP –IEEP.

Roth, C. E. (1968). Curriculum Overwiev for Developing Environmentally Literate Citizens. http://files.eric.ed.gov/fulltext/ED032982.pdf, (04.06.2013).

Roth, C. E. (1992). Environmental Literacy: Its Roots, Evolution and Directions in the 1990s. http://files.eric.ed.gov/fulltext/ED348235.pdf (06.06.2013).

Schneider, S. (1997). Defining Environmental Literacy. Trends in Ecology and Evolution, 12, 457.

Stockholm, (1972). United nations conference on the human environment. http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=97&ArticleD (05.06.2013).

Teksöz, G., Şahin, E., & Ertepınar, H. (2010). Çevre okuryazarlığı, öğretmen adayları ve sürdürülebilir bir gelecek**.** *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 39, 307-320.

Temel, Z. F., & Aksoy, A. B. (2001). *Ergen ve Gelişimi (Yetişkinliğe İlk Adım).* Ankara: Nobel Yayıncılık.

UNESCO (1978). The Tbilisi Decleration: final report intergovernmental conference on environmental education. Organized by UNESCO in corporation with UNEP, http://www.gdrc.org/uem/ee/EE-Tbilisi_1977.pdf, (12.06.2013).

Varışlı, T. (2009). *Sekizinci sınıf öğrencilerinin çevre okuryazarlığının değerlendirilmesinde sosyodemografik değişkenlerin rolü*. Yüksek Lisans Tezi, ODTÜ, Ankara.

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A Qualitative Inquiry about Students' Conceptualizations of Force Concept in terms of Ontological Categories

Ömer Faruk ÖZDEMİR[1]

[1] Assoc. Prof. Dr., Middle East Technical University, Faculty of Education, Ankara-TURKEY

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ABSTRACT

The purpose of this study was to inquire about students' conceptualizations of the force concept in terms of ontological categories. Although some of the literature have been providing supporting evidences about the fruitfulness of ontological categories for explaining the nature of students' alternative conceptions, some others provide strong arguments against it. To tap the controversial issues in the literature, an inquiry was conducted in a classroom context with students who were seeking a degree to become physics teachers. The data consist of four students' written responses to physics problems, reflections about their own conceptualizations from the theoretical perspective of ontological categories, and video recordings of classroom discussions. The analysis of data showed that a theory-driven interpretation (ontological categories) about students' conceptualizations of the force concept did not match with the students' own interpretations about their conceptualizations. Furthermore, the students did not consider ontological category shift a fruitful instructional strategy because of the possible problems they projected for the implementation. The major problem emerged as the difficulty of situating every physics concept into the distinct ontological categories.

Keywords: Alternative Conceptions; Force Concept; Teaching and Learning Physics; Ontological Categories.

INTRODUCTION

An extensive body of research, conducted during the 1960s through the 1990s, explicitly revealed that students' pre-instructional ideas do not always match with scientifically accepted conceptions and they influence further learning (Driver, 1989). In this period of time, several labels were generated to refer to these ideas, such as "pre-conceptions," "misconceptions," "alternative conceptions," and "intuitive knowledge." The key result of these studies, alternative conceptions influence further learning, initiated a significant argument against a well-established belief among numerous cognitive and educational researchers concerning students' failure to understand physics. According to these theorists, the Piagetian developmental stage of formal operational thinking is the prerequisite of learning physics and students' failure in this domain is due to their under attainment of these stages (White, 1993).

Corresponding author e-mail: ozdemir@metu.edu.tr

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In the early 1980s, the psychological and philosophical base of a new paradigm had already begun to emerge among the community of science educators to explore students' difficulties in learning some basic scientific concepts. It was recognized that alternative conceptions were one of the main problems in students' understanding science and this opened a new window to explore students' failure in learning science. This realization stimulated many researchers to develop new learning models to effectively deal with alternative conceptions. Among others, Conceptual Change Model (CCM) received special interest from the educational community. Furthermore, the CCM has become synonymous with constructivism in science education (Mortimer, 1995). The basic idea behind the CCM is that learning is a rational activity and when students' central concepts are inadequate to explain new phenomena successfully, students must replace or reorganize their central concepts (Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1992). However, in the following years, it was realized that what was supposed to be replaced or reorganized was ambiguous (Wittmann, 2002). The ambiguity is not due to the lack of research on identification of alternative conceptions hold by students but the lack of theoretical arguments about the nature of these conceptions. In the following years, several researchers shifted the emphasis on their research program from "identification" to "understanding the nature" of students' alternative conceptions. However, these affords could not readily provide a coherent and consistent framework. Different researchers generated different interpretations about the nature of alternative conceptions and, as a result, different theoretical frameworks emerged in the literature. Chi and her colleagues' (Chi, 1992; Chi, 2005; Chi & Slotta, 1993; Slotta & Chi, 2006) proposal in terms of ontological categories, diSessa's (1988, 1993) phenomenological primitives, Minstrell's (1992) facets of knowledge, Hammer's (2004) cognitive resources, and Vosniadou's (1994) interpretations in terms of naïve theories and mental models are some examples of these frameworks. The focus of attention in these new frameworks is to understand the cognitive, epistemological, and/or ontological resources used by novices while they are reasoning about physical phenomena, rather than solely identifying students' misconceptions.

In this study, I will focus on one of the frameworks generated for the nature of alternative conceptions, namely ontological categories, and delimit the content area to the force concept. The purpose of the study is to provide a qualitative analysis about students' conceptualizations of the force concept from the perspective of ontological categories. Before formulating specific research questions, I will first provide a theoretical framework for ontological categories in the following section.

Ontological Categories

Based on Keil's (1979) interpretations on conceptual development in terms of ontological categories, Chi and Slotta (1993) proposed a theory about the nature of students' alternative conceptions. The major supposition behind the theory is that all the entities in the world belong to different ontological categories and individuals' learn about these entities by implicitly or explicitly situating them into a specific category. While making these suppositions, Chi and Slotta considered three general ontological categories which were referred to as "matter," "processes," and "mental states." There are also subcategories for each of these general categories such as direct and emergent processes under the category of processes, which all together form a tree. The theory claims that these categories are stable and constraining, which means that an individual's conceptualization of a concept fall into one distinct ontological category and changing it to another category requires an extraordinary change process.

According to this interpretation, the nature of many physics concepts falls into the processes category. Gravitational force, electrical current, heat, and light are provided as examples of physical concepts belonging to this category. Chi, Slotta, & Leeuw (1994) identify several ontological attributes of this category such as no beginning and end, no progression, acausal, uniform in magnitude, simultaneous, static, and on-going. Based on ontological categories, Chi et al. interpret the nature of students' alternative conceptions as misclassification of physics concepts according to their ontological characteristics. Several studies (Reiner, Chi, & Resnick, 1988; Reiner, Slotta, Chi, & Resnick, 2000) assert that students tend to consider many of the physics concepts within the matter category in spite of their process specific nature. It was claimed that students interpret these concepts either as material substances or properties of a material substance. Reiner, Slotta, Chi, & Resnick (2000) define several properties of substance based schema such as *pushable* (able to push and be pushed), *containable* (able to be contained by something), *consumable* (able to be "used up"), *additive* (can be combined to increase mass and volume), *locational* (have a definite location), and *transitional* (able to move or be moved).

Chi et al. (1994) argue that robustness of some alternative conceptions is due to ontological differences between novice and expert's conceptualizations of some physical concepts and the difficulty of shifting a specific conceptualization from one ontological category to another. Based on these interpretations, Chi and her colleagues hypothesized that conceptual change can be facilitated by making students be aware of different ontological categories and the true ontological category of a scientific conception.

Slotta and Chi (2006) tested this hypothesis with pre-test post-test control group design by providing experimental group with direct instruction about process ontology. The study was conducted with 24 undergraduate students about electricity. The qualitative and quantitative analysis of the students' responses showed that ontological training helped students gain an appropriate ontological status for the electricity concepts. Another empirical test was conducted by Lee and Law (2001) with students from a secondary school in Hong Kong. Their results also showed that students' conceptions on electric circuits were substance based and supported the claim that instructional strategies enriched with ontological training helped students change their robust alternative conceptions related to electricity. Similar results were also reported in other domains such as genetics (Tsui & Treagust, 2004; Venville & Treagust, 1998), evolution (Ferrari & Chi, 1998), thermodynamics (Clark, 2006), chemical bonds (Harrison & Treagust, 2000), and management (Rooke, Koskela, & Seymour, 2006).

In addition to these empirical studies, Chen's (2007) interpretation of scientific revolutions in the history of science can be considered as an attempt to make a bridge between ontogenetic and phylogenetic development of scientific ideas in terms of ontological categories. Chen provides several cases from the history of science exemplifying the substance bias in the development of several scientific conceptualizations such as heat and motion which were considered identical to substance based conceptualizations of novices. Further evidences about ontological shifts experienced throughout the history of science provided by Chi and Hausmann (2008). Electricity, dinosaur extinction, theories about the causes of some diseases such as epilepsy are some examples of ontological shifts.

In spite of the numerous studies supporting the theory of ontological categories, several researchers provided strong arguments against it. The first opposition came from diSessa (1993b) who tried to show the implausibility of making direct ontological distinctions among physics concept by providing examples from experts' use of several concepts such as entropy, quantum field, and relativity. In recent years, the major arguments were provided against context independent conceptualizations of ontological categories. For example, Teichert, Tien, Anthony, & Rickey (2008) demonstrated students' context dependent conceptualizations of molecular concepts. Gupta, Hammer, & Redish (2010) also emphasized the importance of contextual factors on thinking about specific physics concepts. They provided several examples from both experts and novices illustrating their transitions from one ontological category to another in different contexts.

According to the perspective of ontological categories, the robustness of some misconceptions were due to students' ontological biases towards a substance based conceptualization and within this framework, ontological attributes used by students provide information about the specific ontological category of a concept hold by students. Based on these arguments, students' use of adjectives and predicates related to a concept were taken as a base to make interpretations about students' conceptualizations. The purpose of this study is to understand students' conceptualizations of the force concept in terms of ontological categories. For this inquiry, the "force" concept was chosen because it is a fundamental concept of Newtonian mechanics and provides a baseline for understanding a broad range of physical phenomena. I first analyzed students' conceptualizations of the force concept from the theoretical perspective of ontological categories by following the same procedure recommended by Chi and Slotta (1993). Then, I focused on the students' own interpretations about their conceptualizations. The available data also made it possible to investigate other related issues such as the change process of students' conceptualization of the force concept and their interpretations about ontological categories. The specific research questions were formulated as follows:

1) How do students conceptualize the force concept according to ontological category perspective?
2) How do students change their conceptualizations of the force concept during classroom discussions?
3) How do students interpret their own conceptualizations of the force concept from the perspective of ontological categories?

METHODOLOGY

In this study, two qualitative methodologies were used, case study (Yin, 2003) and cooperative inquiry (Reason, 2003). The case study was used in a way that each individual student considered as a case and their conceptual reasoning about the physics problems was analyzed by using the theoretical framework of ontological categories. These analyses basically consisted of the researcher's search of the available data for the students' substance based attributions to the force concept.

Cooperative inquiry was used as an instructional tool to help students understand and analyze ontological categories as a theoretical framework. In this inquiry, the role of being researcher was distributed among the whole class by engaging them in reading the related literature, analyzing the exemplary cases, and doing retrospective analysis about their own conceptual difficulties related to the force concept. The data emerging from this inquiry were used to analyze students' own interpretations about their conceptualization of the force concept. In the following sections, participants, classroom setting, and data sources were detailed.

a) Participants and Setting

This study was conducted with 29 undergraduate students (19 females and 10 males) in an "instructional method" course designed for students who were seeking a degree to become physics teachers. The major objective of the course was to help students understand the nature of alternative conceptions and gain basic knowledge and skills on the implementation of several instructional strategies in physics classrooms, such as cognitive conflict, anchoring/bridging analogies, extreme case reasoning, ontological category shift, and learning cycle. The data were collected in two consecutive semesters (2007-2008 autumn and spring semesters). All the students attending the course had already taken the core physics courses (mechanics, electromagnetism, electronics, optics and waves) and they were taking education-related courses during the period of data collection. Students' ages ranged from 19 to 28 with a mean of approximately 22 years. Although the students took the "instructional method" course after they completed core physics courses, they still had conceptual difficulties. Therefore, a considerable amount of time was usually spent on students' own understanding of physics concepts by posing different types of conceptual physics problems at the high school level. In response to these questions, students were requested to describe their own reasoning, to discuss it with class, to reflect on their difficulties, and to find appropriate solutions. Finally, the instructor stimulated them to come up with appropriate instructional strategies to overcome the experienced difficulties. Students were also provided with lectures about different interpretations about the nature of alternative conceptions and instructional strategies, and they were required to read assigned papers selected from the literature. In short, this course was designed to increase students' pedagogical content knowledge by engaging them into an inquiry. Students were evaluated mostly based on their contributions to the classroom discussions and competency on the applications of specific instructional strategies covered in the course.

b) Data Sources

The data set used in this study was extracted from different types of activities conducted with students. The data consist of students' written documents and video recordings of the classroom activities. To respond to the research questions the available data sources were categorized as follows which also shows the sequence of the data collection process

Written responses to the problems. At the beginning of the course, students were provided with a set of problems related to mechanics. The problems were open-ended, mostly counterintuitive, and conceptual. Many of the problems were adopted from the force concept inventory (Hestenes, Wells, & Swackhamer, 1992) and the others were developed by the author and his colleagues. There were 10 problems in total and students completed their responses approximately in 45 minutes.

Classroom discussions about the problems. After students written responses were analyzed by the researcher, different predictions generated for each problem were categorized. In the classroom session, each prediction was written on the board and students were requested to give more details about their predictions by explaining their reasoning. Before students begin discussion, they first had a chance to hear the arguments behind each prediction. All the discussions were video recorded for further analysis.

Reflection papers on ontological categories. After the problems were discussed in the classroom session, students were introduced with Chi and her colleagues' interpretations about the nature of alternative conceptions in terms of ontological categories. In an hour lesson, the findings in the literature about students' use of substance based conceptions exemplified and ontological training as an instructional strategy was explained with specific examples. After these explanations students were requested to read the assigned papers about ontological categories and write a reflection paper about ontological categories. Students were also requested to make interpretations about their own conceptualizations of the force concept and make connections with the theory.

Classroom discussions on ontological categories. To help students detail their arguments about ontological categories, a classroom discussion was conducted after they handed in their reflection papers. During these discussions, students were stimulated to reflect on their own conceptual problems experienced during the problem solving and make connections with the theory, especially the students whose conceptualizations of the force concept coded as substance based by the researcher. All the discussion session was video recorded for further analysis.

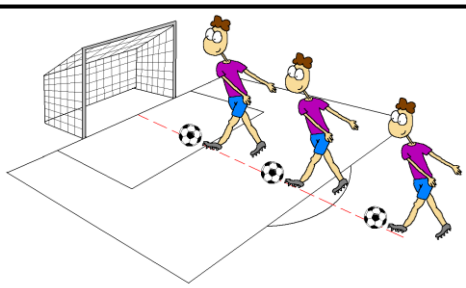
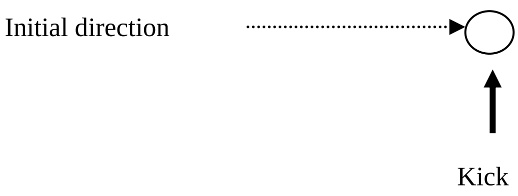
FINDINGS and RESULTS

The data were analyzed separately for each research question. For the first research question (substance based conceptualizations), a straightforward analysis procedure was followed. Based on the theoretical framework of ontological categories, students' written responses and classroom discussions about the problems were analyzed; specific cases where students attributed a substance based characteristics to the force concept was searched and coded accordingly. For the second research question (change process), the data emerging from the students' discussions about the problems were analyzed. In this process, specific attention was given to the particular changes on the students' conceptualization of the force concept during the discussions. These analyses consisted of the researcher's interpretations on the students' use of the force concept from the theoretical perspective of ontological categories. However, for the third research question (students' reflections), students' inquiry and reflections were taken as a base for the analysis.

Students' Substance Based Conceptualization of the Force Concept

The analysis of the students' written responses and classroom discussions about the problems showed that students still had conceptual difficulties related to force and motion after they completed core physics courses. However, only 4 (out of 29) students' difficulties was directly related to substance based conceptualization of the force concept when the available data were analyzed from the perspective of ontological categories. According to this perspective, ontological attributes used by the students provide information about the specific ontological category of the concept hold by the students. The four students' specific attributions to the force concept seemed to be matching with two properties of substance based schema, namely *containable* and *transitional*. The specific attributions to the force concept used by the students were identified as "given," "imparted," and "provided."

Table 1. *The problems on which the students used substance based conceptualization.*

Problem 1		A soccer player is kicking the ball from three different positions as shown on the picture. If you assume that the player is kicking the ball the exact same way in each position, how do you compare the speeds of the ball for each kick when the ball enters the goal?
Problem 2		While a hockey puck is moving in the given direction, it receives a kick. What would be the path of the hockey puck after the kick?

Students' substance based attributions were explicitly observed on two problems which were given on Table 1. Before moving any further, it would be better to talk little bit about these problems. The common characteristic of these problems was that the problem situations included simultaneous and temporary act of forces such as kicking at an object. In addition to the attributions of substance based characteristics, the most explicit form of substance based conceptualization emerged as students' assumption on the existence of the force on an object when there was not actually any force acting on the object. Substance based conceptualization of the force concept did not reveal itself easily if there is a continuing force on objects such as gravitation or continuously pushing or pulling an object. In these situations, it was not easy to distinguish whether students have substance based attributions or not because in both cases there was a force acting on objects.

The four students' substance based conceptualization of the force concept was almost identical in both problems. In both problems, the students thought that there was still a force acting on the object after the kick. The students seemed to be thinking that the temporary force applied by the players during the kick was transferred to the ball. The responses of the four students to the first problem were almost the same. They thought that the ball would enter the goal when the player kicks the ball from a distant position. Below is a student's written response to the first problem.

> "If we ignore the friction, the ball will enter the goal with the highest velocity when the player kicks the ball out of the penalty area. This is because, the ball accelerates with the force *given* by the kick. In a small distance the ball would not accelerate much. But, when the distance was increased, the ball had a chance to increase its velocity on the way to the goal."

According to Newtonian physics, there is no force acting on the ball after the kick – the force is simultaneous and when the kick is over, there is no force acting on the ball anymore. However, the students' conceptualization seemed to be that the force was transferred to the ball after the kick. Therefore, they thought that the force was still acting after the kick and the ball was accelerating. Another interesting point in the students' reasoning was their use of Newton's second law (force causes acceleration). Although students correctly stated Newton's second law, their inappropriate conceptualization of the force concept made this statement meaningless. This is like saying "sugar makes tea sweet" but conceptualizing sugar as something else, like salt. Although the literal statement of the law is correct the actual meaning is completely destroyed.

The following examples describe the four students' reasoning about the second problem. The problem was asking the path of a hockey puck when it receives a kick while moving in a straight line with a constant speed. There were two different responses to this problem. Nevertheless, in both cases the students' conceptualization of the force concept was the same: they thought that the force applied by the player transferred to the puck. One of the students thought that the puck would go straight on the direction of the kick. His argument was quite interesting. He claimed,

> "Objects move in the direction of the net force acting on it. In this problem, the only force acting on the puck is the force *provided* by the kick. Therefore, the puck will move in the direction of the kick. There is no other way."

This student was quite sure with his answer. In actuality, objects do not necessarily move in the direction of the net force acting on the object. Probably he generalized a principle specific to the forces acting on static objects or acting on the same direction with the velocity. He thought that the force was imparted to the puck after the kick. Therefore, he thought that the force was still acting after the kick. Other three students' responses were similar to that of the first problem; they stated a correct physical principle. However, the operation of the principle did not work well because of the students' misconceptualization of the force concept. They thought that the puck would follow a curvy path. Actually, their reasoning can be easily predicted by thinking as if there were continuing force acting on the puck (like gravitation). Below is one of the students' written explanations.

> "The puck would follow the path as shown on the picture above (he drew a curve)… There is only one force acting on the puck which is the force *given* by the kick. The puck is moving under the influence of initial velocity and this force. Therefore, the puck would be distracted continuously from its initial direction and follow a curvy path."

Actually these students' reasoning could be correct if there was a continuing force acting on the puck (such in the case of projectile motion – continuous act of gravitation on a horizontally moving object). However, in this situation there is no continuous force. The force due to kick is simultaneous and there is no force after the kick. Again, we see that although students correctly stated a physical law, their misconceptualization of the force concept led them to an incorrect conclusion.

The Change of Substance Based Conceptualization

In this section, I will describe how the students who were holding a substance based conceptualization (according to ontological category perspective) changed it through classroom discussions and then make speculations about this change process. To describe this process, I will present a considerably long episode from the classroom discussions. In this episode, the students were discussing about the soccer problem. During the discussions, there were 15 students in the class and two of them (Meltem and Defne) were holding a substance based conceptualization.

Instructor:	Okay, here is the problem. In your papers there were two different answers… Let's hear first from the ones who thought that the farther the ball is from the goal, the faster it gets…
Meltem:	I thought that when we increase the distance, the ball would gain more acceleration and enter the goal with greater speed.
Instructor:	Can you explain more why do you think the ball gain more acceleration with the distance?
Meltem:	Actually, I was thinking about the time. If there is more time, the ball will gain more speed. Because there is acceleration all along this time, the speed of the ball will increase.
Instructor:	Then you are saying increase in speed, not the acceleration.
Meltem:	Yes, the speed, not the acceleration. Acceleration will be constant which increases the speed…
Std2:	I could not understand why there is acceleration all along?
Defne:	Because of the kick. Kick is the net force here, which causes acceleration.
	...
Std4:	Then, if we kick the ball from the other goal area, does it enter the goal with more speed?
Std7:	Good question! What if we increase the distance to say a thousand kilometers? There is no way of increasing the velocity.
Meltem:	There is air friction [pause] and eventually the ball will fall…
Std6:	What if there is no friction and gravitation?
Meltem:	I know, it sounds strange but according to the Newton's second low [F=m.a]. The speed must increase…
Std2:	According to the law, if there is no force there is no change in the velocity. The ball's speed does not change all along the way...
Defne:	But there is a force.

Std11:	No, there is not.
Defne:	What about the kick? The kick is a force, isn't it?
Std2:	Yes, but there is no force after the kick…
Std10:	It is like a spring; when the objects leave the spring there is no force after…
Std7:	If there were force after the kick, everything should be speeding up. It would not be a problem to reach the velocity of light in space and we could send spaceships to other galaxies easily.
Meltem:	I understand what you are saying. I did not think about it before. Let me think about it for a while.
Instructor:	Defne, what do you think about this?
Defne:	I am confused. I always thought there was a force after the kick. But, it is correct if there is always force everything should be speeding up. I did not think about it before either.
Std8:	You thought force like energy I guess…
	[We took a break after this comment. During the break I believe students kept discussing about the force concept; however, because they left the class these discussions could not be recorded. When we returned, the discussions continued as follows]
Defne:	I thought about it and it makes sense. If we think force like that we can never get a constant velocity. The force is there while we are pushing or pulling; when it is over, there is no force.

In this episode, we see Defne and Meltem's dissatisfaction with their prediction by the arguments provided by other students. At the beginning of these arguments, other students did not use physics concepts or principles but they tried to falsify the substance based prediction by common sense beliefs supported with extreme cases. Later on, Newton' second law brought into discussion which made the students realize the conceptual discrepancies among them related to the force concept. Throughout the discussions Meltem and Defne realized that Newton' second law did not make sense by using the force concept as they used to think. Through the end of the discussions they seemed to be changing their conceptualization of the force concept.

The following quotations extracted from the students' discussions on the second problem provided more evidence that the students have changed their conceptualization. In this episode, we immediately see that the students who used substance based conceptualization before were changing their arguments on the second problem (hockey).

Defne:	I made the same mistake in this problem. I solved the problem as if there were force acting on the puck after the kick. Therefore my answer was a curved path.
Instructor:	What do you think now?
Defne:	Okay. Let me think. I previously thought it like a projectile motion. But it is not possible. I know if there is no force, objects must go straight or do not move. The kick is simultaneous and the puck gains a velocity in the direction of the kick. It would move in the direction of the kick but the puck was moving before the kick. Well. [Pause] Okay, there is no force after the kick, and then it has to move in a straight line. If there is no force it can't make a curve, it must be straight. We should add up the velocities then… It must be between the kick and the initial velocity.
Instructor:	Meltem, what about you? How do you think about the problem?
Meltem:	I agree.
Instructor:	But you did not think this way before.
Meltem:	Yes, I thought there was force acting on the puck after the kick.

Instructor: What makes you think, now, that there is no force after the kick?

Meltem: Because force is not defined that way. There is force when there is an there is something between the things like pushing or pulling. After that, it is over.

Instructor: Tell us more how did you think about the force before?

Meltem: I do not know exactly. I did not think about the force with details before. I solved tons of problems while I was getting prepared for the university entrance exam and none of them required me to figure out whether there was a force or not. The force was always given. But, in some cases, I assumed that there was no force; for example, if the problem was saying the speed was constant, I immediately assumed that there was no force.

What can we say about this change process? According to the theoretical framework of ontological categories, these students have shifted their conceptualization of the force concept from one ontological category (matter) to another (the process). The theory claims that "once an ontological commitment is made with respect to a concept, it is difficult through any stages of mental transformation to change one's fundamental conception from a *substance* to a *process* (Chi & Roscoe, 2002). Thus, ontologically misattributed concepts would require an extraordinary process of conceptual change" (Slotta & Chi, 2006, p. 263). However, this shift was not as problematic as it was projected by the theory. From Meltem and Defne's statements, we can understand that they did not have a strong ontological commitment to the force concept although their initial reasoning about the problems showed that they attributed substance based characteristics.

Although I could exemplify only Defne and Meltem's case because of the limited space, other two students also changed their conceptualization of the force concept in a short time. The easiness of these students' conceptual change seemed to be due to students' familiarity about the process nature of the force concept. One source of this familiarity might be coming from the students' experiences with springs as one of the students explanation pointed out; "It is like a spring; when the objects leave the spring, there is no force after…"

Students' Reflections on Ontological Categories and Their Own Conceptualizations

The major pattern emerging from students reflections about ontological categories was that they conceptualized ontological categories as a complex issue. Almost all of the students claimed that ontological categories could not make it easier to understand concepts, but make it more complicated and confusing for both teachers and students. The following script extracted from one of the students' reflections is a typical response provided by many of the students:

> "I think ontological categories might explain some of the roots of misconceptions. However, it doesn't seem possible to make students be aware of different types of ontological categories and stimulate them to shift from one category to another. This process might confuse them because even I am not sure about the ontological status of every physical concept. For example momentum, I do not know its ontological status. I know what momentum is and what is not but I cannot tell students about its ontological category."

Only two students (out of 29) provided supporting arguments for ontological categories without a substantial critique. These students arguments were based on a claim that knowing a concept requires being aware of its ontological status. The following quotation was extracted from one of these students' reflections.

> "I think we can help students understand physics concept by teaching them about different ontological categories. To know something with details require knowing its ontological status. For example, if we need to know about whales we have to know that it is a mammal not a fish. Similarly, when students learn about the force concept they have to learn that it is a process not a matter."

The students' reflections whose conceptualization of the force concept was coded as substance was interesting because they did not interpret their conceptualization substance based. Without an exemption, all four students argued that their conceptualization of the force concept was similar to energy or momentum. They explained their conceptual difficulties in terms of failure to totally comprehend an individual concept. Below is one of the four students' reflections.

> "I do not think that ontological categories are an appropriate way of describing the roots of misconceptions. While I was solving the soccer problem, I thought there was a force after the kick. Actually, I did not think about the force something like matter or substance. I realize now that I thought force more like energy or momentum. I guess we need to know exactly what is force, energy, current, momentum etc. Our instructors did not explicitly provide lectures about the details of these concepts; therefore, we did not completely understand these concepts. I guess the problem is simple: we do not know about the concepts. Ontological categories are difficult to grasp and do not seem to be necessary for students to know. We need to help students wholly understand each concept. We can help them by providing different types of examples for these concepts. For example for the force concept we should explicitly show students when there is a force and there is not with broad range of examples."

During the classroom discussions, students restated their opinions they wrote on their reflection papers. The major argument immerging from the discussions was the difficulty of situating all the physics concepts into the distinct ontological categories. Although they did not explicitly stated, they seemed to be thinking that all the physics concepts should be categorized explicitly according to their ontological categories to be used for instructional practices. The discussion began with the following question asked by one of the students.

> "I could not find an ontological category for the momentum. Is there any map or table showing the ontological categories of all the physics concepts?"

Unfortunately we could not find a distinct category for the momentum throughout the discussions and then the discussions shifted to other concepts such as energy, volume, density, and even mass (which should be considered as a form of energy from the relativistic perspective). Although finding a category for the concepts studied in the literature such as heat and electric current was rather easy, the classroom discussion showed that finding an ontological category for every concept encountered in physics is not an easy task. I think the following comment made by one of the students summarizes the general attitude of the students toward ontological categories.

> "I don't think categories are important as long as we know exactly what a specific concept is all about. I remember our discussions in elementary school about whether a watermelon is fruit or vegetable. As long as I know how it tastes, smells, and look like it does not matter which category I am putting them in."

DISCUSSION and CONCLUSION

The literature on ontological categories has been providing very convincing results about students' biases towards substance based conceptualizations and the effectiveness of ontological training on students' understanding of true nature of scientific concepts. However, this research line has been taking an outsider perspective and put little attention on students' own interpretations about their conceptualizations. In this study, when the available data were analyzed from the same perspective, similar conclusions were reached that some students' conceptualization of the force concept seemed to be substance based. However, these students' retrospective analysis about their own conceptualizations showed that they did not consider their conceptualization of the force concept substance based. They did not make an ontological distinction between their previous and new conceptualizations of the force concept. They argued that they experienced difficulty with the force concept because they did not have explicit knowledge about force. They attributed their conceptual problems to the instructional practices ignoring the conceptual aspects and heavily relying on laws and formulas. Students' classroom discussions about the problems also provided supporting evidence that they could easily adopt a scientific conceptualization when they were explicitly informed about the actual meaning of the concept by their classmates.

Most of the students also believed that ontological interpretations on physical concepts make it more complicated to understand. Classroom discussions also supported this belief; when the questions about ontological status of different types of physical concepts were raised, all class including the instructor realized that it is not an easy task. Even for the simplest concepts, like "mass," the categorization process turn out to be a complicated issue. Although we consider mass concept as matter, in the advanced level it is also energy (Einstein's well-known proposition $E=m.c^2$). Should we put it in the matter category or process; or should we adopt a context dependent ontological schema (which was rejected by the theory)? Another similar concept is "momentum;" how should we define its ontological status? Because in the simplest form, momentum is mass times velocity, which includes both matter and process characteristics. The number of examples can be increased but finding a context independent ontological category for every concept does not seem possible.

In spite of these critiques, there was a consensus among students that traditional instruction did not support gaining an explicit knowledge about the physics concepts. In this respect, what the students are arguing against and the theory match with each other. Both argue that without special treatments demonstrating the explicit forms of a concept, it is difficult to construct an appropriate conceptualization. However, the students strongly rejected the idea of conceptualizing the physic concepts in terms of ontologically distinct categories because of the difficulty they experienced in their attempts to locate physics concepts into the distinct ontological categories.

The implications of this study are twofold. The first one is methodological – specific attributions used by individuals and ontological categories do not necessarily match with each other. Therefore, alternative methodologies should be employed to understand students' ontological orientations toward a specific concept. The second one is theoretical. The question is; can every physics concepts be located into context independent distinct ontological categories? In this classroom, we failed to do that. The researchers who are in favor of the theory should provide more evidence with broad range of examples that every physics concept can be located into distinct ontological categories.

REFERENCES

Chen, X. (2007). The Object Bias and the Study of Scientific Revolutions: Lessons from Developmental Psychology. *Philosophical Psychology, 20,* 4, 479–503.

Chi, M. T. H. (1992). Conceptual change within and across ontological categories: Examples from learning and discovery in science. In R. Giere (Ed.), *Cognitive Models of Science: Minnesota Studies in the Philosophy of Science* (pp. 129-186). Minneapolis, MN: University of Minnesota Press.

Chi, M.T.H. (1997). Creativity: Shifting across ontological categories flexibly. In T.B. Ward, S.M. Smith, & J. Vaid (Eds.), *Conceptual Structures and processes: Emergence, Discovery and Change.* (pp. 209-234). Washington, D.C: American Psychological Association.

Chi, M. T. H. (2005). Commonsense Conceptions of Emergent Processes: Why Some Misconceptions Are Robust. *Journal of the Learning Sciences, 14,* 161-199.

Chi, M. T. H., & Roscoe, R. (2002). The processes and challenges of conceptual change. In M. Limon & L. Mason (Eds.), *Reframing the process of conceptual change: Integrating theory and practice* (pp. 3–27). Dordrecht, The Netherlands: Kluwer.

Chi, M. T. H., & Slotta, J. D. (1993). The ontological coherence of intuitive physics. Commentary on A. diSessa's "Toward an epistemology of physics." *Cognition and Instruction, 10*, 249-260.

Chi, M. T. H., Slotta, J. D., & de Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction, 4,* 27-43.

Clark, D. B. (2006). Longitudinal Conceptual Change in Students' Understanding of Thermal Equilibrium: An Examination of the Process of Conceptual Restructuring. *Cognition and Instruction, 24*(4), 467–563

diSessa, A. (1983). Phenomenology and the evolution of intuition. In D. Gentner & A. Stevens(Eds.), *Mental models* (pp. 15–33). Hillsdale, NJ: Lawrence Erlbaum.

diSessa, A. (1988). Knowledge in pieces. In G. Forman & P. Pufall (Eds.), *Constructivism in the computer age* (pp. 49–70). Hillsdale, NJ: Erlbaum.

diSessa, A. (1993a). Toward an epistemology of physics. *Cognition and Instruction, 10,* (2&3), 105-225.

diSessa, A. (1993b). Ontologies in Pieces: Response to Chi and Slotta. *Cognition and Instruction, 10* (2&3), 272-280.

Driver, R. (1989). Students' conceptions and learning of science. *International Journal of Science Education, 11*, 481-490.

Ferrari, M. & Chi, M.T.H. (1998). The nature of naive explanations of natural selection. *International Journal of Science Education, 20,* 1231-1256.

Gupta, A., Hammer, D., & Redish, E. F. (2010). The case for dynamic models of learners' ontologies in physics. *Journal of the Learning Sciences, 19* (3), 285-321.

Hammer, D. (2004). The variability of student reasoning. Lecture 3. Manifold Cognitive Resources. In E. Redish & M. Vicentini (Eds.), *Proceedings of the Enrico Fermi Summer School, Course CLVI* (pp. 320–340). Bologna: Italian Physical Society.

Harrison, A. G., & Treagust, D. F. (2000). Learning about Atoms. Molecules, and Chemical Bonds: A Case Study of Multiple Model Use in Grade 11 Chemistry. *Science Education, 84*, 352-381.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force Concept Inventory. *The Physics Teacher, 30*, 141-158.

Ioannides, C., & Vosniadou, S. (1991, August). *The development of the concept of force in Greek children.* Paper presented at the biennial meeting of the European Society for Research on Learning and Instruction, Turku, Finland.

Keil, F. C. (1979). Semantic and Conceptual Development: An Ontological Perspective. Cambridge, MA: Harvard University Press.

Lee, Y. & Law, N. (2001). Explorations in promoting conceptual change in electric concepts via ontological category shift. *International Journal of Science Education*, *23*(2), 111-150.

McCloskey, M. (1983). Naïve theories of motion. In D. Gentner & A. L. Stevens (Eds.), *Mental models* (pp. 299-324). Hillsdale, NJ: Erlbaum.

McCloskey, M., Washburn, A. and Felch, L. (1983) Intuitive physics: the straight-down belief and its origin, *Journal of Experimental Psychology: Learning, Memory and Cognition,* 9, 636-649.

Minstrell, J. (1992). "Facets of students' knowledge and relevant instruction." Paper presented at the International Workshop: Research in Physics Learning - Theoretical Issues and Empirical Studies, University of Kiel (IPN), Kiel, Germany.

Mortimer, E. F. (1995). Conceptual change or conceptual profile change? *Science and Education, 4,* 267-285.

Posner, G. J., Strike, K.A., Hewson, P.W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*, 211-227.

Reason, P. (2003). Cooperative Inquiry. In J. A. Smith (Ed.), *Qualitative Psychology: A Practical Guide to Research Methods (*pp. 205–231). London: Sage.

Reiner, M., Chi, M. T. H., & Resnick, L. B. (1988, August). Naïve materialistic belief: An underlying epistemological commitment. Proceedings of the Tenth Annual Conference of the Cognitive Science Society (pp. 544-551). Hillsdale, NJ: Erlbaum.

Reiner, M., Slotta, J. D., Chi, M. T. H., & Resnick, L. B. (2000). Naïve physics reasoning: A commitment to substance based conceptions. *Cognition and Instruction, 18,* 1-34.

Rooke, J. A., Koskela, L., & Seymour, D. (2007). Producing things or production flows? Ontological assumptions in the thinking of managers and professionals in construction. Construction Management and Economics, 25, 10, 1077–1085

Slotta J., & Chi, M. T. H. (2006). Helping Students Understand Challenging Topics in Science Through Ontology Training. *Cognition and Instruction, 24(2),* 261-289.

Slotta, J. D., Chi, M. T. H. & Joram, E. (1995). Assessing Students' Misclassifications of Physics Concepts: An Ontological Basis for Conceptual Change. *Cognition and Instruction, 13,* 373-400.

Smith, J. P., diSessa, A. A., & Roschelle, J. (1994). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences, 3*(2), 115-163.

Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. A. Duschl & R. J. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147-176). Albany: SUNY Press.

Teichert, M. A., Tien, L. T., Anthony, S., & Rickey, D. (2008) *International Journal of Science Education, 30,* 8, 1095 – 1114

Tsui, C. Y., & Treagust, D.F. (2004). Conceptual change in learning genetics: An ontological perspective. *Research in Science & Technology Education, 22,* 185-202.

Venville, G. J., & Treagust, D. F. (1998). Exploring Conceptual Change in Genetics Using a Multidimensional Interpretive Framework. *Journal of Research in Science Teaching, 35,* 9, 1031–1055

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4,* 45-69.

White, B. Y. (1993). Thinker tools: Causal models, conceptual change, and science education. *Cognition and Instruction, 10,* 1-100.

Wittmann, M. C. (2002). The object coordination class applied to wave pulses: Analyzing student reasoning in wave physics. *International Journal of Science Education, 25*(8): 991-1013.

Yin, R. K. (2003). *Case Study Research: Design and Methods.* Thousand Oaks, CA: Sage

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Effect of Inquiry-Based Science Activities on Prospective Elementary Teachers' Use of Science Process Skills and Inquiry Strategies

Oğuz ÖZDEMİR[1], Hakan IŞIK[1]

[1] Assoc. Prof. Dr., Mugla Sitki Kocman University, Faculty of Education, Mugla-TURKEY

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ABSTRACT

In this study, the effect of science activities designed by inquiry-based approach on prospective elementary teachers' utilization of science process skills and inquiry strategies is investigated. The study was conducted by a group of prospective elementary teacher (N=119) established by mean of purposed sampling. Data was gathered pre and post instructional practices of the instruments "science process skills and strategies (S&S)- scale" and "science process skills (SS)-test". The data were analyzed by procedures of dependent group t-test and Pearson correlation test which pointed an effect of inquiry - based activities on the prospective teachers` use of science process skills and inquiry strategies. The study concludes with recommendations for further investigations to signify and overcome the barriers challenging the prospective teachers' adaptations and practices of science process skills and inquiry strategies.

Keywords: Inquiry-Based Teaching; Inquiry Strategies; Prospective Elementary Teachers; Science Process Skills; Science Teacher Education.

INTRODUCTION

Students from all levels of education witness through observation the various natural events which make them wonder. Student explanations based on intuitions on nature events are often away from consistency and reliability (Liu, 1998). Also, science textbooks inheriting abstract and prefabricated forms of knowledge contribute limited or none guidance to student experience with science activities and natural events (Lin et al., 2013; Stear et al., 1998). However the ways of investigation and discovery which scientist adopts to study the nature and problems provide students tracks to overcome limitations of traditional science teaching and materials. Reliable and valid explanations for science activities and natural events depend on students experience with the inquiry method framing the scientific studies.

Inquiry as an instructional approach was brought to discussion by progressive philosopher John Dewey at the beginning of 20th century (Abd el-Khalic et al., 2004; Polman & Pea, 2000). The approach signified the importance and essentiality of learning as an experience based on lived processes. Inquiry as a method is defined as the actual processes by which scientists unveil the reality (Chinn and Malhotra, 2002) and it is widely believed that its adaptation to science instruction helps students in understanding the natural events (Chen & Chen, 2012). Even though inquiry instruction seems to be resonating as hands –on and minds-on practices among science education community, the views hold on for the place and praxis of inquiry approach in science education are further perplexed by various perspectives. Abd el Halick et al., (2004) assesses inquiry perspectives in science education as a mean which shapes the instruction and helps students gain science content and as a gain which students can acquire through the science instruction. Anderson (2002) oversees inquiry first as the ways of investigation and discovery which were practiced by scientists, secondly as the instructional ways through which students can be able to learn science and lastly as various approaches of teaching science practiced by teacher.

What would be the most appropriate way to follow in science education to practice inquiry approach? Nonetheless there is no certain answer generated for such a quest however certain strategies can be followed to conduct inquiry teaching in science classroom. The strategies would be the ones of such: to produce and analyze a case or event which is scientifically focused and framed on a question, gathering evidence, producing explanations to answer the questions, evaluating and testing the results from various perspectives and communicating the outcomes objectively with a community of peers (Biggers & Forbes, 2012). Exemplars of instructional practices are benchmarked with existence of authentic questions originating from or in the vicinity of students´ lives (Keys & Brayn, 2001; Miri et al., 2007). Within such a context, science activities form an arena where students can experience the importance and meaning of inquiry at a personal level (Crawford, 2000). Students must be decorated with critical thinking abilities adequately to bring out and answer the questions inheriting some personal meaning as a life experience (Southerland, Gess-Newsom & Johnston, 2003). Therefore, in-class practices of inquiry instruction provide students with opportunities to be critical and skeptical to compare existing knowledge with observed events. At the same time, along with the discovery of facts of nature by check and balances of ideas and knowledge with the newly experienced phenomena at hand, the inquiry-based science activities organize the scientific content knowledge at personal levels (Entwistle & Ramsden, 1983, cited in BouJaoude, Salloum &El-Khalick, 1994).

Sandoval and Reiser (2003) emphasize the experience and learning of scientific activity processes that paves way to inquiry learning for unearthing logical explanations as well as satisfying epistemological validity. Within the same framework, NRC (1996, 2000) provides the essential process and skills for students to be able to conduct inquiry successfully. Inquiry skills similar to science process skills describe the steps which students must be able to do within the learning environment. These are developing satisfactory explanations based on observations for events and phenomena in science courses, supporting scientific explanations with evidence and arguments and defending the outcomes before a group of peers with the scientifically established means of communications. Inquiry as a multifaceted methodology covers the process skills such as making observations, putting questions for research, planning investigations, comparing exiting knowledge with experimental results, comprehending the results, collecting evidence and using proper means and methods for analysis and interpretation, proposing and communicating answers, explanations and expectations. Therefore, the process skills in science education can be achieved along with the accomplishing inquiry based teaching.

Along with the change on teacher and student roles in learning in a constructivist learning environment, students' academic performance on science subjects is associated with acquisition and display of science process skills. Within such a framework of science instruction, science teacher`s role as a guide and facilitator has been required especially in science activities where the opportunities of observations and experimentations are provided for students. As a matter of fact, Rogers and Abell (2007) signify the change in teacher and student roles in science laboratory courses. Within such a context, student performances in stages starting with the subject of the inquiry investigation, continuing with gathering and interpreting evidence are valued as chances for students to make guided or independent decisions. However, drawbacks in teacher' intervention as a guide to students' learning process in inquiry-based science instructions challenges the practice of such an approach to extensive scale (Chin & Chia, 2004; Smith & Anderson, 1989).

Studies conducted with the science teachers of K-9 levels provide the barriers and limitations by the implementations of inquiry-based science instruction. Roehrig and Luft (2004) found that the middle school science teachers were confined with the lack of knowledge and skills to conduct inquiry teaching and were also concerned with the class management and curricular planning. Crawford (2007) revealed that deficiencies in teachers' conceptions on the conduct of science diminish their implementation of inquiry.

Studies conducted to investigate in-class inquiry instructions display the shifts in the focus of inquiry strategy. In a study with a sample of Nicaraguan primary school level teachers of science, Lucero, Valcke and Schellens (2013) showed that teachers preferred assisting students to pass through the stages of an activity instead of guiding them to think on different perspectives and decision making processes. Kim, Tan and Lee (2013) investigated teachers' perceptions on inquiry-based science teaching approach in Singapore national curriculum and found that teachers took students' acquisition of content knowledge as a benchmark to accomplish via science activities rather than the progression of skills and abilities to conduct an activity independently. From an overall perspective, inquiry practices is under scrutiny and questioned because of the recipe type science activities which are in confirmatory nature where students are the seekers of right and certain answers and effort to develop dexterity with science materials as skills (Crawford, 2007).

Findings provided by aforementioned studies can be interpreted such that the teachers instructing science might have been actually challenged by the lack of motivational and confidence related shortcomings, and not familiar with the required pedagogical training to conduct inquiry-based science teaching approach. In Turkey, science teachers were founded to be determined to teach science with inquiry approach but they lack experience and skills to put it into practice (Sahin, Isıksal & Ertepınar, 2010; Koksal & Berberoğlu, 2014). As a matter of fact, low scores gained by Turkish students in TIMMS exams for the science questions requiring some use of inquiry skills can be regarded as the indicator of that inquiry practices being implemented in the schools are not effective in acquisition of the skills by students foreseen by the curriculum (Koksal & Berberoglu, 2014). Overall, professional training and guidance is necessary for in-service and as well as prospective teachers to conduct inquiry based instruction of science activities. Moreover, Melville and Bartley (2010) signified the importance of professional learning opportunities designed for instructors of science courses to enrich their conceptions of inquiry teaching perspectives besides the mastery on inquiry teaching of a subject matter. Lin, Hong, Yang and Lee (2013) revealed with a group of Taiwan primary school instructors of science courses that at the first hand they have to learn inquiry strategies for their own need. As a result, this study accepts the view that teachers of science need to be decorated with science skills and inquiry strategies to teach science.

While the importance of inquiry-based teaching and learning has been rising in science education, the studies have showed the limitations and barriers to its implementation of the inquiry approach. Teachers of science courses are instrumental in implementing the science curriculum at schools. Aforementioned studies globally depict a picture for the performances of teachers of science courses on curricular activities that inquiry practices by both in-service and prospective teachers must be investigated. Therefore the solutions for satisfactory inquiry based science teaching must be associated with the way actually teachers of science are educated to implement such a purpose.

In particular, any consideration for the answers and solutions to the challenging situation must regard the fact that prospective teachers of science subjects might have been obliged to start the profession before being educated properly on inquiry based teaching. The teachers need to be decorated with features of science process skills and inquiry strategies to manage a classroom with inquiry based learning environment. With such an impulse, this study investigated the effect of inquiry based science activities on prospective elementary teachers' use of science process skills and inquiry strategies.

In general, inquiry approach is implemented as guided and open inquiry sessions where students have chance of learning with teacher guidance in a constructivist environment. Inquiry learning is generally associated with extreme participation and responsibility of the students (Welch et al., 1981). Teachers of science are expected to be independent learners of science concepts to some degree. Such implementations emerge a question on the efficiency of teacher guidance in student science learning (Koksal & Berberoğlu, 2014). This study includes science activities designed by the prospective elementary teachers. The teachers brought the subject of the activities, did planning and investigation of the problem, decided on the analysis, interpret and display of the results. They were guided on necessity by the researchers to include certain stages such as science process skills and inquiry strategies. Following research questions were answered by this study:

1.1. How frequent and to what level are the science process skills utilized by prospective elementary teachers during science activities?
1.2. What changes occurred for the frequency and level of the science process skills utilized by prospective elementary teachers during science activities?
2.1. Which inquiry strategies are often used by prospective elementary teachers during science activities?
2.2. How do the utilization frequencies of inquiry strategies change during the science activities?
3.1. What are the correlations among inquiry strategies used by prospective elementary teachers during science activities?
3.2. How do the correlations among the inquiry strategies used by prospective elementary teachers changed during science activities?

METHODOLOGY

a) Sample

Sample of the study was chosen with the technique of purposeful sampling. Two criterions were established for the sampling procedure in a plain way. Firstly, prospective teachers who would be selected to participate in the study are expected to be the ones teaching science subjects at the elementary school level. Secondly they should have been enrolled in a university level science course. All 119 prospective elementary teachers enrolled in the third grade course Science and Technology Teaching II in a college of education in Turkey at the year of 2011-2012 were participated in the study. Forty-five of the participants (%37,8) were male and seventy-four of them (%62,2) were female.

b) Data Collection Instruments

Investigation of inquiry based science activities was conducted with the data gathered by two quantitative instruments. These are "science process skills and inquiry strategies scale (S&S-scale)" and "science process skills test (SS-test)". S&S scale was developed by the researchers and consists of two subscales on science process skills and inquiry strategies. In the first subscale, the participants are asked to provide information on how often in science courses they utilize the skills such as: observation, measurement, recoding data, interpreting data, classification, comparison, estimation, making hypothesis, identifying and testing variables and making a conclusion. The responses are marked as "the least" or "the most". The validity of this subscale is confirmed by two university level instructor in the field. Second dimension consists of eight statements on inquiry strategies regarding the critical perspective toward a new idea or observational event and confirmation of the truthiness of existing and newly admitted knowledge. Participants mark on Likert- scale indicating their use of each strategy in science courses. Development of these subscales included a trial of pilot study which was used to evaluate and refine the statements. Cronbach alpha values of these scales are 0, 60 and 0, 65 at the beginning of the study. These values may be regarded as right below the acceptable border value. Such low scores of reliability can be reasoned with on the fact that this study is not measuring achievement or performance but rather interested in the personal constructs such as attitudes toward or utilization of skills and abilities (Kline, 1999). Beside the prospective elementary school teachers' self reports, objectified data on their performances on the use of science process skills were evaluated with science process skills test (Çelik, 2013). The test includes 30 multiple choice items on science process skills which are in the focus of the study. KR-20 reliability value of the test was 0,80.

c) Data Collection and Analysis

The study is conducted as pre and post experimental design. The data in the study was gathered by pre and post application of the instruments S&S-scale and SS-test. In SS-scale, the responses to the first subscale regarding science process skills were coded as "1" for the least use and "2" for "the most use". The responses to the second subscale regarding inquiry strategies were coded as "1" for "the least", "2" for "seldom", "3" for "sometimes", "4" for "usually" and "5" for "always". The responses to science process skills test were coded as "0" for wrong and "1" for true responses. Then, all the data were entered and analyzed with SPSS 17 statistical program.

The evidence for the status and change of the utilization frequency of science process skills and inquiry strategies by prospective elementary teachers were obtained with the descriptive analysis of the responses to SS-scale items and as well as the comparison of their pre and post mean values with t-test analysis for dependent groups. Moreover, to obtain evidence on the question of that how successfully the science process skills were actually applied by the participating prospective teachers during the science activities, the responses to the SS-test and the self reported utilization frequencies of science process skills were analyzed with Pearson correlation analysis between the pre and post mean values of these items. Lastly, to reveal any relations among the utilization frequency of inquiry strategies by the teachers, the Pearson correlation analysis was conducted for the responses to the related items.

d) Instructional Process

The study was taken place in the course of Science and Technology Teaching II for a time length of twelve weeks. The course covers the science subjects which are thought to the fourth and fifth grade students in elementary school. The prospective elementary teachers were grouped as three or four and then each group planned, designed and applied a science activity on these subjects. The researchers are also the instructors of the course and provided guidance to the participants in the conduct of the activities. Duration of each activity is limited to one class hour. All activities are designed by inquiry based approach and included an experimentation phase. The activities started with a question to make other students wonder and motivate about the activity or its ending. The researchers guided the prospective teachers to include instances of observation, measurement, comparison in the activities therefore the peers who are following the activity have opportunity to practice and apply the related skills. Moreover, through questions or statements, the students conducting the activity tried to signify the contradicting results with daily life and intuition based ideas hold by people.

To involve students in active use of inquiry learning approach for science process skills and inquiry strategies, written and oral feedback instruments are used to motivate students to follow up and evaluate each activity carefully. To strengthen the teachers' involvement in the activity, they were asked to practice a technique of "Prediction-Observation-Explanation" phase and invited to share what they explored and discovered orally with the class. They were also involved in situations to answer the questions of such "what is interesting in my observation", "what is new and different from what I have already know", "what I can prove with what I already know" and "what are contradicting with what I already know". Thorough the oral and written sessions on such questions, the teachers faced with epistemological challenges and organized their knowledge and experience. Moreover, "the activity evaluation form" which is designed by the researchers was filled by the participants individually upon following the activity. The statements in the form asked to evaluate the discovery, argumentation, participation, creativity and genuine characteristics of the activity. The participants were also obliged to write a journal after each activity. The purpose of journal writing is to help them to evaluate activity outcomes with the questions of "what", "how" and "why". Along with such follow-up studies, a discussion and critical environment in the class was established and the participants were guided to experience inquiry as well as gain interest and awareness toward analyzing the activities.

FINDINGS

The findings of the study were based on the pre and post administration of SS-scale and SS-test during the course. The purpose of the findings is to reveal and address any perceivable effect of inquiry-based science activities on the utilization frequency of the science process skills and inquiry strategies by prospective elementary teachers.

Total score could be taken from the science process skills subscale is ranged between 10 and 20. Table 1 shows that the pre-instruction mean score was 16, 1. This value is close to the middle of "the least" and "the most" meaning that the teachers´ use of science process skills can be interpreted as being average before the instruction. At the end of the inquiry based instruction, the value was raised to 18, 1 level. This change was tested to be significant ($p<.05$). Therefore, inquiry-based science activities influenced the utilization frequency of the skills by the participants to some degree.

Eight items comprising the frequency of the prospective teachers´ use of the inquiry strategies scored between 8 and 40. Table 1 shows that the mean value for the utilization frequency of the strategies by participants was 25, 6 before the course started. This value marks a point near to "sometimes". At the end of the course, the value was raised to 29, 3 level. This change was tested to be significant ($p<.05$). Therefore, inquiry-based science activities influenced the utilization frequency of the inquiry strategies to some degree.

Table 1. *T-Test Results for the Science Process Skills and Inquiry Strategies Subscales in S&S*

Subscales	MUF	Std	P
Skills- pre	16,13	1,66	,001
Skills- post	18,16	1,17	
Strategies- pre	25,68	4,41	,000
Strategies- post	29,03	3,27	

MUF: Means of utilization frequencies

Further descriptive analysis was administered to investigate the item-wise change among science process skills. Percentages of the reported utilization frequencies of the science process skills were happened to be raised between pre and post instruction as seen in table 2. The investigation was advanced to a point that there might have been some skills which were challenging and actually proportioned least in comparison to the changes in others. At the pre-instruction, the participants were challenged with the skills of "measurement", "interpretation", "hypothesis construction" and "identifying and testing variables". The post-instruction values depicted that the difficulties with the skills "measurement" and "variable identification and testing" were still exist to some degree. Overall, the changes were observed for the skills upon the regular inclusion of skills in inquiry-based science activities in the course.

Table 2. *Pre-Post Percentages of Science Process Skills in S&S-Scale.*

Item	Pre		Post	
	Least (%)	Often (%)	Least (%)	Often (%)
1(Observation)	16,8	83,2	4,2	95,8
2 (Measurement)	45,4	54,6	31,9	68,1
3 (Data Recording)	39,5	60,5	21,8	78,2
4 (Data Interpretation)	52,9	47,1	20,2	79,8
5 (Classifying)	37,8	62,2	17,6	82,4
6 (Comparison)	20,2	79,8	1,7	98,3
7 (Making Estimate)	24,4	75,6	10,1	89,9
8 (Making Hypothesis)	70,6	29,4	33,6	66,4
9 (Identifying and Testing Variables)	58,0	42,0	42,9	57,1
10(Making Inferences)	24,6	74,6	2,5	97,5

Table 3. *T-Test Results for the Pre-Post Values of Utilization of Science Process Skills.*

Item	Pre	Post	p
1(Observation)	1,83	1,95	,004
2 (Measurement)	1,55	1,68	,032
3 (Data Recording)	1,60	1,78	,003
4 (Data Interpretation)	1,47	1,79	,000
5 (Classifying)	1,61	1,82	,001
6 (Comparison)	1,80	1,98	,000
7 (Making Estimate)	1,75	1,90	,003
8 (Making Hypothesis)	1,29	1,66	,000
9 (Identifying and Testing Variables)	1,41	1,56	,022
10(Making Inferences)	1,78	1,97	,000

The mean values of the pre and post instruction utilization frequencies of the each skill by participants were analyzed to test for any significant change before and after the instruction in the study. The t-test results presented in table 3 indicate that the utilization frequencies of the skills by the participants were changed significantly during the instruction of inquiry based science activities (p<.05).

The percentages of the utilization frequency of the inquiry strategies at the pre and post instructions were investigated descriptively to anticipate the ones which might be difficult or challenging to the prospective teachers before and after the instruction. Table 4 displays that the raises in the percentages of the use of inquiry strategies by the participants were incident following the instruction. Some of the strategies were reported to be used extensively at the end of the instruction. These are "discovery of phenomenon by observation and experimentation", "benefiting from scientific sources", "explaining a situation with scientific reasons", " not refusing a different idea or knowledge conflicting with the existing belief or idea", "revealing similarities and differences between existing ideas and observed phenomena", "trying to produce scientific explanation for a daily life event". Moreover, at the end of the study none of the participants mentioned the investigation of observed events with the approach of "not appealing to scientific reasoning". Similarly, at the end of the study, the teachers were not to be readily to refuse a situation just because of the fact that it conflicts with what he or she knows or believes. A peak-like rise in the awareness to use such strategies shows that inquiry-based instruction of science activities help the teachers in adopting and addressing them during learning cases.

Table 4. *Mean Values of Utilization Frequencies of Inquiry Strategies*

	None		Seldom		Sometimes		Often		Always	
Strategy	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
11	4,2	1,7	26,1	11,8	33,6	29,4	25,2	42,0	10,9	15,1
12	3,4		19,3	1,7	35,3	47,1	31,1	43,7	10,9	7,6
13	2,5		16,8		46,2	47,1	25,2	38,7	9,2	14,3
14	5,1		19,5		23,7	36,1	29,7	42,0	22,0	21,8
15	12,7	7,6	26,3	16,0	35,6	34,5	17,8	25,2	7,6	16,8
16	5,9		10,9		37,0	31,9	31,9	51,3	14,3	16,8
17	0,8		10,9		45,4	32,8	29,4	47,1	13,4	20,2
18	4,2	1,7	27,7	17,9	42,0	36,8	18,5	35,9	7,6	7,7

Table 5. *T-test Results for the Pre and Post Instruction Utilization Frequencies of Inquiry*

Item	**Pre**	**Post**	**p**
11	3,12	3,57	,001
12	3,26	3,57	,006
13	3,21	3,67	,000
14	3,44	3,85	,001
15	2,81	3,27	,002
16	3,37	3,84	,000
17	3,43	3,87	,000
18	2,95	3,29	,007

The strategies used by the participants to conduct inquiry at the pre and post instruction levels were compared with t-test for dependent groups to reveal the access levels succeeded by the prospective teachers during the inquiry-based learning of science activities. Table 5 displays that the utilization frequencies of the strategies by the participants to conduct inquiry changed significantly between the pre and post instruction levels (p<.05). This shows that inquiry based science activities helped the teachers to adopt and employ these strategies.

Table 6. *Pre-Post Test Correlation Results for the Utilization of Inquiry*

Pre-Instruction							
Item	12	12	14	15	16	17	18
11	,255*	,216**	,048	-,038		,221**	,492**
12		,283**	,279**	,091	,163*	,171*	,294**
13			,157*	,090	,273**	,317**	,385**
14				,175*	,159*	,252**	,106
15					,162	,196*	,083
16						,375**	,159*
17							,215
Post-Instruction							
11	,330*	,262**	-,008	,103	,130	,109	,334**
12		,401**	,285**	,075	,212*	,121	,251**
13			,208*	,028	,314**	,299**	,435**
14				,257*	,191*	,183*	,034
15					,099	,171*	,072
16						,441**	,189*
17							,251**

During the study of science activities, inquiry strategies are needed to be employed as a whole rather than as a single. Therefore, correlation investigation of the utilization frequencies of the strategies was conducted at the pre and post instruction levels. Table 6 showed that significant correlations exist among the strategies 21, 22, 23, 27 and 27 at the pre and post instruction ($p <.05$). Correlations were detected among some strategies at the pre and post instructions showing that the strategies were employed mutually by the participants. The strategy 21 (I try to discover natural events and phenomena through observation and experimentation) was correlated with 22, 23 and 28 at the pre and post instruction. The strategy 22 (I try to discover natural events and phenomena through scientific sources) was correlated with strategies 23, 24 and 28 at the pre and post instruction. Strategy 23 was correlated with strategies 24, 26, 27, and 28 at the pre and post instructions. Strategy 25 was correlated with strategy 26 at the pre and post instruction. Strategy 26 was correlated with strategies 27 and 28 at the pre and post instructions. The prospective teachers reported that they seemed to start using some strategies at the post-instruction level. Strategy 27 was correlated with the strategy 28 only at the post instruction level. Correlations exist at the pre instructional level seemed to be vanishing at the post instructional level. Strategies 21 and 22 both were correlated with strategy 27 at the pre-instruction level. No new correlation was detected at the post-instruction which was not seen at the pre-instruction level. Rather than the emergence of decaying correlations through the inquiry based activities from pre to post instruction, the overall correlation results seemed to provide strength into that the prospective teachers used them in a holistic way.

The prospective teachers' responses to the SS-test were analyzed to find out any changes between pre and post instruction. For this purpose, a t-test for dependent groups was conducted to compare the responses to the multiple choice test items. The table 7 shows for the pre and post-instruction levels that the means scores were 14, 72 and 18,01 respectively out of a maximum possible score of 30. T-test analysis revealed that the change in the mean score is significant ($p<.05$). The access levels to the science process skills achieved by the participants were actually changed significantly before and after the inquiry-based science activities. During the instruction, the teachers were not taught explicitly on how to solve any science process skill questions. However, the effective change in the scores was followed upon the inquiry-based science activities providing the instances of identification and practice of science process skills.

Table 7. *T-Test Results for Pre and Post Instruction Results of Science Process Skill Test*

	Mean	N	Std.	p
Pre	14,72	77	3,28	0,000
Post	18,01	77	4,14	

Table 8. *Pre and Post Test Percentages of the Responses Given Some Items in the SS-Test*

Test Items	Pre		Post	
	Correct %	Incorrect %	Correct %	Incorrect %
3 (Measurement)	30,9	69,1	80,9	19,1
4 (Observation)	59,0	41,0	78,7	21,3
6 (Identifying and Testing Variables)	72,7	27,3	75,2	24,8
7 (Estimation)	48,9	51,1	53,9	46,1
10 (Making a Conclusion)	36,0	64,0	70,2	29,8
15 (Making Hypothesis)	61,2	38,8	86,5	13,5
19 (Data Interpretation)	27,3	72,7	48,9	51,1

Table 9. *T-Test Results of Some Items in the SS-Test*

	Pre	Post	p
3 (Measurement)	0,30	0,80	,000
4 (Observation)	0,58	0,79	,000
6 (Identifying and Testing Variables)	0,27	0,74	,000
7 (Estimation)	0,48	0,53	,380
10 (Making a Conclusion)	0,35	0,70	,000
15 (Making Hypothesis)	0,64	0,85	,000
19 (Data Interpretation)	0,61	0,86	,000
3 (Measurement)	0,27	0,85	,000

A further analysis was conducted to establish the relation between the instruction and the participants' responses to the SS-test. For this purpose, the responses to certain items of the test in congruence with the science process skills of measurement, observation, identifying and testing variables, estimate, making a conclusion, making a hypothesis, and interpreting results were selected and then responses to these items were compared at the pre and post instruction levels. Table 8 shows that the responses were mostly incorrect at the pre-instruction level for items 3, 7, 10 and 19. On the contrary, the responses to these items were mostly correct at the post-instruction level. The change might be taken as a support to establish an influence of inquiry-based science activities on the test results. The pre and post instruction response to items 6 “identifying and testing variables” were changed least during the instruction. The participants were still challenged with the items 7 and 19 related to the skills of making predictions and conclusions, the substantial part of the responses these two items were incorrect even after the instruction. For all seven items congruent with the science process skills, an item-wise analysis was conducted to investigate the occurrence of significant individual changes. The results displayed in table 9 illustrate that the significant changes ($p < .05$) were occurred for the items except item 7 “making predictions”.

DISCUSSION

The data based on the results was discussed to answer the changes and relations between the prospective elementary teachers' use of the skills and strategies upon the inquiry-based science activities on these variables. The current study was driven by the fact that science process skills and inquiry strategies are mutual and necessary to be excelled to reach any knowledge with observation.

The pre-instruction application of BSB-scale and BSB-test showed that the teachers did not use science process skills so often. Particularly, the skills of measurement, interpreting data, hypothesis, identifying and testing variables, making estimate and conclusions were the ones by which the teachers struggled to utilize during the events of daily life and in-class. In case of utilization of inquiry strategies at the pre-instruction level, the teachers were determined to not to take a critical or skeptical approach as a guideline to compare and contrast the already known with the witnessed phenomena at hand. Particularly, the strategies the teachers' use of them were limited are related to discovering facts with observation and experimentation, producing explanations on a scientific base, and explaining daily life events with science. This result is corresponding with the fact articulated by Koksal and Berberoglu (2014) that the science teachers in Turkey lack the training to practice inquiry abilities. Similarly, the studies by Melville and Bartley (2010), Lin, Hong, Yang and Lee (2013) showed that teachers of science were need of professional training and support to overcome the drawbacks caused by lack of practices on inquiry learning and teaching. Salient factors which could explain the teachers´ low level implementation of inquiry strategies are ineffective learning environment where inquiry practices are conducted (Hofstein, Nahum & Shore, 2001; Liu & Treagust, 2005), and cultural and social beliefs which shape educational attitude and interest (Dkeidek, Mamlok-Naaman & Hofstein, 2012; Roehrig & Kruse, 2005).

This study found that the teachers' use of science process skills and inquiry strategies were frequent at post-instruction level. The changes could be influenced by techniques adopted and enforced in the inquiry-based science activities planned and conducted by the teacher candidates. They were guided by the researchers particularly to include science process skills. The peers following the activities were cautioned to be elaborative and meticulous and therefore critical and skeptical on what they were witnessing in the class. The prospective teachers need guidance and special courses specifically on what and how to be a critique and skeptic of their own experiences (Dkeidek, Mamlok-Naaman & Hofstein, 2012).

The skills which seemed to be not improved enough during the instruction are related to interpreting the data, making predictions and making conclusions. These skills may require more active involvement as doers rather than a role of an audience as an observer. Similarly, the teachers were still refusal of explanations for situations which conflicts with existing knowledge, or belief. The teachers might be need of more cases of observation and experimenting because of the strength of accommodated unscientific ideas and beliefs. Teachers may be involved in inquiry practices as an apprentice and therefore obtain the chances to acquire the skills and strategies by observing other at work (Groendijk & Bandura, 2013). The study shows that only being in the vicinity of a science activity as an observer is not enough to excel in practicing inquiry teaching and learning. Brown et al (2006) cautioned for the fact that science teaching at university level, even though the instructors were eager to teach science course with inquiry approach, because of the limitations of time and sources the plans were usually been tailored. Such barriers and forced adaptations of inquiry practices in the teacher education programs might lead to the lack of abilities to learn science and the need for courses to teach teachers how to design, develop and improve science activities (Song & Schwarz, 2013). Education faculties on teacher education must consider a continuum of courses which enforce prospective teachers to personalize inquiry learning through.

Any strategy as a key to do inquiry cannot be singled out from a variety ones but on the contrary numerous strategies can be needed to excel the inquiry approach. Coordination and integrity among the inquiry strategies shows that variety of cognitive tools is being actually employed to seek and discover. However, intricate and complicated nature of inquiry practices prevents the implementation of each strategy during learning and as well as teaching science (Marshall, Horton, Igo & Switzer, 2009; Puntambekar, Stylianou & Goolstein, 2007). While at the pre-instruction level the multiple use of strategies were self-reported among the prospective teachers, the inquiry-based science activities seemed to strengthen the integrity of the inquiry strategies at the post instruction level. However, further studies are recommended on the wholeness of utilization of strategies by learners.

CONCLUSION

Inquiry based science teaching has been planned to be a curricular target at national level in Turkey (MEB, 2013). The quality of science education and the abilities the teachers of science were equipped with have been issues of widespread discussions. The barriers and limitations the teachers face when they intend to conduct inquiry teaching are needed to be emerged. Upon the emergence of such difficulties, the valid and reliable models of professional training and instructional materials can be foreseen for in-service and prospective teachers. One of many hypothetical questions on the practice of inquiry based science teaching, this study was interested in one to answer the status and change in prospective elementary teachers' use of science process skills and inquiry strategies during the inquiry-based science activities. This study also offers a model for inquiry teaching in the teacher education in science courses. New and genuine models need to be brought before the science education community and must be tested. Studies are also required to investigate thoroughly the preparation of the teachers of science at the education departments. Teacher education is the place where attention must be paid and efforts must be focused to obviate further problems. This study also recommends the longitudinal studies along with data in qualitative nature to elaborate on teachers' use of skills and strategies in science classes.

REFERENCES

Abd-el-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N.G., Mamlok-Naaman R., Hofsteın A., Niaz, M., Treagust D., & Tuan H. (2004). Inquiry in science education: International perspectives, *Science Education*, 88,397– 419.

Anderson, R. D. (2002). Reforming science teaching? What research says about inquiry. *Journal of Science Teacher Education*, 13,1, 1–12.

Biggers, M. & Forbes, C.T. (2012). Balancing teacher and student roles in elementary classrooms: Preservice elementary teachers' learning about the inquiry continuum, *International Journal of Science Education*, 34,14, 2205-2229.

BouJaoude, S., Salloum, S., & Abd El-Khalick, F.(2004). Relationships between selective cognitive variables and students' ability to solve chemistry problems, *International Journal of Science Education*, 26, 1, 63–84.

Brown, P. L., Abell, S. K., Demir, A., & Schmidt, F. J. (2006). College science teachers' views of classroom inquiry. *Science Education*, 90, 784 – 802.

Chen, C.H. & Chen, C.Y. (2012). Instructional approaches on science performance, attitude and inquiry ability in a computer-supported collaborative learning environment, *The Turkish Online Journal of Educational Technology*, 11, 1, 113-122.

Chin, C. & Chea, L.G. (2004). Problem-based learning: Using students' questions to drive knowledge construction, *Science Education*, 88, 707-727.

Chinn, C. A., & Malhotra, B., A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, 86, 175– 218.

Celik, P. (2013). The effect of problem-based learning on teachers' achievement in physics, learning strategies and science process skills, Unpublished Dissertation Thesis, Dokuz Eylul University, Institute of Educational Sciences, Izmir.

Crawford, B.A. (2000). Embracing the essence of inquiry: New roles for science teachers, *Journal of Research in Science Teaching*, 37, 9, 916- 937.

Crawford, B.A.(2007). Learning to teach science as inquiry in the rough and tumble of practice, *Journal of Research in Science Teaching*, 44, 4, 613–642.

Dkeidek, I., Mamlok-Naaman, R. & Hofstein, A. (2012). Assessment of the laboratory learning environment in an inquiry-oriented chemistry laboratory in Arab and Jewish high schools in Israel, *Learning Environments Research*, 15,141–169.

Groenendijk, T., Janssen, T., Rijlaarsdam G. & Bergh, H. (2013). Learning to be creative. The effects of observational learning on students' design products and processes, *Learning and Instruction*, 28, 35-47.

Hofstein, A., Nahum, T. & Shore R.(2000). Assessment of the learning environment of inquiry-type laboratories in high school chemistry, *Learning Environments Research*, 4,193–207.

Keys, C.W., & Bryan, L. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, 38, 631–646.

Kim, M., Tan, A.L. & Lee, F.T. (2013) New vision and challenges in inquiry-based curriculum change in Singapore, *International Journal of Science Education*, 35, 2, 289-311.

Kline, P. (1999). The handbook of Psychological Testing (2nd ed). London: Routledge.

Köksal, E.A. & Berberoglu, G. (2014). The Effect of guided-inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science, *International Journal of Science Education*, 36,1, 66-78.

Lin, H.S., Hong, Z.R., Yang, K.K., & Lee, S.T (2013). The impact of collaborative reflections on teachers' inquiry teaching, *International Journal of Science Education*, 35,18, 3095-3116.

Liu, X.(1998). Structural characteristics of students' conceptions of natural phenomena, *Research in science & Technological Education*, 16,177-202.

Liu, C. & Treagust, D.F. (2005). An instrument for assessing students' mental state and the learning environment in science education, *International Journal of Science and Mathematics Education*, 3, 625–637.

Lucero, M., Valcke, M. & Schellens, T. (2013). Teachers' beliefs and self-reported use of inquiry in science education in public primary schools, *International Journal of Science Education*, 35,8, 1407-1423.

Marshall, J. C., Horton, R., Igo, B. L., & Switzer, D. M. (2009). K-12 Science and mathematics teachers' beliefs about and use of inquiry in the classroom, *International Journal of Science and Mathematics Education,7,* 3, 575-596.

MEB. (2013). İlköğretim Kurumları (İlkokullar ve Ortaokullar) Fen Bilimleri Dersi (3,4,5,6,7, ve 8. Sınıflar) Öğretim Programı, Talim Terbiye Kurulu Başkanlığı, Ankara.

Melville, W. & Bartley, A. (2010) Mentoring and community: Inquiry as stance and science as inquiry, *International Journal of Science Education*, 32,6, 807-828.

Miri, B., David, B.C. & Uri, Z. (2007). Purposely teaching for the promotion of higher-order thinking skills: A case of critical thinking, *Research in Science Education*, 37,353–369.

National Research Council. (1996). National Science Education Standards. Washington, DC: National Academy Press.

National Research Council. (2000). Inquiry and the National Science Education Standards: A Guide for Teaching and Learning. Washington, DC: National Academy Press.

Puntambekar, S., Stylianou, A., & Goldstein, J. (2007). Comparing enactments of an inquiry curriculum: Lessons learned from two teachers. *Journal of the Learning Sciences*, 16,1, 81-130.

Polman, J.L., & Pea, R.D. (2000). Transformative communication as a cultural tool for guiding inquiry science, *Science Education*, 85,223–238.

Roehrig G. H. & Luft J. A.(2004). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons, *International Journal of Science Education*, 26,1, 3-24.

Roehrig, G. H. & Kruse, R. A. (2005). The role of teachers' beliefs and knowledge in the adoption of a reform-based curriculum, *School Science and Mathematics,* 105,8, 412-422.

Rogers, M.A.P., & Abell, S.K. (2008). The design, enactment, and experience of inquiry-based instruction in undergraduate science education: A case study, *Science Education*, 92,591 – 607.

Sahin, E., Isiksal, M. & Ertepinar, H. (2010). In-service elementary school teachers' beliefs in science teaching practices, *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 39, 296-306.

Sandoval, W.A. & Reiser, B.J. (2004). Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry, *Science Education*, 88, 345– 372.

Smith, C.D. & Anderson, C.W. (1999). Appropriating scientific practices and discourses with future elementary teachers, *Journal of Research in Science Teaching*, 36,7, 755-766.

Strear, H., Goodrum, D., & Hackling, M. (1998). High school laboratory work in Western Australia: Openness to inquiry, *Research in Science Education,* 28, 2, 219-228.

Song, Y. & Schwenz, R. (2013). An inquiry-based approach to teaching the spherical earth model to preservice teachers using the global positioning system, *Journal of College Science Teaching* ,42,4,50-58.

Southerland, S.A., Gess-Newsome, J. & Johnston, A. (2003). Portraying science in the classroom: The manifestation of scientists' beliefs in classroom practice, *Journal of Research in Science Teachıng*, 40, 7,669–691.

Welch, W. W., Klopfer, L. E., Aikenhead, G. S., & Robinson, J. T. (1981). The role of inquiry in science education: An analysis and recommendations, *Science Education*, 65, 33–50.

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Science and Technology Teachers' Opinions About Problems Faced While Teaching 8th Grade Science Unit "Force and Motion" and Suggestions for Solutions

Aykut Emre BOZDOĞAN[1], Mustafa UZOĞLU[1]

[1] Assoc. Prof. Dr., Giresun University, Faculty of Education, Giresun-TURKEY

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ABSTRACT

The aim of this study is to explore the problems encountered while teaching force and motion unit in 8th grade science and technology course from teachers' perspectives and offer solutions to eliminate these problems. The study was conducted with 248 science and technology teachers working in 7 regions in Turkey in 2012-2013 academic year. Descriptive method was used in the research. The data of the research was obtained with a questionnaire developed by the researchers. Content analysis, arithmetic mean, and standard deviation were used for the analysis of the data. The teachers stated that the problems and solutions in force and motion unit in science and technology course depending on time, text book and work book, lack of connection to daily life, feature of the unit, students and implementations were examined. As a result of the study the teachers justified that abstract and complicated subject, lack of equipment and tools, and students' not being able to use scientific process skills adequately were the problems in force and motion unit in science and technology course. To solve the problems, the teachers suggested that course hours should be increased, labs should be improved, more equipment and tools should be provided and teachers should give more opportunities to the students to do more activities, link the subjects to daily life and materialise them, use technology (video, flash, presentations, sides and so on) in their classes, solve more problems about the topic and the number of activities in workbook should be increased.

Keywords: Science Education; Force and Motion Unit; Problems and Suggestions for Solutions.

INTRODUCTION

Constructivist approach, opposed to learning, has been affecting the national and international education and training over the last decades (Cole, 1997; Malik & Khurshed, 2011). Educators and researchers who are all in substantial agreement about constructivism state that it presents an approach which enables to activate the learner. This approach is based on the belief that learners interact with the outer world based on their existing experiences and learners are the makers of meaning and knowledge.

Corresponding author e-mail: mustafauzoglu@gmail.com

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Constructivism simply must not be perceived as a transfer of knowledge to one's mind from the outer world (Bodner, 1986; Driver, Asoko, Leach, Mortimer & Scott, 1994). Merrill (1991) draws attention on the following qualities constructivism:

1. Knowledge is constructed from experiences.
2. Learning is an individual interpretation of the world.
3. Learning is an active process relying on experiences.
4. Conceptual understanding results from the individuals' altering their perceptions.
5. Learning can be contextualized in real life environments.

Following the introduction of the positive effects of constructivist approach on student's learning and development in many ways, countries compete with reach other to implement constructivism in their education programs. Turkey is one of the countries which tries to integrate constructivism in its education programs. Turkey has made changes in its education programs via Ministry of National Education (MNE), an institution responsible for the educational policy of the country. In 2004, all the education programs were reorganised according to constructivist approach, MNE started piloting between 2004 and 2005 and they ensured that education programs scattered country-wide between 2005 and 2006 (Çetin & Günay, 2006; Cengiz, Uzoğlu & Daşdemir, 2012).

Science and technology education program is one of the programs reorganized according to constructivist approach. The main goal of science program is to enable all individuals to become scientifically literate (MNE, 2006). Scientific literacy has become a necessity for all the individuals of the society in the world filled with products of scientist research. Human beings feel the need to use scientific knowledge to make choices to meet their needs emerging almost in every stage of their lives and to participate in the public talks and discussions about important issues involving science and technology (National Research Council, 1996). Scientific literacy is defined as "the integration of skills, attitudes, values, understanding, and the knowledge about science required for individuals to develop skills for examination- inquiry, critical thinking, problem solution and decision making , engaging in life long learning, and sustaining their curiosity about their environments and the world" (Ministry of National Education, 2006). According to Norris and Phillips (2003), scientific literacy is understood in two related but different ways. The first one means the ability to read and write and the second one means knowledgeability, learning and education. Hand, Prain, Lawrence & Yore (1999) believe that scientific literacy requires to convince emotional tendencies and skills to construct scientific understanding, interaction to give information about the big ideas of science to others and students to learn the actions given information about. A scientifically literate person understands the nature of science and scientific knowledge, basic science concepts, principals, laws and theories and uses them in appropriate ways; uses scientific process skills while solving problems and making decisions; understands the interaction between science, technology, society and environment; develops scientific and technical psychomotor skills and shows that he has scientific attitudes and values (MNE, 2006).

Science and technology course is the course where students can gain scientific literacy, a very important concept, in schools. It was already stated that the main purpose of science and technology course is to train all the individuals as scientifically literate. Science and technology curriculum renewed in 2005 was composed of learning areas and the related units to these areas. The learning areas in 4th, 5th, 6th and 7th grades were identified as living beings and life, physical phenomenon, matter and change, the Earth and universe. The units and the topics in the units related to each learning areas beginning from 4th grade to 8th grade are tried to be taught in a spiral process (Çepni, Ekiz, Ayas & Akyıldız, 2010; MNE, 2010).

It is a known fact that there are difficulties encountered in science and technology course, where scientific literacy is attempted to be acquired. Both national and international indicators reveal that science education in Turkey is inadequate when compared to other countries (Özden, 2007). Especially national and international examinations such as TIMSS, PISA and SBS (a national standardized test) have revealed the failure of primary school students in science education (Cengiz, Uzoğlu & Daşdemir, 2012).

Although there has been generally a growing increase in understanding of science and technology course and student success in the course with the recent changes in curriculum, this increase is not at a desired level. However, the students' negative attitudes still continue and their success levels are quite low (Ünal & Ergin, 2006; Avcı, 2006). When literature is analysed, many studies conducted about the implementation of the new curriculum and the problems encountered draw attention (Riess, 2000; Ünal & Ergin, 2006; Avcı, 2006; Özdemir, 2006; Özden, 2007; Yangın, 2007; Şengül, Çetin & Gür, 2008; Güven, 2008; Aydın & Çakıroğlu, 2010; Doğan, 2010; Küçüköner, 2011; Cengiz, Uzoğlu & Daşdemir, 2012; Geçer & Özel, 2012).

Geçer & Özel (2012) in their study identified the problems encountered in science and technology course such as crowded classrooms, inadequate laboratory and equipment and tools, lack of time, using blackboards and textbook to teach the course. Cengiz, Uzoğlu & Daşdemir (2012) revealed that teachers indicated the following points for the failure in science and technology course: lack of time for implementation of activities, broad subjects, parents' lack of interest in students' studies, teachers' not familiarizing with the curriculum, students' not having opportunities to practise the activities one on one, and not taking into consideration the level of students adequately. Moreover, they suggested that most teachers stated their problems while teaching science subjects related to mathematics and abstract subjects. Küçüköner (2011) conducted a study to explore the difficulties encountered while implementing science and technology curriculum and offer solutions for the problems expressed by the teachers and indicated that the problems arose due to providing equipment and tools and the content of the curriculum. Doğan (2010) stated that the teachers indicated the following points as very important problems: parents' lack of interest in students' studies, the identification of the subjects by the Ministry of National Education, lack of time, crowded classrooms, inadequate physical conditions of laboratory, classrooms and libraries.

Aydın & Çakıroğlu (2010) pointed to crowded classrooms and inadequate in-service training and Güven (2008) detected lack of equipment and tools and course hours. On the other hand, Şengül, Çetin & Gür (2008) stated that graduating from different departments (physics, chemistry, biology) affected education negatively, and teachers faced problems with completing the curriculum on time, doing laboratory work, and doing evaluation. Özden (2007) identified the main problems in science and technology education as lack of teachers who are actively responsible for developing curriculum, inadequate training of teachers about the program during the transition process, crowded classrooms, training students for the exams, lack of connection with the other lessons, and inadequate physical conditions of the school. Yangın (2007) in his study classified the most important problems while teaching science and technology subjects as lack of teaching materials, a large number of students and lack of physical conditions of the classrooms, and teachers' lack of knowledge about curriculum. Özdemir (2006) grouped the problems the teachers faced while teaching the course in his study: problems with students, textbooks, student' parents, teachers' themselves, curriculum, physical conditions and equipment. Riess (2000) defined the following as important problems in his study: science and technology curriculum's ignoring the development of science history and philosophy, and lack of student motivation and interest in the subject. On the other hand, suggestions have been made in literature to solve the problems encountered while teaching science and technology course (Yılmaz & Morgil, 1992; Özdemir, 2006; Özden, 2007; Şengül, Çetin & Gür, 2008; Doğan, 2010; Küçüköner, 2011; Geçer & Özel, 2012; Cengiz, Uzoğlu & Daşdemir, 2012). Küçüköner (2011) suggested that the activities done to reach learning outcomes should be connected to daily life, in-service training based on practise should be offered to the teachers, class size should be adapted to implement the renewed curriculum and guide books consisting of evaluation criteria and concrete assessment and evaluation applications should be developed. Doğan (2010) emphasized that there are not many subject and they are precise and simplified, parents are involved in education and training process, class size (the number of students) is reduced, laboratory, equipment and tools are supplied, and the physical conditions of the school is improved. Yılmaz and Morgil (1992) in their study suggested a decrease in number of students, training qualified teachers, and equipment and tools' being compatible with the curriculum. Özdemir (2006) recommended that the number of students should be decreased in crowded classrooms, teachers should be valued both financially and spiritually, adequate equipment and tools should be supplied, cooperation between school and family should be established, libraries should be developed, and the laboratory facilities should be improved and experiments should be carried out. Şengül, Çetin & Gür (2008) asserted that science and technology courses must be taught by science and technology teachers, not by teachers who graduated from different departments and drew attention by adding that teachers use portfolio and projects in evaluation and follow the new technologic developments. Geçer & Özel (2012) stated that textbooks should be simplified because of time constraints, computer labs should be established, centres should be set for choosing, repairing, and using laboratory equipment and tools. Cengiz, Uzoğlu & Daşdemir (2012) stated the importance of visual lessons, providing cooperation of student's parents and training teachers with methods and techniques. Özden (2007) suggested the following as precautions to be taken to solve the problems: decrease in class size, not evaluating success with only examinations, and improving education system.

The problems in science and technology education will hinder students' critical thinking, curiosity, creativity and attitudes towards nature (Özden, 2007). Therefore, many studies have been conducted to reveal how to deal with learning difficulties in science and technology courses. When the studies conducted were analysed, it was found that all the studies attempted to explore the general problems and their solutions. When detecting the problems in curriculum, units were not encountered. Therefore, the problems and the solutions related to science education will be attempted to be studied on unit basis in this study. It is a known fact that both students and teachers have difficulty in learning and teaching the 8^{th} grade force and motion unit from physical phenomenon field. Thus, after the views of teachers working in seven regions of Turkey are received via questionnaire developed for this study, the problems and the suggestions for solutions related to force and motion unit will be determined. The following research questions were sought answers in the study:

1. What do science and technology teachers consider as problems while teaching force and motion unit depending on time, textbook, not being able to connect it to daily life, features of subjects, students and implementation?

2. What do science and technology teachers suggest for the solution of problems in force and motion unit?

METHODOLOGY

a) Research model

Descriptive method was used in the study. This method is used to illuminate a phenomenon, to make evaluations in line with the standards and to reveal the possible relations between the events. In such research the main purpose is to identify and define the phenomenon investigated (Çepni, 2007). This method was used in the study to explore and identify the problems which science and technology teachers encounter within the context of "Force and Motion" unit included in the 8th grade "Physical Phenomenon" learning field.

b) Population

Snowball sampling, one of the non-probability sampling techniques, was used for the selection of the population (Tanrıögen, 2009). Within this context, each science and technology teacher chosen from 49 cities randomly out of 7 regions was contacted and the other science and technology teachers recommended by them were included in the study. The population of the research composed of teachers chosen across Turkey in 2012-2013 education year. The data of the research were collected from 248 science and technology teachers, 127 males and 121 females, chosen in 49 cities out 81 cities. The distribution of science and technology teachers participating in the study by cities and regions **(shown in black)** was given below.

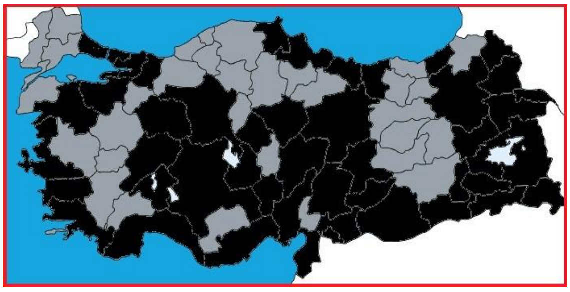

Figure 1. *Distribution of the cities where the study was carried out*

Table 1. *Distribution of the population*

Regions	**Number of cities**	**Number of teachers**
Marmara	7	33
Aegean	5	19
Mediterranean	5	43
Central Anatolia	9	28
Black sea	6	45
Eastern Anatolia	12	54
South eastern Anatolia	5	26
TOTAL	**49**	**248**

c) Data Collection Tools

The following steps were involved during data collection process.

1. Interviews were carried out by randomly selected two in-service science and technology teachers who taught primary education science and technology courses and the problems encountered while teaching "Force and Motion" were presented. The teachers who were interviewed were asked what kind of problems they had encountered while teaching force and motion unit and in the light of the responses, the questionnaire form was divided into 6 headings with the help of the experts from the field (Table 3).
2. Questionnaire form was developed to explore the problems encountered while teaching 8th grade "Force and Motion" unit. Content validity was tried to be obtained by receiving the opinions of experts from two fields, one in-service science and technology teacher and one language expert for each questionnaire form.
3. The questionnaire form developed by the researchers consists of demographic information, total 34 items using a five point Likert type scale on a continuum from strongly agree to strongly disagree and 3 open ended questions. The interval width the Likert type scale was computed with a formula (a= range width / number of groups) and the choices and borders of the range were formed in the scale composed.

Table 2. *Score Interval of Measurement Tool*

Rating	Choices	Border
5	Strongly agree	4.21- 5.00
4	Agree	3.41- 4.20
3	Don’t know	2.61- 3.40
2	Disagree	1.81- 2.60
1	Strongly disagree	1.00- 1.80

4. The distribution of items in Likert-type measurement scale according to the titles were shown in Table 3.

Table 3. *Distribution of Questionnaire items*

Sections in the Questionnaire	Number of items
1. Problems about time	3
2. Problems about textbook and workbook	6
3. Problems about connection to daily life	4
4. Problems about the features of the subject	1
5. Problems about students	15
6. Problems about implementation	5
TOTAL	**34**

d) Data Analysis

Arithmetic mean ($\overline{X}$) and standard deviation, descriptive statistical methods, were used for the statistical analysis of the qualitative data gathered to seek answers for the sub-problems within the context of the general purpose of the research. The data related to numerical developments were tabularised and interpreted. The data obtained from the open ended questions were analysed via content analysis. The main purpose of content analysis is to gain concepts and relations which can explain the data gathered. The data gathered are first conceptualised, organized logically and the themes which define the data were identified. Content analysis involves the following order: coding of the data, organising codes, defining themes, and themes and identifying findings and interpreting (Yıldırım & Şimşek, 2004). Within this framework, the data obtained from the teachers were coded by two researchers and themes were composed by taking into consideration their common features. Within this framework, the first stage is coding of data and in this stage, two researchers examined the responses given to the open ended questions in the questionnaire and they coded them by dividing them into meaningful sections. In the second stage, common aspects were found by gathering the codes and the themes were composed. In the third stage, the data were organized according to the themes revealed and in the last stage, the data were tabulated and interpreted. After the operations which were performed by two experts separately, the analyses of two experts were compared and the points where they had reached consensus and where they had divergent point of views were identified. The internal consistency reliability of the research (Reliability: Consensus view/ Consensus view + Divergent views) was calculated. As a result of calculation, it was found that there was a 88% agreement.

Tables were composed to understand the themes and their frequency distributions were given. Below the tables were given the teachers’ statements which express their opinions without making any changes.

FINDINGS

The problems science and technology teachers encountered while teaching 8^{th} grade science unit called “Force and Motion” were examined and they were presented in Table 4.

Table 4. *Arithmetic Mean Distribution of Problems Encountered While Teaching 8th Grade Force and Motion Unit*

		$\overline{X}$	Ss	$\overline{X}$ t
A. Time Oriented Problems				
1.	Time given for **"Buoyant Force"** is not sufficient.	3.98	1.027	
2.	Time given for **"Why do some objects float?** is not sufficient.	3.64	1.147	**3.71**
3.	Time given for **"Pressure"** is not sufficient.	3.52	1.179	
B. Textbook and Workbook Oriented Problems				
1.	Examples and activities in the textbook are not sufficient for **"Ascending force"**.	3.98	0.979	
2.	Examples and activities in the textbook are not sufficient for **"Why do some object float?"**	3.82	1.051	
3.	Examples and activities in the textbook are not sufficient for **"Pressure"**.	3.68	1.087	**3.76**
4.	Examples and activities in the workbook are not sufficient for **"Ascending force"**.	3.82	1.015	
5.	Examples and activities in the workbook are not sufficient for **"Why do some objects float?"**	3.70	1.124	
6.	Examples and activities in the workbook are not sufficient for **"Pressure"**.	3.58	1.153	
C. Problems Oriented with connection To Daily Life				
1.	Examples of force and motion in 4th and 5th grade cannot be connected to daily life.	3.06	0.930	
2.	Examples of force and motion in 6th grade cannot be connected to daily life.	2.89	1.122	**2.96**
3.	Examples of force and motion in 7th grade cannot connected be related to daily life.	2.91	1.129	
4.	Examples of force and motion in 8th grade cannot be connected to daily life.	2.96	1.137	
D. Problems Oriented with the Features of the Unit				
1.	Because force and motion units are abstract, students have difficulty in connecting them to the concepts.	4.10	0.841	**4.10**
E. Student Oriented Problems				
1.	**Students' lack of knowledge about concepts in force and motion unit.**			
	*1a. Students **lack knowledge** about liquids subject.*	*3.72*	*0.984*	**3.84**
	*1b. Students **lack knowledge** about gas subject.*	*3.74*	*1.009*	
	*1c. Students **lack knowledge** about mass, volume and density..*	*4.06*	*0.941*	
2.	**Students' various misconceptions about concepts in force and motion unit according to teachers.**			
	*2a. Students have **misconceptions** about mass and weight.*	*4.15*	*0.976*	
	*2b. Students have **misconceptions** about volume and weight.*	*3.42*	*1.260*	
	*2c. Students have **misconceptions** about the force of gravity acting on objects in the liquid.*	*3.45*	*1.078*	
	*2d. Students have **misconceptions** that buoyant force acting on the object has more weight than the weight of the object.*	*3.78*	*1.038*	**3.76**
	*2e. Students have **misconceptions** about liquid pressure depending on amount of the liquid.*	*3.81*	*1.034*	
	*2f. Students have **misconceptions** that the diameter of the tube is important in Torricelli experiment.*	*3.60*	*1.016*	
	*2g.Students have **misconceptions** that objects sink due to their weight.*	*4.15*	*0.841*	
3.	**Students cannot use scientific process skills adequately with the activities in force and motion unit.**			
	*3a. Students have difficulty with **mathematical calculations.***	4.42	0.791	
	*3b. Students have difficulty with **comparing process.***	4.06	0.885	**4.06**
	*3c. Students have difficulty with doing the **measurements** related to experiments.*	3.91	0.904	
	*3d. Students have difficulty with **interpreting and inferring** process.*	4.08	0.895	
	*3e. Students have difficulty with **recording data properly** process.*	3.85	0.929	
F. Problems oriented with Implementation				
1.	Within the context of the unit, activities cannot be done properly due to lack of equipment and tools.	3.97	0.675	**3.97**

When Table 4 is analysed, it is found that the most common problem science and technology teachers encountered while teaching 8th grade science unit called "Force and Motion" was due to the features of this unit ($\overline{X}$ =4.10). Because the subjects were abstract, the teachers stated that the students had difficulties in connecting them to the concepts. The second biggest problem the teachers encountered was that the students could not use scientific process skills adequately in the activities of the unit ($\overline{X}$ =4.06). Within this framework, the teachers stated that the students had great difficulty in mathematical calculations ($\overline{X}$ =4.42), interpreting and inferring ($\overline{X}$ =4.08), and comparing ($\overline{X}$ = 4.06) processes. In addition, due to lack of equipment and tools, the teachers stated that they could not adequately do the activities ($\overline{X}$ =3.97). The other problems the teachers encountered were lack of student knowledge about the concepts in force and motion unit ($\overline{X}$ =3.84) and their misconceptions ($\overline{X}$ = 3.76), lack of examples and activities in the textbook and workbook ($\overline{X}$ =3.76) and lack of course hours ($\overline{X}$ =3.71), respectively. The least important problem teachers encountered was that the students could not make the link between the examples about force and motion and daily life ($\overline{X}$ =2.96).

The distribution of the problems science and technology teachers encountered while teaching 8th grade science unit called "Force and Motion" in terms of teachers' gender, graduation, and years of experience was examined and presented in Table 5.

Table 5. *The distribution of the problems science and technology teachers encountered while teaching 8th grade science unit called "Force and Motion" in terms of teachers' gender, graduation, and years of experience*

Problems	Gender		Graduation				Years of Teaching Experience			
	Male (127)	Female (121)	Physics (20)	Chemistry (23)	Biology (20)	Science (185)	1-5 years (108)	6-10 years (50)	11-15years (31)	16 years and above (59)
1. Lack of course hour s	3.72	3.70	3.45	3.73	4.13	3.69	3.65	3.88	3.72	3.68
2. lack of activities and examples in the textbook and workbook	3.78	3.74	3.85	3.51	4.19	3.73	3.75	3.87	3.80	3.66
3. Not connecting subjects to daily life	3.01	2.90	3.48	3.06	3.40	2.84	2.72	3.01	3.08	3.29
4. Abstract and complicated subjects	3.98	4.23	3.87	4.08	4.35	4.10	4.20	4.02	4.20	3.94
5. Lack of knowledge in students	3.82	3.86	3.56	3.65	3.80	3.90	3.96	3.88	3.96	3.52
6. Some misconceptions with students	3.78	3.74	3.80	3.82	3.68	3.76	3.78	3.92	3.79	3.58
7. Students' not being able to use scientific process skills adequately	4.11	4.01	3.87	3.88	3.90	4.13	4.08	4.24	4.09	3.88
8. Not being able to do the activities due to lack of equipment and tools	3.98	3.97	3.97	3.93	3.91	3.98	4.03	4.08	3.85	3.84

When Table 5 was analysed, the most frequently encountered problems by female teachers were complicated and abstract subjects ($\overline{X}$ =4.23), students' not being able to use scientific process skills adequately ($\overline{X}$ =4.01) and not being able to do the activities due to lack of equipment and tools ($\overline{X}$ =3.97). The most frequently encountered problems by male teachers were students' not being able to use scientific process skills adequately ($\overline{X}$ = 4.11), complicated and abstract subjects ($\overline{X}$ =3.98) and not being able to do the activities due to lack of equipment and tools ($\overline{X}$ =3.98). It was found that both the female and male science and technology teachers suffered from the same difficulties during teaching. It was revealed that the least important problem both the female ($\overline{X}$ =2.90) and male ($\overline{X}$ =3.01) science and technology teachers had while teaching the unit was that subjects were not linked to daily life.

When the teachers' graduation from the departments is taken into consideration, different findings draw attention. It was determined that the teachers who graduated from physics had fewer problems than the other teachers who graduated from different departments while teaching the unit. The teachers who were physics graduates mostly complained that they could not adequately do the activities due to lack of equipment and tools ($\overline{X}$ =3,97). The teachers who were biology graduates draw attention as they encountered a lot of problems. The teachers who were biology graduates encountered the following problems: complicated and abstract subjects ($\overline{X}$ =4.35), lack of examples and activities in the textbook and workbook ($\overline{X}$ =4.19) and lack of course hours ($\overline{X}$ =4.13). The teachers who were chemistry graduates had mostly problems about complicated and abstract subjects ($\overline{X}$ =4.08). It was determined that the problems encountered by the teachers who are graduates of science teaching department were mostly students' not being able to use scientific process skills ($\overline{X}$ =4.13), complicated and abstract subjects ($\overline{X}$ =4.10), and not being able to do the activities due to lack of equipment and tools ($\overline{X}$ =3.98). In addition, it was pointed out that the least important problem all the teachers encountered while teaching the unit was that subjects were not linked to daily life.

When the problems encountered by the teachers in terms of their years of teaching experiences were analysed, it was found that experienced teachers with 16 and more years of teaching experience had encountered the fewest problems. It was found that novice teachers (1-5 years) complained about complicated and abstract subjects ($\overline{X}$ =4.20), students' not being able to use scientific process skills ($\overline{X}$ =4.08), not being able to do activities due to lack of equipment and tools ($\overline{X}$ =4.03) and lack of student knowledge ($\overline{X}$ =3.96). The same condition was observed with the teachers with teaching experience between 6 and 10 years and between 11 and 15 years.

The distribution of problems the teachers encountered while teaching 8th grade force and motion unit in terms of teachers' region of service was analysed and presented in Table 6.

Table 6. *The Distribution of Problems the Teachers Encountered While Teaching 8th Grade force and Motion Unit in terms of Teachers' Region of Service*

Problems	Region of Service						
	Marmara (33)	Aegean (19)	Mediterranean (43)	Central Anatolia (28)	Black sea (45)	Eastern Anatolia (54)	South-eastern A. (26)
1. Lack of course hours	3.60	4.40	3.79	3.52	3.96	3.32	3.80
2. Lack of activities and examples in the textbook and workbook	4.07	3.65	3.84	3.72	3.86	3.56	3.58
3. Subject's not making links with daily life	3.15	3.19	3.15	3.01	2.80	2.83	2.69
4. Abstract and complicated subjects	4.28	4.36	3.91	4.14	4.22	3.88	4.21
5. Lack of knowledge in students	3.93	3.64	3.79	3.80	3.96	3.77	3.92
6. Some misconceptions with students	3.75	4.06	3.54	3.62	3.95	3.69	3.91
7. Students' not being able to use scientific process skills adequately	4.08	3.97	3.88	4.12	4.25	4.01	4.13
8. Not being able to do the activities due to lack of equipment and tools	3.91	4.01	3.80	3.82	4.15	4.02	4.05

When the problems encountered by the teachers while teaching the unit in terms of region of service were analysed, it was determined that the teachers who encountered the most problems were working in Black sea and Aegean regions and the teachers who encountered the fewest problems were working in Eastern Anatolia, Mediterranean, and Central Anatolia regions (Table 6).

The teachers' views for the solutions of the problems in 8th grade Force and Motion unit were explored and presented in Table 7.

Table 7. *Frequency distribution of the suggestions made according to teacher views to solve the problems in 8th grade Force and Motion unit*

Suggestions	A f	B f	C f
Suggestions for course hours			
Course hour must be increased	56	34	34
There must be a separate applied course	6	3	3
Suggestions for curriculum			
The scope of the subject must be narrowed and science and technology courses must be scattered in curriculum.	13	---	---
Some concepts (mass, density, volume, weight, force, balanced force, resultant force) must be taught at primary education level.	5	4	---
Formulas must be included in curriculum.	2	5	1
Subjects must be removed from the curriculum and must be taught in the later years.	2	1	2
This subject must be taught in the second term.	3	1	1
Science-technology-society-environment gains must be included more about this topic.	1	1	1
“Buoyant force and why some objects float” subjects must be replaced.	1	1	---
Within the context of the subject, density must be given in a common unit.	---	1	---
Within the context of the subject, volume must be taught under a different title.	---	1	---
Solid pressure must be taught.	---	---	1
Buoyant force of the liquid and liquid pressure must be taught in different months.	---	---	1
Suggestions for the content of the textbook and workbook			
More activities must be included in the textbooks.	11	11	11
Interesting and remarkable knowledge, activities, visuals, and cartoons must be included in the textbooks.	8	8	11
The examples in the text must be increased and suited to LDE.	9	1	2
MNE books must be used.	3	3	3
Supplementary materials must be used due to inadequate textbooks.	3	2	3
Evaluation questions in the textbooks must be appropriate to the students’ level.	2	---	2
Gas pressure in the textbooks must be explained in detail.	---	---	2
The number of activities about combined vessels and U pipes must be increased.	---	---	2
Activities about manometer and barometer must be added.	---	---	2
Suggestions for physical opportunities			
Laboratories must be improved and lacking equipment and tools must be supplied.	44	25	23
There must be ready experiment kits about the subjects.	3	3	4
Precision measuring tools must be used (dynamometer, scales.)	1	1	---
Central laboratories must be established in the cities and towns and must be put into service.	1	---	---
Course materials must be easy to reach, cheap and available in the market.	1	---	---
Small pools must be built in the school garden.	---	1	---
Teachers’ suggestions for in-class implementations			
Teachers must provide students more opportunities to do more activities as far as possible	39	30	21
Teachers must link the subjects to daily life and concretize them.	26	15	19
Teachers must use technology (video, flash, presentations, slides..etc)	15	18	22
Teachers must solve many questions about the subjects	19	9	11
Teachers must explain the key points of the subjects without teaching the theoretical subjects much.	16	3	---
Teachers must use alternative methods and techniques (brainstorming, excursions to science museum, sea, and lakes) for permanent learning.	6	6	4
Students must be assigned original performance tasks about the subject and teachers must have the students do additional work.	2	8	1
First level teachers must have the students gain scientific process skills such as doing observation, and reading graphs.	3	---	---
Teachers must explain the subjects in detail.	---	3	---
Teachers must be given seminars and practical training about how to teach these subjects	2	---	1
Teachers must receive help from the trainers in the field.	---	1	1
Teachers must teach buoyant force and the position of the object in the liquid together	1	---	---
Teachers must use different evaluation methods at the end of the course	1	---	---
Teachers must help the students to understand the relations between the concepts	1	---	---
Student			
Students’ operational skills must be developed with mathematics teachers	13	9	10
Students’ readiness level towards a subject must be controlled and their motivation must be promoted.	5	3	2
Student number must be reduced	5	2	2
Students’ misconceptions must be identified and they must be eliminated.	2	2	2

A. Buoyant force subject B. Subject of Why do some subjects float? C. Pressure subject

In order to solve the problems encountered while teaching 8th grade science unit called "Force and Motion", %68 of the teachers offered suggestions on the subject of "Buoyant Force", %55 on "Why Do Some Objects Float?", and %48 on "Pressure". The most important suggestions offered by the teachers were that due to comprehensive subjects, "course hours must be increased", "Laboratories must be improved and lacking equipment and tools must be supplied" and also "Teachers must provide students with more opportunities to do more activities as far as possible". Following the suggestions above, these were given respectively: "Teachers must link the subjects to daily life and concretize them", "Teachers must use technology (video, flash, presentations, slides etc.) in their courses", "Teachers must solve many questions about the subjects", "More activities must be included in the textbooks", "Students' operational skills must be developed with mathematics teachers", and "Interesting and remarkable knowledge, activities, visuals, and cartoons must be included in the textbooks". In addition to the most frequently mentioned suggestions, it was discovered that teachers offered interesting suggestions such as "Formula must be included in curriculum", "Subjects must be removed from the curriculum and must be taught in the later years", "MNE books must be used", "Central laboratories must be established in the cities and towns and must be put into service", and "Small pools must be built in the school garden".

Some teachers proposed the following suggestions to solve the problems related to buoyant force.

"This unit must be studied in the 2nd term because when students learn force-motion unit, they have problems with calculations as they have not learned equation with one unknown completely in mathematics course" (M_{7}, M_{45}, M_{58}, M_{90}, M_{148}, F_{25}, F_{34}, F_{243}).

"I suggest that two-hour hands-on training must be added in addition to 4 hour science course" (M_{88}, M_{100}, M_{125}, M_{227}, M_{235}, F_{99}, F_{110}, F_{115}, F_{116}).

"Subject must be linked to daily life" (M_{56}, M_{66}, M_{85}, F_{55}, F_{215}, F_{210}).

"More exercises and activities must be included in the textbook" (M_{33}, M_{98}, M_{103}, M_{122}, M_{128}, F_{34}, F_{68}, F_{79}, F_{105}).

"Formulas must be included in curriculum. It is sometimes difficult to explain the logic behind some questions without a formula." (M_{16}, M_{30}, M_{35}, M_{41}, M_{67}, M_{98}, M_{101}, F_{33}, F_{39}, F_{110}, F_{118}, F_{116}).

Some teachers stated the following suggestions to solve the problems related to why some objects float.

"There must be more visual things. Textbooks are inadequate" (M_{76}, M_{88}, M_{102}, M_{212}, M_{245}, F_{30}, F_{65}, F_{78}, F_{92}, F_{102}, F_{234}).

"Course hour is inadequate to do activities and solve problems" (M_{88}, M_{101}, M_{112}, M_{114}, F_{55}, F_{76}, F_{200}).

Some teachers offered the following suggestions to solve the problems related to pressure.

"Better exemplifications must be provided and enough time must be allocated for the solution of the questions" (M_{85}, M_{103}, M_{228}, M_{201}, F_{59}, F_{114}, F_{116}, F_{243}).

"Pressure, especially gas pressure, is not covered much in the textbook. Supplementary materials about gas pressure must be developed and told" (M_{19}, M_{45}, M_{75}, M_{112}, F_{55}, F_{110}, F_{118}).

"Simpler and clearer examples must be included in the textbooks" (M_{88}, M_{103}, M_{139}, M_{155}, K_{85}, F_{102}, F_{210}, F_{229}, F_{248}).

DISCUSSION, CONCLUSION and IMPLICATIONS

Science and technology teachers stated that students have difficulty in making links between the concepts because the subjects in "Force and Motion" unit are abstract, they could not use scientific process skills (mathematical calculations, interpreting, inferring and comparing) adequately in these activities and they could not do the activities within the context of the unit due to lack of equipment and tools. This result indicates a parallelism with many studies conducted about the problems encountered in science and technology course in literature (Riess, 2000; Ünal & Ergin, 2006; Avcı, 2006; Özdemir, 2006; Özden, 2007; Yangın, 2007; Şengül, Çetin & Gür, 2008; Güven, 2008; Aydın & Çakıroğlu, 2010; Doğan, 2010; Küçüköner, 2011; Cengiz, Uzoğlu & Daşdemir, 2012; Geçer & Özel, 2012).

Teachers stated that students had lack of knowledge and misconceptions. They also reported that the least frequently encountered problem was that they could not link the examples in force and motion unit to daily life. Unlike this study, some studies revealed that the most common problem encountered was not being able to make links between the course and daily life (Cengiz, Uzoğlu & Daşdemir, 2012).

Science and technology teachers' views were examined in terms of different variables and it was reported that the most frequently encountered problems both by female and male teachers included the complicated and abstract subjects, students' not being able to use scientific process skills adequately and not being able to do the activities due to lack of equipment and tools. It was determined that the least frequently encountered problems both by female and male teachers included not being able to link subjects to daily life. When the teachers' departmental graduations were taken into consideration, different results emerged. It was found that the teachers who were graduates of Physics department/ teacher education encountered very few problems while teaching the unit, but the teachers who were graduates of biology department encountered a lot of problems. This result partially corresponds with the views of Şengül, Çetin & Gür (2008) who stated that graduates from different departments of the university (physics, chemistry, biology) affected teaching negatively. When the problems teachers encountered due to their years of teaching experience were examined, it was discovered that the experienced teachers who have been working 16 years or more encountered the fewest problems. This result is compatible with the studies of Kabakçı, Akbulut & Özoğul (2009) which revealed that experienced teachers had fewer problems. When the problems teachers encountered due to their region of service were examined, it was determined that the teachers working in Black Sea and Aegean regions encountered many problems whereas the teachers working in East Anatolia, Mediterranean, and Central Anatolia regions did not encounter as many problems as they did.

The main suggestions offered by the teachers to solve these problems included "an increase in class hours due to complicated subjects", "improving laboratories and supplying more equipment and tools", and "teachers' giving students more opportunities to do exercises". Besides these suggestions, the following solutions were offered respectively: " Teachers must connect the subjects to daily life and concretize them", "Teachers must use technology (videos, flash, presentations, slides, etc) in their lessons", " Teachers must solve more problems about the subject", "More activities must be added in the textbook", "Students' operational skills must be developed through cooperation with maths teachers", and " Textbooks must include interesting information, activities, visuals, and cartoons." When the literature is analysed, similar suggestions offered in this study to solve the problem draw attention (Yılmaz & Morgil, 1992; Özdemir, 2006; Özden, 2007; Şengül, Çetin & Gür, 2008; Doğan, 2010; Küçüköner, 2011; Geçer & Özel, 2012; Cengiz, Uzoğlu & Daşdemir, 2012). Küçüköner (2011). In addition to the most frequently mentioned suggestions, it was identified that teachers offered interesting suggestions such as "Formulas must be included in curriculum", "Subjects must be removed from the curriculum and taught in later grades", "Central laboratories must be established in the cities and towns and must be put into service", "MNE books must be used", and "small pools must be built in the school garden".

REFERENCES

Avcı, Ö. (2006). Van İl merkezinde İlköğretim II. Kademe Fen bilgisi Öğretiminde Kullanılan Yöntemlerde Karşılaşılan Sorunlar. (Yayımlanmamış yüksek lisans tezi). Van Yüzüncü Yıl Üniversitesi Fen Bilimleri Enstitüsü, Van.

Aydın, S., & Çakıroğlu, J. (2010). İlköğretim fen ve teknoloji dersi öğretim programına ilişkin öğretmen görüşleri: Ankara örneği. *İlköğretim Online, 9(1),* 301-315.

Çetin, O. & Günay, Y. (2006). Fen öğretiminde yapılandırmacı öğrenme yaklaşımının öğrenci tutumlarına ve öğrenme ortamına etkileri. *Eurasian Journal of Educational Research,* 25, 73-84.

Bodner, G.M. (1986). Constructivism: a theory of knowledge. *Journal of Chemical Education*, 63, 873-878.

Cengiz, E., Uzoğlu, M. & Daşdemir, İ. (2012). Öğretmenlere göre fen ve teknoloji dersindeki başarısızlık nedenleri ve çözüm önerileri. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi*, 14(2), 393-418

Cole, P. G. (1997) "Constructivism and scientific realism? Which is the better framework for educational research," *Australian Journal of Teacher Education*: Vol. 22 (1), 41-49.

Çepni, S. (2007). Araştırma ve Proje Çalışmalarına Giriş. Trabzon: Celepler Matbaacılık. Geliştirilmiş 3. Baskı.

Çepni, S., Ayas, A., Ekiz, D. & Akyıldız, S. (2010). Öğretim ilke ve yöntemleri. Celepler matbacılık, Trabzon.

Çetin, O. & Günay, Y. (2006). Fen öğretiminde yapılandırmacı öğrenme yaklaşımının öğrenci tutumlarına ve öğrenme ortamına etkileri. *Eurasian Journal of Educational Research,* 25, 73-84.

Doğan, Y. (2010). Fen ve teknoloji dersinin öğretiminde karşılaşılan sorunlar. *Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi.* 7(1), 86-106.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23* (7), 5-12.

Garbett, D. (2011) "Constructivism Deconstructed in Science Teacher Education," *Australian Journal of Teacher Education*, 36 (6), 36-49.

Geçer, A. Özel, R. (2012). Elementary Science and Technology Teachers' Views on Problems Encountered in the Instructional Process Educational Sciences: Theory & Practice - 12(3), 2256-2261

Güven, S. (2008). Sınıf öğretmenlerinin yeni ilköğretim ders programlarının uygulanmasına ilişkin görüşleri. *Millî Eğitim Dergisi*, 177, 224-236.

Hand, B., Prain, V., Lawrence, C., & Yore, L. (1999). A writing in science framework designed to enhance science literacy. International Journal of Science Education, 21, 1021–1035.

Kabakçı, I., Akbulut, Y. Özoğul, P. (2009). Perceived problems of computer teachers. *Eurasian Journal of Educational Research*, 34, 199-214.

Küçüköner, Y. (2011). 2005 fen ve teknoloji dersi öğretim programının uygulanmasında karşılaşılan sorunlar ve öğretmen gözüyle çözüm önerileri. *Erzincan Eğitim Fakültesi Dergisi.* 13(2), 11-37.

MNE (2006). *İlköğretim Fen ve Teknolji Dersi 6. Sınıf Öğretim Programı* Talim ve Terbiye Kurulu Başkanlığı Ankara.

MNE (2010). İlköğretim fen ve teknoloji öğretmen kılavuz kitabı. Bediralp Matbaacılık, İstanbul.

Merrill, M. D. (1991). *Constructivism and Instructional Design. Educational Technology*, May 45-53.

Malik, S.K. & Khurshed, F. (2011). A Proposed Constructive Instructional Design (CID) for Teaching of Social Studies at Elementary Level. *European Journal of Social Sciences, 23(4)*, 531-552.

NATIONAL RESEARCH COUNCIL. (1996). The National Science Education Standards. Washington, DC: National Academy Press.

Norris, S.P., & Phillips, L.M. (2003). How literacy in its fundamental sense is central to scientific literacy. Science Education, 87 (2), 224–240.

Özdemir., H. (2006). İlköğretim Okulları 4.ve 5. sınıf Fen Bilgisi Öğretim Programlarında Karşılaşılan Sorunlar ve Çözüm Önerilerine İlişkin Öğretmen Görüşleri (Konya İli Örneklemi). (Yayımlanmamış yüksek lisans tezi).

Özden, M. (2007). Problems with Science and Technology Education in Turkey. *Eurasia Journal of Mathematics, Science & Technology Education*, 2007, 3(2), 157-161.

Riess, F. (2000). Problems with German Science Education. *Science & Education*, 9, 327–331.

Şengül, S. H., Çetin, G. & Gür, H. (2007). The Primary School Science Teachers' Problems in Science Teaching. *Turkısh science education*, 5(3), 82-88.

Tanrıögen, A. (2009). Scientific Research Methods. Anı Publishing, Ankara, Turkey.

Yangın, S. (2007). *2004 Öğretim Programı Çerçevesinde İlköğretimde Fen ve Teknoloji Dersinin Öğretimine İlişkin Öğretmen ve Öğrenci Görüşleri.* (Yayımlanmamış doktora tezi). Gazi Üniversitesi Eğitim Bilimleri Enstitüsü, Ankara.

Ünal, G., Ergin, Ö., 2006. Buluş Yoluyla Fen Öğretiminin Öğrencilerin Akademik Başarılarına, Öğrenme Yaklaşımlarına ve Tutumlarına Etkisi, *Türk Fen Eğitimi Dergisi 3(1).*

Yıldırım, A., & Şimşek, H. (2004). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*. Ankara: Seçkin Yayıncılık.

Yılmaz, A. & Morgil, İ. (1992). Türkiye'de fen öğretiminin genel bir değerlendirilmesi, sonuçları ve öneriler. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 7, 269 -278.

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The Effect of Performance Based Evaulation on Preservice Biology Teachers' Achievement and Laboratory Report Writing Skills

Perihan GUNES[1], Hikmet KATIRCIOGLU[2], Mirac YILMAZ[3]

[1] Assist. Prof. Dr., Aksaray University, Faculty of Education, Aksaray-TURKEY
[2] Assoc. Prof. Dr., Gazi University, Faculty of Education, Ankara-TURKEY
[3] Assist. Prof. Dr., Hacettepe University, Faculty of Education, Ankara-TURKEY

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ABSTRACT

The aim of this study is to determine the effect of performance based evulation on preservice biology teachers' cognitive achievements and laboratory report writing skills about DNA isolation. In the study, nonequivalent control-group design were used to determine the effect of performance based evaluation on pre-service biology teachers' achievement and laboratory report skills about DNA isolation. The sample of the study was 70 pre-service teachers. A rubric and DNA isolation achievement test were developed for the data collection. Data was collected by pre-and post-administration of achievement test and administration of rubric. Before the beginning of the study, a pre-test was applied in order to determine the cognitive field levels of students on DNA isolation. Then, a DNA isolation test was applied to the experiment and control groups. While the experiment group was given a rubric to be used during writing their laboratory reports, the control group was not. At the end of the study, a post-test was applied in order to determine students' cognitive field levels. To detect the differences between the experimental and the control groups, the independent samples t-test was used. At the end of the study, it was determined that preservice teachers who use rubrics display a higher skill in writing laboratory reports and have a higher cognitive field level compared to those who do not.

Keywords: Rubric; Analytic Rubric; Holistic Rubric; DNA Analysis; Gene Technology; Preservice Teacher; Report Writing Skill.

INTRODUCTION

Recently, many educators have emphasized that the evaluation methods used today do not provide knowledge for the individuals' self-assessment nor the state of his development. These kind of evaluation methods should be used less frequently for evaluating student achievement (Kutlu, 2004; Bahar et al., 2006). As such evaluations fall short in measuring the higher order cognitive skills (such as designing an experiment, writing a new story, or presenting a paper) of students that are required to be graded (Kutlu, 2004). However, throughout their education, students must be able to use advanced mental skills in addition to knowledge that is based on recall to participate in meaningful learning. Kutlu, Doğan & Karakaya (2008) described the higher order cognitive skills as the entire cognitive, affective

Corresponding author e-mail: perihanguness@gmail.com © ISSN:1304-6020

and psychomotor features used by individuals while displaying their skills. Zoller (2000) approached the higher order cognitive skills as asking questions, critical and systematic thinking, problem solving, analyzing, evaluating, and synthesizing new information and decision-making. To educate individuals who can meet the needs of modern society, eduaction systems should set the development of students' higher order as high priority (Kutlu et al., 2008). This necessity requires educators to also measure and evaluate higher order cognitive skills. However, the current tests used in science teaching give little information about how students use the knowledge they have gained. That situation makes an emergent call for the use of new evaluation approaches that check the product and the process, which is globally referred to as performance-based evaluation, combining with pre-existing measurement and evaluation approaches.

Performance-based evaluation can be applied to real-life situations. Moreover, it can measure an activity with multiple solutions or strategies that includes higher order cognitive skills, which can be measured over a wide-ranging period of time, from a couple of minutes to a couple of days (such as modeling), or a situation that can produce original answers (such as explaining the solution to a mathematical problem) (Aschbacher, 1991; Baron, 1991; Madaus and O'Dwyer 1999; Stiggins, 1987). Kubiszyn and Borich (1996), on the other hand, underlined the necessity for propounding a product, having an observable performance while propounding that product and enabling it to involve the process of high order thinking in order to ground an evaluation on performance. Besides, the researchers indicated that the performance-based evaluations had to enable the social skills and group studies, as well as the interdisciplinary transition and information exchange (as cited in Berberoğlu, 2006). Performance-based evaluation is composed of two important parts. One is the performance task, and the other is the rubric (Popham, 2007). Miller (2005) defines performance tasks as activities where students are required to develop their own answers rather than choosing among the options presented to them. Students' knowledge can be structured by giving them performance tasks, and this is important for effective learning (as cited in Marzano, Pickering, and Mctighe, 1993). Thus, performance-appropriate evaluation tools are necessary to evaluate performance. Rubrics are said to be one of the most widely used tools to complete performance evaluations (Kutlu et al., 2008)

Rubrics are documents where the criteria taken into consideration for a given study are listed and the quality of each criterion is provided with detailed definitions (Andrade, 2000; 2001; 2005; Andrade and Du, 2005; Andrade, Wang, Du & Akawi, 2009; Goodrich, 1997). Having various forms and levels, the rubric could be used for a good number of course fields (Moskal, 2000). Rubric is especially used by teachers due to their dissatisfaction in giving a mark to practice-based fields like projects and oral presentations (Reddy, 2007). According to Popham (2007), rubrics are composed of three parts, namely, evaluation criteria, criterion definitions, and grading strategies.

1. Evaluation criteria: These are the factors that an evaluator uses when deciding on the quality of a student's performance. In other words, these are the requirements for a student to be considered successful (Wiggins, 1991).

2. Quality definitions: These are the detailed definitions of what a student has to do to achieve a certain performance level (Popham, 2007).

3. Grading strategies: These include whether the grading will be conducted according to the process or the result (Moskal, 2000).

Rubrics are descriptive grading schemes, including grading requisites. They are important because they include the use of higher order cognitive skills, which are the direct result of the emphasis on performance (Hafner and Hafner, 2003). While there is no standardized method to develop rubrics, certain criteria should be considered during the rubric development process. These are continuity, parallelism, consistency, even distribution, reliability, and validity (WNCP, 2006).

Recently, researchers have discussed the benefits of using rubrics in education, indicating that the application of rubrics in classes is appealing for both teachers and students. The reasons for this can be better understood when the reasons for using rubrics are examined (McCollister, 2002; Halonen et al., 2003; Andrade & Du, 2005). One of the most important goals of rubric use is to enable students to openly express their expectations about learning (Luft, 1997; 1999). They feel more responsibility for the evaluation of their learning (Phillip, 2002), and they actively participate in the evaluation process by partaking in self-evaluation (Wittaker, Spencer, and Duhaney, 2001). Students are able to determine their own needs and evaluate their own performance with rubrics (Andrade and Du, 2005). When used for the right reasons, rubrics make each teacher's grading system transparent so that students better understand the standards they are expected to meet (McCollister, 2002). In addition to enabling students to develop higher order cognitive skills and meta-cognitive strategies (Halonen et al., 2003), the application of rubrics supports and enhances learning (Andrade, 2000; Andrade and Boulay, 2003). The use of rubrics improves student achievement and learning by increasing each student's belief in their own self-efficiency (Quinlan, 2006). Moreover, it helps students improve their self-regulation skills by supporting meta-cognitive strategies such as planning, observation, and regulation (Saddler & Andrade, 2004). Reddy (2007) states that effective, valid, and reliable rubrics that provide clear, satisfactory and detailed feedback increase student satisfaction with the evaluation. They also augment learning by influencing self-evaluation, where students observe their own processes, such as evaluation, renewal, and performance grading. This implies that, in addition to increasing academic achievement, rubrics can augment other aspects of a student's learning, such as interest, personal proficiency and individual regulation.

As tools, rubrics are also appealing to teachers because they are strong in both teaching and evaluation (Andrade, Du & Wang, 2008; Goodrich, 1997). With the help of rubrics, teachers can have a more objective and consistent evaluation of their grading practices (Andrade, 2005; Wittaker, Spencer, and Duhaney, 2001). A valid rubric decreases the possibility of a biased decision about a student's performance by preventing the evaluator from focusing on factors such as a student's gender, race, age, appearance, ethnicity, or previous academic achievement. This quality of rubrics makes it possible to evaluate students objectively, and it becomes good supporting documentation for the teacher when he or she meets with the student and his or her parents (Andrade, 2000; Whittaker, Spencer, and Duhaney, 2001). At this point, the need for high quality rubrics that are to be used in teaching and learning processes comes to the fore. This implies that there is a necessity for a good comprehension of the rubric preparation process and that learning processes should be supported by well-prepared rubrics. For well-prepared rubrics to be used, the teachers, i.e., the evaluators should be well-educated in the use of rubrics. Additionally, the rubrics that are implemented should be developed by experts and be well tested.

In today's world, where our expectations of school and education consistently increase, science and the biological sciences, which facilitate our life and increase its quality, have an important role in supporting our decisions and enabling us to make the right ones. Therefore, the benefits of rubrics and their expansion in terms of science, technology, society, and environment, should be discussed by the field educators. When considering the transference of knowledge on the topics of molecular genetics in the biological sciences to individuals, the importance of multifaceted learning that will be realized on an advanced mental level must be better understood.

"Modern biotechnology" (or "gene technology"), in terms of its advantages and disadvantages related to health, economics, industry, environment, ecology, social and ethical topics, should be carefully discussed. The importance of communicating the ethical, economic, social, medical, and ecological results of gene technology to the individual and carefully examining the development of personal judgment and evaluations (approving/not approving, risk perception, and the ability to evaluate dangers), as well as the fact that these activities increase the importance of gene technology education, have been emphasized by several scientists (Schallies and Wellensiek, 1995; Harms and Bayrhuber, 1999; Harms, 2002). Discussing the teaching and the learning level of DNA isolation, which includes purification of the DNA by separating it from the live cell, using a rubric, is also important.

In the light of previous literature, the current study aimed to determine the effect of performance based evaluation on pre-service biology teachers' cognitive achievements and test report writing skills about DNA isolation. The following questions were addressed.

I. Is there a difference between the skills of students writing reports on DNA isolation levels when rubrics are used vs. when they are not used?

II. Is there a difference between the cognitive field levels of students studying DNA isolation when rubrics are used vs. when they are not used?

METHODOLOGY

a) Type of the Study

In this study, quantitative research designs patterns are used. The data are gathered using a nonequivalent control-group design, which is a quasi-experimental design. The most commonly used quasi-experimental design in educational research is the nonequivalent control-group design. In this design, research participants are not randomly assigned to the experimental and control groups, and both groups take a pretest and a posttest (Gall, Gall, Borg, 2007)

b) Study Group

The study group consists of 70 pre-service biology teachers who are sophomores at a state university. They were selected using cluster sampling, and they were appointed as one experiment and one control group in class level (Karasar, 2006). There were 31 students in the experimental group and 39 students in the control group. Ninety percent of the study group were female participants (N=63), and 10% were male participants (N=7). Second grade preservice teachers did not have an experience about rubrics. Besides, they did not have theoretical and practical studies about the DNA isolation, either.

c) Data Gathering Tools

DNA Isolation Cognitive Field Achievement Test: To determine students' cognitive field achievement levels with respect to DNA isolation, a 5-choice multiple-choice test was prepared. For this test, 5 objectives of student achievement were determined by the researcher. At least two questions that measure each objective were written, and a multiple-choice achievement test with a total of 22 questions was prepared. The achievement test was presented to two biology experts and two biology education experts. In accordance with the views and suggestions of the experts, necessary corrections were made and a pre-trial form was constructed. The constructed pre-trial form was administered to 174 university students studying in the biology education department during the spring semester of the 2010-2011 academic year. After this application, the article difficulty and differentiation indexes of the test were calculated. According to the results obtained from these calculations, 3 articles with an article difficulty lower than 0.20 were discarded. The remaining articles had article difficulties ranging from 0.22 to 0.59. The average article difficulty was calculated as 0.61, and it was determined that the test was of medium difficulty. The inner consistency reliability coefficient of the final test with 19 articles was determined to have a Cronbach's α=0.73.

DNA Isolation Rubric: To determine each student's laboratory report writing skills with respect to DNA isolation, including their weaknesses and strengths within the scope of general biology classes, a rubric was prepared. During the development process of the analytical rubric, which was intended to determine students' levels in reaching the objectives of laboratory report writing, four quantifiable objectives were determined. A performance item was established for each objective. These performance items became the evaluation criteria for the rubric. The resulting evaluation criteria were as follows: being able to write down the materials of the experiment, being able to write down the actual realization of the experiment, being able to write down the observations of the experiment, and being able to write down the results of the experiment. Each evaluation criterion was graded using 1-3 points. The summary of the scoring is as follows:

1 point: The skill needs to be developed

2 points: Acceptable

3 points: Highly successful

Then, each evaluation criterion was individually defined. For each evaluation criterion, for the spot where the scoring levels intersect, the performance expected of the student for that level is defined in detail from 3 to 1 (from good to bad). The ability to make observations was divided into two sub-categories; likewise, the ability to interpret was divided into 5 sub-categories, and all these sub-categories were separately defined. For example, for the experiment materials evaluation criterion, "All materials used in the experiment were documented in full" was written down for 3 points; "Many of the materials used in the experiment were documented" was written down for 2 points; and "Materials used in the experiment were not documented" was written down for 1 point (Appendix 1: DNA Isolation rubric). 4 experts examined the score adjustment levels between the evaluators for the reliability of the rubric. And while doing so, the evaluators were required to score a laboratory report that was prepared with the help of the rubric separately through the rubric. And then the reliability coefficients between the scores given by the evaluators were calculated with the Kendall conformation coefficient. As a result of the study, the conformation coefficient between the evaluators was determined as Kendall W=0, 81 (Kendall, Babington-Smith, 1993)

d) Data Analysis

The SPSS 20.00 statistics program was used to analyze the data. Item difficulty and discrimination indexes were measured by ITEMAN, which is an article analysis test, and the internal consistency reliability coefficient was calculated with Cronbach's alpha. To detect the differences between the experimental and the control groups, the independent samples t-test was used. In the interpretation of the results, the level of meaningfulness of the p value was determined as 0.05.

e) Intervention

The study was conducted by performing the DNA isolation experimentation within the context of the lesson of general biology laboratory II. The lesson of general biology laboratory II is conducted in two sections. While the 1st section is separated as the experimental group, the 2nd section is separated as the control group. We studied with the experimental group in the first two hours of the 4-hour lesson of general biology laboratory II and with the control group in the following two hours. At the beginning of the study, the pre-service teachers in the experimental and control group were informed about the DNA isolation and they were required to apply the experimentation of DNA isolation on their own.

The experimental and control group realized the experimentation in 4 groups according to the following order.

1. A half tomato was peeled and then diced. It was smashed until it became a puree within the press.
2. The solution A was prepared by putting 3 gr salt, 3 ml detergent and 24 ml distillate water in a beaker. This solution was put in a press and properly smashed with the pulped tomato.
3. The thickened puree was distilled with the help of a gauze or a thin strainer and put in a beaker.
4. 15 ml pineapple juice was added to the distilled part and then mixed.
5. 5 ml was taken from that mixture, placed within a tube and 10 ml cold alcohol was added to it.
6. We waited for 4 – 5 minutes and then observed DNA on the alcohol layer.

As a result of the intervention, the pre-service teachers in the experimental and control group were required to discuss about the results of the experiment with their friends in the group. As a result of the discussions, they were all expected to write a report regarding the experiment. They were required to write the experiment report by considering the materials being used in the experiment, as well as the performance of the experiment, observations of the experiment and the order of the results/interpretation of the experiment. While the experimental group was given the DNA isolation rubric that was developed to determine how to evaluate the reports while writing their reports, the control group was not given such a rubric. The control group only received oral explanations about how to write the report. The experiment reports that were obtained at the end of the study were evaluated by an expert through considering the criteria in the rubric.

FINDINGS

Test Report Writing Skill Acquisition Levels of Preservice Teachers

Table 1 shows the t-test findings. The results indicate that there is a statistically significant difference between the report writing achievement scores of the experiment and the control groups in favor of the experiment group.

Table 1. *Preservice Teachers' Rubric Total Point Averages Independent Samples T-Test Results*

Laboratory Report Writing Skills	Group	N	$\overline{X}$	SS	sd	t	p
Total Points	Experiment	31	23.5	3.265	68	13.96	0.000*
	Control	39	14.4	2.137			

*p<0.05

Table 2 shows the t-test findings. The data indicate that while there is not a statistically significant difference in the material writing skills of the control and the experiment group, there is a meaningful difference in favor of the experiment group in terms of the skills of being able to realize, observe and interpret the experiment.

Table 2. *Preservice Teachers' Rubric Averages Independent Samples t-Test Results*

Laboratory Report Writing Skills	Group	N	$\overline{X}$	SS	sd	t	P
Materials used in the Experiment	Experiment	31	2.58	0.502	68	0.330	0.743
	Control	39	2.54	0.555			
Construction of Experiment	Experiment	31	2.90	0.301	68	2.003	0.049
	Control	39	2.69	0.521			
Observation of Experiment	Experiment	31	5.10	1.270	68	5.469	0.000*
	Control	39	3.43	1.250			
Interpretation of Experiment	Experiment	31	12.90	2.330	68	16.497	0.000*
	Control	39	5.77	1.220			

*p<0.05

The data in Table 3 show the rubric skills averages of the experiment and the control groups with the t-test findings. In Table 2, observations and interpretations of the experiment were taken into consideration as a whole, whereas in Table 3, they are examined separately. Data obtained from the rubric show that there is a statistically significant difference between the experiment and control groups in favor of the experiment group when observation 1, observation 2, interpretation 1, interpretation 2, interpretation 3, and interpretation 5 achievement scores are considered.

Table 3. *Preservice Teachers' Observation and İnterpretation Rubric Averages Independent Samples T-Test Results*

Laboratory Report Writing Skills	Group	N	$\overline{X}$	SS	sd	t	p
Observation 1	Experiment	31	2.77	0.617	68	4.661	0.000*
	Control	39	1.82	0.997			
Observation 2	Experiment	31	2.32	0.945	68	3.361	0.001*
	Control	39	1.62	0.815			
Interpretation 1	Experiment	31	2.61	0.715	68	11.460	0.000*
	Control	39	1.13	0.339			
Interpretation 2	Experiment	31	2.35	0.661	68	8.307	0.000*
	Control	39	1.26	0.442			
Interpretation 3	Experiment	31	2.55	0.810	68	11.960	0.000*
	Control	39	1.00	0.000			
Interpretation 4	Experiment	31	2.77	0.617	68	13.140	0.000*
	Control	39	1.10	0.447			
Interpretation	Experiment	31	2.61	0.715	68	8.158	0.000*
	Control	39	1.28	0.647			

*p<0.05

Cognitive Field Levels of Preservice Teachers

The experiment and control groups' cognitive field achievement test pre-test averages independent samples t-test results are shown in Table 4. The results indicate that there is no statistically significant difference between the cognitive field achievement test pre-test averages of the experiment and control groups.

Table 4. *Pre-Application Cognitive Field Levels of Students' Independent Samples T-Test Results*

Group	N	$\overline{X}$	SS	sd	t	p
Experiment	31	14.26	3.44	68	1.150	0.254
Control	39	13.28	3.59			

The experiment and control groups cognitive field achievement post-test averages independent groups t-test results are shown in Table 5. The data indicate that there is a statistically significant difference between the cognitive field achievement post-test averages of the experiment and control groups in favor of the experimental groups.

Table 5. *Post-Application Cognitive Field Levels of Students*

Group	N	$\overline{X}$	SS	sd	t	p
Experiment	31	15.52	3.48	68	2.015	0.048*
Control	39	13.82	3.51			

*p<0.05

The results shown in Table 6 show that there is a statistically significant difference between the cognitive field achievement pre-test and the post-test averages of the experiment group and that there is no statistically significant difference between the cognitive field achievement pre-test and post-test averages of the control group. It was detected that the experiment groups achieved a higher success level in the post-test compared to the pre-test.

Table 6. *Experiment Group Pre-test and Post-test Average Points Matched t-Test Results*

Group	Test Type	N	$\overline{X}$	SS	Sd	t	p
Experiment	Pre-test	31	14.26	3.44	30	-3.198	0.003*
	Post-test	31	15.52	3.48			
Control	Pre-test	39	13.28	3.59	38	-1.007	0.320
	Post-test	39	13.82	3.51			

*p<0.05

DISCUSSION AND SUGGESTIONS

As a result of the study, it was determined that the rubric and achievement test successes of students showed a difference according to the educational method. As a result of the study, when the total points students earned on the DNA isolation rubric were considered, the experiment group was more successful compared with the control group in terms of acquiring report writing skills (Table 1). In similar studies on this topic, in terms of skills acquisition levels, students who use rubrics are more successful compared with those who do not (Andrade, 2001; Sefer, 2006; Gunes, 2011). In their respective studies, Andrade (2001) proves that rubrics are influential in enabling students to acquire effective writing skills; Sefer (2006) proves that they are influential in enabling students to acquire problem solving skills, and Gunes (2011) proves that they are influential in enabling students to acquire research skills.

Using rubrics to develop and acquire skills can be given as one of the reasons affecting student achievement. The reason students who use DNA isolation rubrics are more successful is that learning outcomes and the required achievement levels are clearly indicated in rubrics.

When the experiment report writing skills of the experiment and control groups were examined individually, it was observed that the experiment group was more successful compared to the control group (Table 2).

When the report writing skills acquisition levels of the preservice teachers were examined individually, the experimental group achieved a higher success level in terms of observation and interpretation of experiment results skills compared with the control group (Table 3). In his research on students' skills in interpreting experiment results, Rutherford (2007) found that students who use rubrics can interpret experimental results more successfully. In their study about learning studies with groups, Cohen, Lotan, Scarloss, Schultz and Abram (2002) suggested that individuals who were informed about the evaluation criteria had better-quality group studies and discussions. Andrade and Du (2005), on the other hand, indicated that using a rubric could enable students to do quality homeworks, have better grades and decrease their anxieties about what they would learn. According to the results of our study, it could be asserted that the use of a rubric in the DNA isolation experimentation will be effective upon the development of the skills of preservice teachers such as writing an experimentation report involving higher order cognitive skills like making accurate observations, as well as interpreting and writing the experimentation results, which could signify that the rubric would increase the higher order cognitive skills. Interpreting the study results in a broader term, on the other hand, it could be thought that the success of preservice teachers who were informed about the evaluation criteria by means of the rubric was affected by the decrease of their anxieties about how to write the experimentation report and the betterment of their perceptions regarding this subject.

The reason for the high success level in DNA isolation is that the perceptions of the preservice teachers regarding experimental report writing improves, and using rubrics is therefore effective in developing experimental report writing skills.

It was found that there is no meaningful difference in any class level between the cognitive field pre-test points of preservice teachers who use or do not use rubrics (Table 4). The points taken from the pre-test indicated that the control and the experimental group have a certain level of presumption about the topic.

There was a meaningful difference between the cognitive field post-test points of preservice teachers who use DNA isolation rubrics and those who do not, in favor of the experiment group (Table 5). The fact that the experimental group used rubrics is shown as the reason for this.

In this study, it was found that compared to the pre-test, the experimental group had a higher success level in the post-test (Table 6). The reuslts showed similarities with the research findings of Gunes' study (2011) related to the effect of rubrics on the research skills and cognitive field levels of primary school students. Gunes (2011) found that the cognitive level of the experiment group that used rubrics was higher in the pre-test compared to the post-test. Moreover, the cognitive level of the control group did not show any difference from the pre-test to the post-test. In the qualitative study of Gunes (2011) that was conducted with primary school students, the students indicated that the rubrics increased their success, which signifies that the results of study are supported by qualitative data. In our study, the fact that the experimental group used rubrics in research activities may have been effective in the occurrence of this difference. Rubrics may have a positive effect on the improvement of preservice teachers' perceptions and skills and on the improvement of their academic achievements.

The findings of the study allowed to make several suggestions. First, expressing what pre-service teachers should take into consideration when preparing an experimental report can have a positive effect both on the enhancement of their perceptions and skills and on the enhancement of their academic achievement. Second, the importance of using rubrics during the evaluation process, expanding the use of rubrics, and improving preservice teachers by informing them about rubrics can contribute to their education. Third, a discussion of developing new rubrics for molecular genetics, gene technology and other biology subjects and applying these rubrics to wide and various groups, thereby increasing student success and advancing cognitive skills and the effects of complimentary evaluation tools can be suggested. Finally, It could be suggested to also conduct studies that investigate the factors affecting the success and are supported by qualitative data.

REFERENCES

Andrade, H. G. (2000). Using rubrics to promote thinking and learning. *Educational Leadership*, *57* (5), 13-18.

Andrade, H. G. (2001). The effects of instructional rubrics on learning to write. *Current Issues in Education [On-line]*, 4 (4). Accessed October 12. 2010 http://cie.asu.edu/volume4/number4/.

Andrade, H.G. (2005). Teaching with rubrics: The good, the bad, and the ugly. *College Teaching*, *53* (1), 27-31.

Andrade, H.G., & Boulay, B. A. (2003). Role of rubric-referenced self-assessmentin learning to write. *The Journal of Educational Research*, *97* (1), 21-30.

Andrade, H. G., & Du, Y. (2005). Student perspectives on rubric-referenced assessment. *Practical Assessment, Research and Evaluation 10* (3), 1-11.

Andrade, H. G., Du, Y., & Wang, X. (2008). Putting rubrics to the test: The effect of a model, criteria generation, and rubric-referenced self-assessment on elementary school students' writing. *Educational Measurement: Issues and Practice*, *27* (2), 3–13.

Andrade, H. G., Wang, X., Du, Y., & Akawi, R. L. (2009). Rubric-referenced self assessment and self efficacy for writing. *The Journal of Educational Research*, *102* (4), 287-301.

Aschbacher, P. R. (1991). Performance assessment: State activity, interest and concerns. *Applied Measurement in Education*, *4* (4), 275-288.

Bahar, M., Nartgün, Z., Durmuş, S., & Bıçak, B. (2006). *Geleneksel alternatif ölçme ve değerlendirme öğretmen el kitabı*, Ankara: Pegem A Yayıncılık.

Baron, J. B. (1991). Strategies for development of effective performance exercises. *Applied Measurement in Education*, *4* (4), 305-318.

Berberoğlu, G., (2006). *Sınıf içi ölçme ve değerlendirme teknikleri*. İstanbul: Morpha.

Cohen, E., Lotan, R., Scarloss, B., Schultz, S. & Abram, P. (2002). Can group learn? *Teacher College Record*, *104*, 1045-1068.

Gall, M. D., Gall, J. P., & Borg, W., (2007). *Educational research an introduction*, USA:Pearson İnternational Edition.

Goodrich , H. G. (1997). Understanding rubrics. *Educational Leadership*, *54* (4). 14-17.

Gunes, P. (2011). *Dereceli puanlama anahtarının ilköğretim öğrencilerinin araştırma becerisi ve bilişsel alan düzeyine etkisi*. Yayınlanmamış doktora tezi, Hacettepe Üniversitesi Fen Bilimler Enstitüsü, Ankara.

Hafner, J. C., & Hafner, P. M. (2003). Quantitative analysis of the rubric as an assessment tool: An Emprical Study of Student Peer-Group Rating. *International of Science Education*, *25* (12), 1509-15298.

Halonen, J. S., Bosack, T., Clay, S., McCarthy, M., Dunn, D. S., Hill IV, G., W., McEntarffer, R., Mehrotra, C., Nesmith, R., Weaver, K. A., & Whitlock, K. (2003). A rubric for learning, teaching, and assessing scientific ınquiry in psychology. *Teaching of Psychology*, *30* (3), 196-208.

Harms, U. & Bayrhuber, H. (1999). Biotechnologie im Unterricht, Biotechnologie und Gentechnik. In M. Schallies, und K.D. Wachlin eds. Biotechnologie und Gentechnik, Springer Verlag Berlin, Heidelberg, Newyork, 87-98.

Harms, U. (2002). Biotechnology Education in schools. *Electronic Journal of Biotechnology*, *5*(3). http://www.ejbiotechnology.info/content/vol5/issue3/ teaching/01/ (Accessed August 8. 2004).

Karasar, N. (2006). Sosyal bilimlerde nitel araştirma yöntemleri (16th Ed.), Ankara: Nobel Yayın Dağıtım.

Kendall M. G., Babington-Smith B. (1993). The Problem of m Rankings. *The Annals of Mathematical Statistics*, *10* (3), 275- 287.

Kutlu, Ö. (2004). *Tek Soru İle Öğrenci Performansının Belirlemesi*. Accessed November 13. 2010. http://www.erg.sabanciuniv.edu/iok2004/bildiriler.

Kutlu, Ö., Doğan, C. D., & Karakaya, İ. (2008). *Öğrenci Başarısının Belirlenmesi: Performansa ve Portfolyaya Dayalı Durum Belirleme.* Ankara: Pegem Akademi.
Luft, J. A. (1997). Design your own rubric. *Science Scope*, *20* (5), 25-27.
Luft, J. A. (1999). Rubrics: Design and use in science teacher education. *Journal of Science Teacher Education*, *10* (2), 107-121.
Madaus, G. F., & O'Dwyer, L. M. (1999). A short history of performance assessments. *Phi Delta Kappan, 80* (9), 688-696.
Marzano, R. J., Pickering, D., & McTighe, J. (1993). *Assessing student outcomes: Performance assessment using the dimensions of learning model*. Virginia: Association for Supervision and Curriculum Development.
McCollister, S. (2002). Developing criteria rubrics in the art classroom. *Art Education, 55* (4), 46-52.
Moskal, B. M. (2000). Scoring rubrics: What, when and how? *Practical, Assessment, Research and Evaluation,* 7(3). Retrieved October 24, 2013 from http://PAREonline.net/getvn.asp?v=7&n=3.
Phillip, C. (2002). Clear expectations: Rubrics and scoring guides. *Knowledge Quest, 31*(2), 26-27.
Popham, J. W. (2007). *Classroom Assessment: What Teachers Need to Know (5th Ed.)*. USA: Pearson Education.
Ouinlan, A. (2006). *Assessment made easy: Scoring rubrics for teachers from K-college*. Lanham, MD: Rowman and littlefield education.
Reddy, M. (2007). Effect of rubrics on enhancement of student learning. *Educate 7* (1), 3-17.
Rutherford, S. (2007). Using a Laboratory Conclusion Rubric. *Science Activities: Classroom Projects and Curriculum Ideas*, *43* (4), 9-14, DOI: 10.3200/SATS.43.4.9-14.
Saddler, B. & Andrade, H. G. (2004). The writing rubric. *Educational Leadership, 62*(2), 48-52.
Schallies, M. & Wellensiek, A. (1995). Biotechnologie/Gentechnik Implikationen für das Bildungswesen. Arbeitsbericht, Akademie für Technikfolgenabschätzung in Baden-Württemberg, Stuttgart.
Sefer, D. G. (2006). Dereceli puanlama anahtarının (rubrik) problem çözme becerisinin değerlendirilmesinde kullanılması. Yayınlanmamış yüksek lisans tezi, Hacettepe Üniversitesi Sosyal Bilimler Enstitüsü, Ankara.
Stiggins, R. J. (1987). Design and development of performance assessments. *Educational measurement: Issues and Practice*, *6* (1), 33-42.
Whittaker, R. C., Spencer, S.J., & Duhaney, D. (2001). Creating instructional rubrics for inclusive classroom. *Teaching Exceptional Children*, *34* (2), 8-13.
Wiggins, G. (1991). Standart, not standardization: Evoking quality student work. *Educational Leadership, 48* (5), 18-25.
WNCP, (2006). *Rethinking classroom assessment with purpose in mind: Assessment for learning, assessment as learning, assessment of learning*. Canadian. Accessed August 22. 2010 http://www.wncp.ca/media/40539/rethink.pdf.
Zoller, U. (2000). Teaching college science towards the next millennium: Are we getting it right? *Journal of College Science Teaching*, *29*, 409-414

Appendix 1: DNA Isolation Rubric

Score / Criterion		3 (Highly successful)	2 (Acceptable)	1 (Needs to be developed)	Score
Materials used in the experiment		All materials used in the experiment were documented in full.	Many of the materials used in the experiment were documented.	Materials used in the experiment were not documented.	
Realization of the experiment		All phases related to the realization of the experiment were correctly listed.	Phases related to the realization of the experiment were somewhat correctly listed.	Phases related to the realization of the experiment were listed completely incorrectly.	
Observation of the experiment	**Observation 1**	Completely correct observations were made about the place of the structure we observe in the experiment.	Somewhat correct observations were made about the place of the structure we observe in the experiment.	Completely incorrect observations were made about the place of the structure we observe in the experiment.	
	Observation 2	Correct observations were made as to what the structure we observe in the experiment looks like.	Somewhat correct observations were made as to what the structure we observe in the experiment looks like.	Completely incorrect observations were made as to what the structure we observe in the experiment looks like.	
Results/Interpretation of the Experiment	**Interpretation 1**	Completely correct results were arrived at as to why mechanical breaking is performed.	Partially correct results were arrived at as to why mechanical breaking is performed.	Completely incorrect results were arrived at as to why mechanical breaking is performed.	
	Interpretation 2	Completely correct results were arrived at as to why Solution A is used.	Somewhat correct results were arrived at as to why Solution A is used.	Completely incorrect results were arrived at as to why Solution A is used.	
	Interpretation 3	Completely correct results were arrived at as to what function filtration has in the experiment.	Somewhat correct results were arrived at as to what function filtration has in the experiment.	Completely incorrect results were arrived at as to what function filtration has in the experiment.	
	Interpretation 4	Completely correct results were arrived at as to what function the pineapple juice has in the experiment.	Somewhat correct results were arrived at as to what function the pineapple juice has in the experiment.	Completely incorrect results were arrived at as to what function the pineapple juice has in the experiment.	
	Interpretation 5	Completely correct results were arrived at as to what function the alcohol has in the experiment.	Somewhat correct results were arrived at as to what function the alcohol has in the experiment.	Completely incorrect results were arrived at as to what function the alcohol has in the experiment.	
				TOTAL SCORE	

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Developing a Holistic Measurement on Nuclear Issues for Preservice Science Teachers

Hilal KÜÇÜK[1], Gökhan GÜVEN[1], Hediye Şule AYCAN[2]

[1] Research Assist., Muğla Sıtkı Koçman University, Faculty of Education, Muğla-TURKEY
[2] Prof. Dr., Muğla Sıtkı Koçman University, Faculty of Education, Muğla-TURKEY

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ABSTRACT

In this study, a conceptual understanding test and a knowledge test were developed to investigate the conceptual understanding and knowledge levels of pre-service science teachers about a socio-scientific topic, nuclear energy and nuclear plants. The study addresses the reliability and validity of these developed tests. While the 34-question knowledge test was administered to 441 pre-service science teachers, the 15-question conceptual understanding test was administered to 223 pre-service science teachers. In the test development process, to establish the validity expert opinions were sought, item analyses and factor analyses were conducted and reliability computations were performed. At the end of the editing, after the correction and elimination of some problematic questions, the final form of the knowledge test emerged with 30 questions and the conceptual understanding test emerged with 13 questions. As a result of the analyses, it was found that the knowledge test consists of four factors and explains 56.98% of the total variance while the conceptual understanding test is made up of three factors and accounts for 46.35% of the total variance. Furthermore, the Cronbach's alpha coefficient of the conceptual understanding test was found to be 0.77 and KR-20 and two-tier reliability coefficients of the knowledge level test were calculated to be 0.86 and 0.85 respectively.

Keywords: Pre-service Science Teachers; Nuclear Energy; Nuclear Plant; Validity; Reliability.

INTRODUCTION

Energy has become an indispensible part of modern life. Throughout the last two centuries, the main component in the developments in many fields of industry, [1]modern life, science and technology has been energy. However, with the rapid growth of the world population, many countries are now confronted with energy-induced challenges. In order to be able to deal with such problems, some countries have been engaged in the search for sources of energy as alternative to fossil fuels and one of these alternatives is nuclear energy. While some developed countries such as the USA, France and Japan are still making full use of nuclear energy, some other countries adopt approaches against nuclear energy. In Turkey, discussions about nuclear energy date back to the 1960s and during that period, attempts were

[*] Franklin says; "If you would not be forgotten as soon as you are dead, either write something worth reading or do things worth writing." In memory of Hilal Küçük (1986 - ∞)…

Corresponding author e-mail: gokhanguven@mu.edu.tr © ISSN:1304-6020

made to establish nuclear plants but all these attempts failed due to various reasons. At present, there are two nuclear plants in the process of construction in the Turkish cities of Sinop and Mersin. Preliminary research is being conducted for the construction of a nuclear plant in the Trakya-İğneada region of Turkey.

Lack of agreement on the use of nuclear energy among countries has led to some disputes on the generation and use of nuclear energy. The public is informed about these disputes on nuclear energy and construction of nuclear plants by the media. It is seen that there are two extreme sides to these disputes in the media. On one hand, some media adopting the view of *Nuclear Renaissance* argue that the cleanest way of saving the world from the nightmare of global warming is nuclear energy as it does not emit greenhouse gases, it does not yield waste ashes and it is a more efficient means of energy production when compared to its alternatives. On the other hand, some other media adopting the view of a *Nuclear Nightmare* argue that nuclear energy poses great security risks and waste-disposal challenges; they refer to the Chernobyl accident in 1986 and the Fukusima accident in 2011 (Kaya, 2012) as examples.

Though the media serves the function of informing the public on the issue, some misleading news, animations, speculations and quotations on television, newspapers and the Internet result in members of the public experiencing a dilemma about nuclear energy and nuclear plants. As a result, the public can be either too indifferent or too sensitive to risky situations. Moreover, due to lack of information the concept of nuclear energy and radiation can be perceived more negatively and be more confusing. It is widely observed that individuals having negative or positive perceptions of the issue cannot justify their position and have some problems. The opinions expressed by lay-people about the issue mostly stem from unquestioned social learning rather than scientific inferences based on scientific reading and research. People not reading about or researching the issue may turn out to be indifferent to the problem of nuclear energy and view it like a science fiction scenario not much related to their daily lives. As some other people think that this is the problem of scholars, they may not be willing to be involved in decision-making processes even if they have the right to do so. However, when the relevant literature is investigated, it is seen that there is a great lack of information in society and they cannot evaluate the up-to-date nuclear energy-related problems and issues critically (Cohen, 1998; Matsuura and Iırı, 2002; Yalcin and Kilic, 2005). Hence, it is of great importance to educate individuals to be able to question and evaluate the issue of the generation of nuclear energy and construction of nuclear plants with critical and scientific rationality.

It can be easily argued that for a society to be an information society, teachers are of vital importance. Teachers may exert great influence on the development of critical thinking, problem solving and scientific thinking skills of their students (Ralph and Wayne, 1967). However, to do so, first, teachers should be educated well. According to Gultekin (2002), the only way of training qualified teachers is to get pre-service teachers to undergo a quality teacher training program.

Besides this, it is clear that the teachers who introduce students to nuclear issues should be science teachers. In this respect, when the pre-service science teacher training programs are analyzed, it is seen that nuclear issues are only taught in a few courses. During the observation performed by the researchers in these courses, it was seen that the pre-service science teachers had great difficulties in discussing this highly popular socio-scientific issue. This may be because of the lack of information or misconceptions possessed by the pre-service teachers. Some other research has also revealed that teachers and students have difficulties in discussing the issue of nuclear energy and plants due to deficiency in knowledge or misinformation (Atila, 2004; Ozdemir and Cobanoglu, 2008).

When the literature on nuclear energy and nuclear plants is investigated, it is seen that it mostly focuses on the evaluation of the attitudes and interest of students from different grade levels and teachers from different subject areas. In some of the related studies, university students' attitudes and interests in nuclear energy and wastes (Berberoglu and Tosunoglu, 1995; Karagoz, 2007; Larsen, 1993; Ozdemir and Cobanoglu, 2008; Taskin, 2004) or elementary students' opinions and feelings about the use, effects, benefits and harmful effects of nuclear energy and construction of nuclear plants (Kilinc, Boyes and Stanisstreet, 2013; Maharaj-Sharma, 2011) were investigated. It can be argued that the pre-requisite of making correct inferences and developing appropriate attitudes is based on prior knowledge. Given the fact that interests and attitudes develop depending on prior knowledge, it becomes clear that the determination of individuals' knowledge and conceptual understanding through reliable tests can be of great importance as well. In this regard, together with the scales of attitude and interest on nuclear issues, tests to understand what pre-service science teachers know about nuclear issues can fill the gap in the literature to some extent.

In order to be able to critically approach any issue, the related basic concepts should be understood and internalized. In this regard, the basic concepts of nuclear energy and nuclear plants should be accurately taught and learned, correctly interpreted and thus, by forming the right knowledge, the advantages and disadvantages of nuclear energy and nuclear plants should be appropriately evaluated. Hence, the importance of a holistic measurement which covers the conceptual understanding of the basic concepts and knowledge of pre-service science teachers on nuclear issues is important.

Based on the belief that this problem may be possessed by many pre-service science teachers, the purpose of the present study is to develop a holistic measurement to comprehensively understand what pre-service science teachers know about nuclear issues. Accordingly a conceptual understanding test which includes the basic concepts on nuclear issues, determining the attitudes that influence the decision-making processes and a knowledge test to understand the basic knowledge level of the pre-service science teachers were be developed. We believe that it would be easier to accurately determine the sources of the level of misunderstanding of pre-service science teachers on nuclear issues through these two tests together.

METHODOLOGY

In this section, the characteristics of the study groups in which the reliability and validity of the two tests were established will be discussed.

a) Conceptual Understanding Test of the Concepts of Nuclear Energy and Nuclear Plants

The first test consists of 15 questions. During the development process of the questions, first, a concept map was constructed by reviewing some books written in this field. After seeking the opinions of experts in the field of chemistry about this concept map, concepts such as *strong nucleus force, instability, radioactive decay, radiation, ionized radiation, non-ionized radiation, half-life, fission* and *fusion* were included within the concept map. Then, concept analysis including scientific definitions and misconceptions reported in the literature was conducted for each concept and the test questions were developed based on these concept analyses. The conceptual understanding test includes conceptual and phenomenological questions that can be answered by the students who internalized these concepts. The questions developed by using all the concepts may be categorised under three main concepts: *Radioactivity, environmental effects* and *nuclear reactions*.

When the relevant literature is examined, it is seen that the concepts of knowledge level and conceptual understanding may mean different things. It is known that knowledge level can be improved through recall and exercise (Stephanou, 1999). However, in a science course, it is widely observed that even the most successful students provide memorized answers to questions. When questions requiring deep analysis are asked, it is seen that students have in fact some misconceptions about the issues that they seem to know only superficially (Unal Coban, 2009). In this regard, the concept called conceptual understanding can become really difficult to evaluate by means of classical methods including multiple-choice, false or correct and short answer questions and they may not be adequate to claim that students deeply internalized the concepts. Hence, such measurement instruments should include questions requiring students to transfer their knowledge into different settings so that they can use their knowledge. In a similar manner, Demirelli (2003) states that for learning to occur at the understanding and comprehension levels, the questions of “Why” and “How” should be answered. Thus, whether a student has the conceptual understanding or not can be evaluated through a test including these types of questions.

In order to determine whether students have reached a conceptual understanding level, there are many different types of evaluation techniques that have been developed. Among these, the effective ones are those including open-ended questions to define students’ opinions. Through tests including such questions, students’ opinions can be more comprehensively evaluated and the reasons for their opinions can be well understood (Kabapinar, 2003). Driver and Erickson (1983) argue that there are two dimensions involved in the elicitation of students’ opinions for such tests. These are conceptual and phenomenological dimensions. At the conceptual level, students are asked to give explanations about the concept, and use or define the concept in a context. At this level, while collecting the data, techniques such as conceptual associations, free writing and concept maps can be used. At the phenomenological dimension, on the other hand, an incident is presented and students are asked to make predictions about the incident and then they are asked to provide explanations about their predictions (Driver and Erickson, 1983; Kucukozer, 2004). Within the framework of the present study, by taking these factors into consideration, the conceptual understanding test was planned to contain such open-ended questions.

If we examine the questions of the conceptual understanding test that was prepared, it could be said that the first, second and third questions of the conceptual understanding test are phenomenological questions that can be answered by using the information of the fundamental forces in nature such as strong nuclear force, electromagnetic force, weak nuclear force and the force of gravity. The fourth and fifth questions in the test are conceptual questions for which students are expected to provide explanations in their own words about the concepts in question. In order to be able to answer the sixth and seventh phenomenological questions of the test, students have to know the concepts of radiation and nucleus stability. The eighth question can be answered based on the fact that radioactive substances cannot be changed by physical factors as long as radioactive substances do not affect the nucleus. The ninth question of the test is a phenomenological question that can be answered by knowing the ionization effect of radiation. The tenth question requires knowing that radioactive decays are exothermic reactions. The eleventh question of the test is phenomenological and requires information about the types of radioactive decay and their areas of influence. In order to be able to answer the twelfth question of the test, students must know that radioactive wastes are produced as a result of radioactive decay of radioisotopes; after decay, these wastes go on emitting radiation at gradually decreasing amounts. When exposed to such wastes, students need to know about the types of radiation that are produced and the effects of exposure to them. The thirteenth question of the test is a conceptual question measuring three different basic concepts. The fourteenth question is a phenomenological question that requires students to know the difference between the concepts of fission and fusion. The last phenomenological question requires knowing the effects of ionized radiation on the human body.

b) Knowledge Test on Nuclear Energy and Nuclear Plants

In order to measure the pre-service science teachers' knowledge level about nuclear energy and nuclear plants, a knowledge test was developed by the researchers. Before developing the test, the sub-headings and scopes of the topic of nuclear energy and plants were determined by considering the grade levels of the pre-service science teachers. Then the opinions of three science education experts in their fields were sought. In light of their opinions, the sub-headings of the topic were determined to be *nuclear force*, *radioactive substance*, *radioactive isotope*, *half-life*, *radioactive decay*, *radiation*, *fission* and *fusion*, *the state of nuclear plants in the world*, *working principles of nuclear plants*, *advantages* and *disadvantages of nuclear plants* and *the effects of nuclear plants on human health and the environment*.

A question pool including multiple-choice questions about each sub-heading of the topic of nuclear energy and plants was constructed. During the construction of this question pool, various sources including achievement tests reported in the relevant literature, question pools including these sub-headings, test worksheets and chemistry textbooks were referred to. Moreover, by developing additional multiple-choice questions, the researchers contributed to the existing question pool. The questions in the pool were classified according to cognitive domains of Bloom's taxonomy. In the final form of the test there were 34 multiple-choice questions that were suitable for 3rd and 4th-year pre-service science teachers to answer.

FINDINGS

In this section, the findings related to validity and reliability of the conceptual understanding test and knowledge test that were developed to evaluate the students' information about nuclear energy and nuclear plants are discussed. These findings are related to item analyses, content, face and construct validity and reliability of the test questions.

Findings related to Conceptual Understanding Test of Nuclear Energy and Nuclear Plants

Validity is one of the important characteristics to be considered while developing an evaluation tool. The validity of an evaluation tool involves what this tool aims to measure and how well it fulfils this goal (Anastasi and Urbina, 1997; Tavsancil, 2006). In the literature, validity is generally discussed under three headings (Sencan, 2005). The first is related to whether the evaluation tool used is suitable for the feature to be evaluated. The second is related to whether evaluation is performed in compliance with the rules of evaluation. The third is related to whether the data obtained are actually reflecting the characteristic intended to be evaluated. In relation to these headings, validity can be classified under different categories. Some of these are content validity, construct validity, predictive validity and face validity. In the present study, in order to test the content and face validity of the test, the concept analyses of the conceptual understanding test together with the expert opinions form developed by the researchers were scrutinised by five instructor experts in their fields. The instructors analyzed each question in terms of scientific suitability, suitability for student level and comprehensibility. In order to evaluate the consistency between the experts' responses about the test questions, agreement values were calculated through agreement an percentage formula (Miles and Huberman, 1994).

According to agreement results, some corrections were made to questions 1, 3, 7, 9, 11 and 15. No question was discarded from the test. After undergoing the scrutiny of the experts, the questions were administered to 223 pre-service science teachers studying at Muğla Sıtkı Koçman University in Turkey. Of these students 16.6% (n=37) are senior students, and 83.4% (n=186) are third-year students. The reason for the selection of the students for the administration of the test is that they have already completed a course related to nuclear issues.

In the analysis of the responses to the conceptual understanding test of the present study the data were coded according to a quintet coding scheme developed by Abraham, Williamson and Westbrook (1994) (Table 1). The same scheme was also used in other studies (Abraham, Gryzbowski, Renner and Marek, 1992; Haidar and Abraham, 1991; Simpson and Marek, 1988; Westbrook and Marek, 1991, 1992).

Table 1. *Conceptual Understanding Evaluation Scheme*

Degree of conceptual understanding	Criteria for scoring
0 – No understanding (NU)	Blank, repeats question, irrelevant or unclear response, no explanation given for choice of answer
1 – Specific misconception (SM)	Scientifically incorrect responses
2– Partial understanding with a specific misconception (PU/SM)	Responses that show understanding of the concept, but that also contain a misconception
3 – Partial understanding (PU)	Responses that contain a part of the scientifically accepted concept
4 – Sound understanding (SU)	Responses that contain all parts of the scientifically accepted concept

The existence of such a coding system allows the calculation of item difficulty and discrimination indices and conducting reliability and construct validity for a conceptual understanding test. After coding, item difficulty and discrimination indices were calculated for each question. According to Ozguven (1994), the item difficulty is the percentage of participants correctly responding to the question. When item difficulty converges to 0.00, it means that the question is very difficult and when it converges to 1.00, it means the question is very easy. The item difficulties of the test questions were determined through item analysis. The questions having item difficulty values ranging from 0.30 to 0.70 were retained in the final form of the test. In addition to item difficulty, the discrimination value of each question was also calculated. The questions having discrimination values higher than 0.30 were included in the test.

According to the item analysis results, it was decided to discard questions 8a, 8b, 8c, 10a and 10b so as not to distort the conceptual structure of the test. After the exclusion of these questions from the test, exploratory factor analysis was conducted using SPSS 14 and the factor structure of the test was investigated to check the construct validity. Construct validity is useful to explain what the analysis results are related to. Construct validity is a process of inquiry of what the measurement scale and scores obtained from it mean (Ozguven, 1994). Factor analysis is a technique used to transform associated data structures into fewer new data structures independent from each other, to reveal common factors by grouping the variables assumed to explain a formation or an event and to group the variables affecting a formation (Ozdamar, 2002). That is, it is a technique providing an empirical basis for acquiring fewer independent variables by combining moderately or highly related variables. In this way, it can be possible to reduce many variables to a few groups or dimensions. And each of these groups or dimensions is called factor (Balci, 2009).

According to exploratory factor analysis, the Keiser-Meyer-Olkin (KMO) test result was found to be .814. The Bartlett coefficient was significant at the .000 level. A significant

Bartlett result shows that the data have multi-variable normal distribution and accordingly, it shows that the other assumptions of the factor analysis are also met. According to the analysis results, while four-factor construct explains 53.865% of the total variance, if three-factor construct is selected, it can explain 46.358% of the total variance. Given that while developing the conceptual understanding test, the concepts determined through expert opinions were collected under three main headings, it can be said that three-factor construct is more suitable for the test. Factor loadings of the questions according to three-factor construct are given in Table 2.

Table 2. *The Factor Structure of the Conceptual Understanding Test*

Questions	**Factor Loadings of the Factors**		
	Radioactivity (1st factor)	***Environmental effects (2nd factor)***	***Nuclear reactions (3rd factor)***
1-2-3-4-5-6	0.407-747		
7-9-11-12-15		0.357-0.749	
13-14			0.745-0.708
Variance explained	19.289%	15.469%	11.599%
	Total variance : 46.358%		

Exploratory factor analyses were conducted on this three-factor structure. This three-factor structure was justified by the confirmatory factor analysis. The confirmatory factor analysis was carried out using Lisrel 8.7.

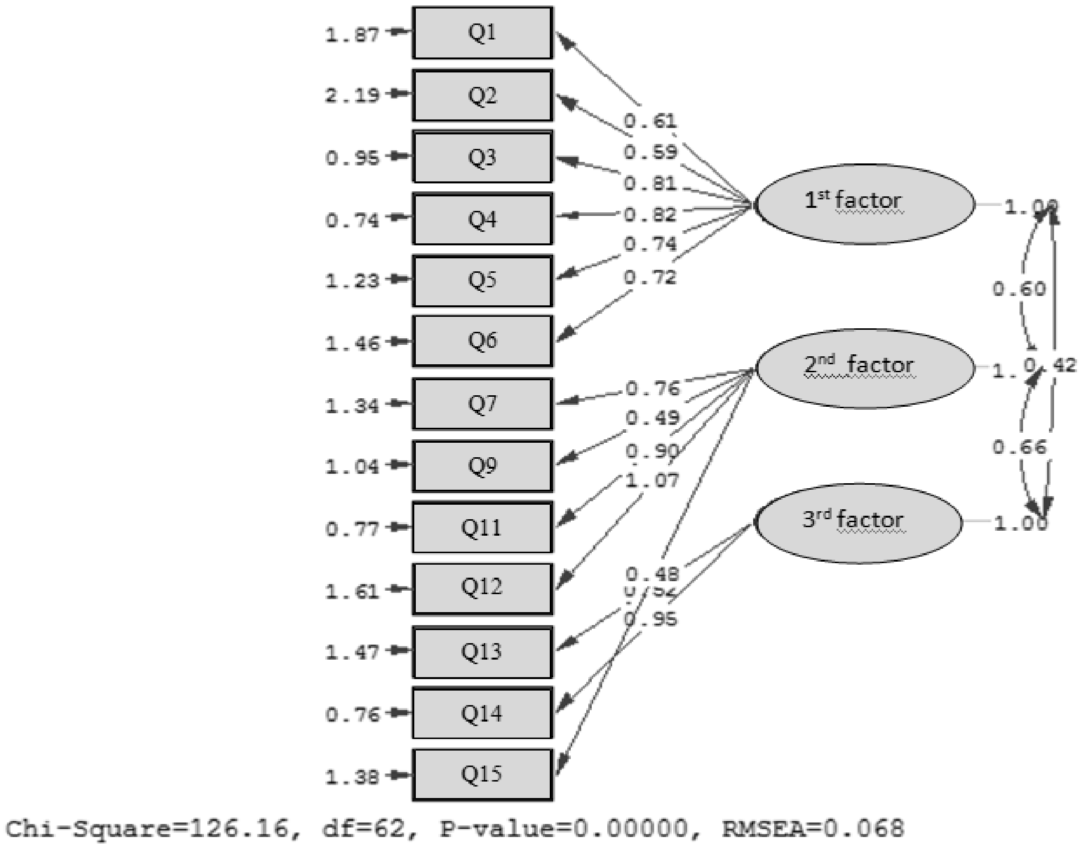

Figure 1. *The Results of the Confirmatory Factor Analysis of the Conceptual Understanding Test*

In light of the data presented in Figure 1, it can be argued that fit indices of the conceptual understanding test consisting of 13 questions are significant (X^2=126.16, sd=62, p=.000, X^2/sd=2.035). In addition to this, fit indices are RMSEA=.068, GFI=.92, AGFI=.88, CFI=.94, NNFI=.92 and IFI=.94. Based on these results, the model can be claimed to have a good fit; hence, no modification was made to the questions. Within the context of the reliability analyses of the conceptual understanding test, the Cronbach's alpha (α) coefficient was calculated and reliability coefficient for the whole of the test was found to be .775. According to Cepni (2007), reliability means consistency shown by the measurement scale when more than one measurement of the same feature is made.

Findings related to Knowledge Test of Nuclear Energy and Nuclear Plants

During the development process of the test, required applications were performed with the questions were administered to 441 senior and third-year pre-service science teachers from the science teaching programs of Muğla Sıtkı Koçman University, Dokuz Eylül University and Celal Bayar University in the 2013-2014 academic years. Of the participants, 38.7% (n=171) are third-year students and 61.3% (n=270) are senior students.

Item difficulty index and item discrimination index were calculated for the knowledge test and questions with difficulty value below or above 0.50 and discrimination indices lower than 0.30 were discarded from the test. The questions having low values were modified or discarded from the test in line with the opinions of experts. In this regard, questions 20 and 21 were modified and four questions were excluded from the test. While doing this, the content validity of the test was ensured. As a result, the number of questions in the test was reduced to 30. The distribution of the questions in the final form of the knowledge test according to cognitive domains is presented in Table 3.

Table 3. *Distribution of the Questions in the Knowledge Test according to Cognitive Domains*

Content	Information	Understanding	Analysis	Synthesis
Nuclear force	1			
Radioactive substances	2	3, 4 ,5		
Radioactive isotopes		7	6	
Half-life	8	9		
Radioactive decay	11	10	12	
Radiation	13, 14			
Fission and fusion	15, 16, 18, 19	17		
Nuclear plants in the world and in Turkey	20, 21			22
Working principle of nuclear plants	23	24, 28		27
Advantages and disadvantages of nuclear plants		25, 30		
Effects of nuclear plants on human health and nature		26		29
Total number of questions	13	12	2	3
Percentile	43	40	7	10

First, the exploratory factor analysis (EFA) was conducted to establish the construct validity of the knowledge test. While determining the questions to be kept in the test as a result of the EFA, the following criteria were observed. Eigenvalues should be at least 1, loading values should be at least .30 (Martin and Newel, 2004), questions' should be located in one factor and there should be at least .10 difference between the factors located in two factors (Buyukozturk, 2007). Moreover, Orthogonal Varimax was used in EFA. In social sciences, this method is preferred in factor rotation (Cokluk, Sekercioglu and Buyukozturk, 2010). As a result of the EFA, the KMO was found to be .902 and the Barlett test was found to be significant at the level of $p < .001$. As a result of the EFA, a four-factor construct explaining 56.985% of the total variance was obtained.

Table 4. *The Factor Structure of the Knowledge Test*

Questions	Factors and Factor Loadings			
	Radioactivity (1st Factor)	Nuclear energy (2nd Factor)	Working principle of a nuclear plant (3rd Factor)	Effects on human health and nature (4th Factor)
1-2-3-4-5-6-7-8-9-10-11-12	0.59 - 0.74			
13-14-15-16-17-18-19		0.36- 0.77		
23-24-27-28			0.43- 0.68	
20-21-22-25-26-29-30				0.31-0.82
Total variance	18.523%	13.142%	12.804%	12.516%
	Total variance : 56.985%			

As can be seen in Table 4, there is a four-factor construct explaining 56.985% of the total variance. In multi-factor designs, when the variance explained is between 40% and 60%, it is considered to be sufficient (Tavsancil, 2006).

Model fitness of the question-factor construct obtained from EFA analysis was tested through confirmatory factor analysis (CFA). There are several fit indices used to justify the adequacy of the model tested through CFA. In the present study, the DFA, Chi-Square Goodness, GFI (Goodness of Fit Index), AGFI (Adjusted Goodness of Fit Index), CFI (Comparative Fit Index), NNFI (Non-Normed Fit Index), IFI (Incremental Fit Index) and RMSEA (Root Mean Square Error of Approximation) fitness indices were investigated. A fitness value of 0.90 is considered to be acceptable for GFI, AGFI, CFI, NNFI and IFI indices and a perfect fitness value is considered to be 0.95 (Simsek, 2009). For RMSEA, 0.08 is set to be acceptable fitness and 0.05 is set to be perfect fitness value (Thompson, 2004). In CFA, fitness indices of the four-factor model were investigated. The data for CFA are shown in Figure 2.

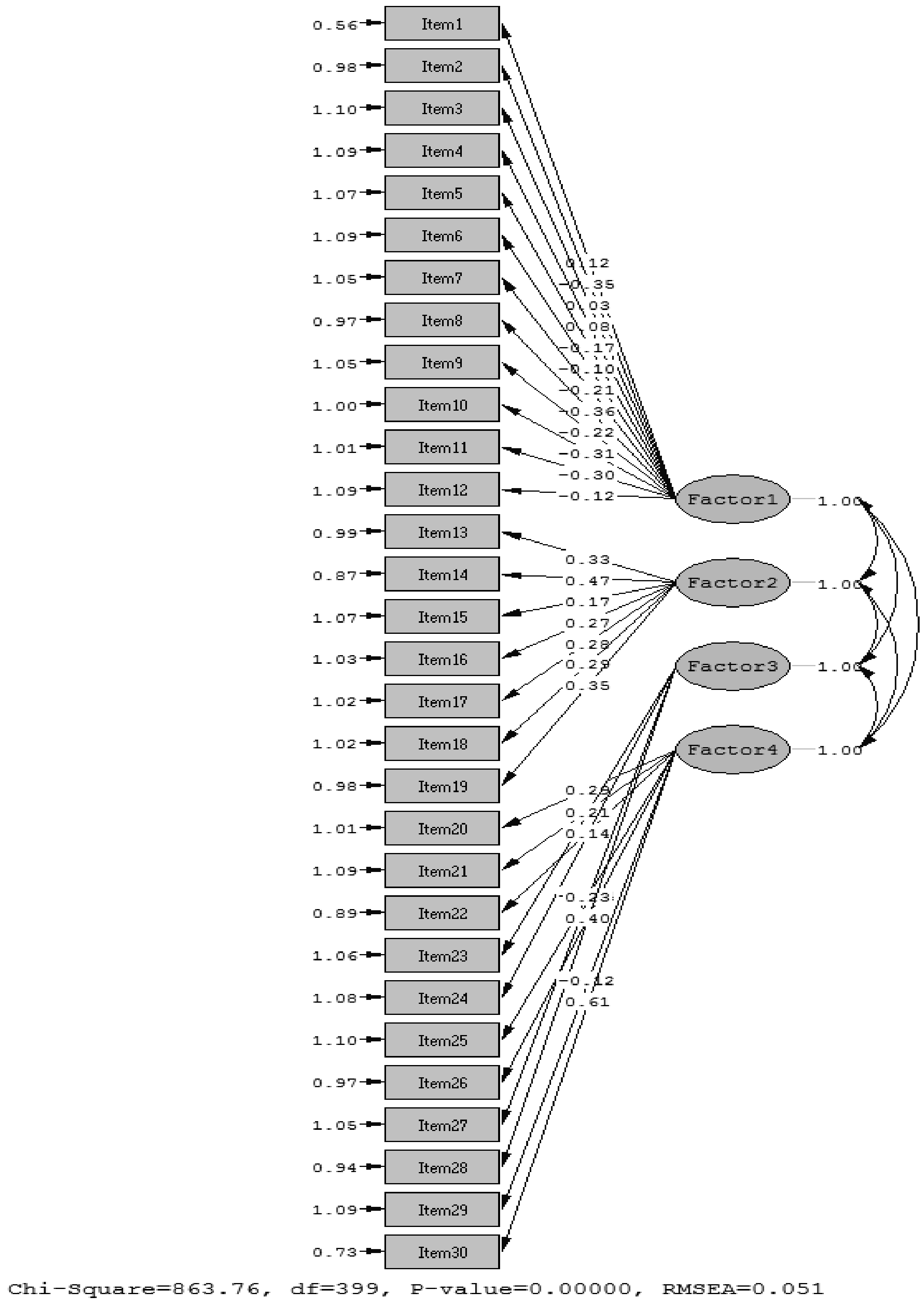

Figure 2. *The Results of the Confirmatory Factor Analysis of the Knowledge Test*

When Figure 2 is examined, it is seen that the fit indices of the knowledge test consisting of 30 questions and 4 factors are significant (X^2=863.76, sd=399, p = .000, X^2/sd=2.16). Fitness index values were found to be as follows: RMSEA= .051, GFI= .93, AGFI= .89, CFI= .97, NNFI= .96, and IFI= .95. As CFA analysis shows that the model has a good fitness, no modification was made to the questions. Therefore, it can be argued that four factors revealed by the exploratory factor analysis (*Radioactivity, nuclear energy, working principle of a nuclear plant and effects on human health and nature*) were justified through the confirmatory factor analysis.

Within the context of the reliability of the test, the Kuder-Richardson 20 (KR-20) and two-tier reliability calculation method were employed (Table 5).

Table 5. *Internal Consistency Reliability Coefficients of the Knowledge Test*

Internal consistency (Reliability)	*Radioactivity* (1st Factor)	*Nuclear energy* (2nd factor)	*Working principle of a plant* (3rd Factor)	*Effects on human health and nature* (4th Factor)
KR-20	.92	.86	.81	.87
Two-tier reliability	.90	.85	.83	.87

KR-20 and two-tier reliability coefficients found for the knowledge test are .86 and .85, respectively. These values show that the knowledge test has a highly reliable construct (Ozdamar, 2002).

DISCUSSION and CONCLUSİONS

In the present study, a conceptual understanding test and knowledge test on nuclear issues, especially on nuclear energy and nuclear plants were developed for the pre-service science teachers. The conceptual understanding test evaluates basic concepts that can be used in socio-scientific discussions and interpretations about nuclear energy and nuclear plants by the pre-service science teachers. The knowledge test, on the other hand, includes questions to evaluate the knowledge about nuclear energy and nuclear plants possessed by the pre-service teachers.

In order to develop the conceptual understanding test, 15 questions were developed for the first draft of the test and then corrections were made on the questions based on expert opinions. Then the test was administered to pre-service science teachers, and based on the data obtained from this piloting, item analyses were conducted. In line with the obtained item discrimination and difficulty indices, questions having low indices were discarded from the test. Then, exploratory factor analysis was conducted to check the construct validity and factor structures of the test. According to the results of this analysis, a three-factor construct explained 46.358% of the total variance. Hence, the conceptual structure was subsumed under three headings: *Radioactivity*, *environmental impacts* and *nuclear reactions*. The factor structure of the conceptual understanding test was tested by confirmatory factor analysis. The fit indices obtained through the confirmatory factor analysis were found to be significant and the model showed a good fit. Within the framework of the reliability analyses of the conceptual understanding test, the Cronbach's alpha (α) coefficient was found to be .775 for the whole test.

The first draft of the knowledge test was developed to include 34 questions and after item analyses and expert opinions were considered, some questions were corrected or discarded from the test. Following this, exploratory factor analysis of the test was conducted and sub-factors were determined. Thus, it was found that the knowledge test has a four-factor structure explaining 56.985% of the total variance. The structure obtained by exploratory factor analysis was tested in terms of fitness through confirmatory factor analysis. As a result of the exploratory and confirmatory factor analyses, the test model including 30 questions that can be grouped under four factors was found to be statistically suitable. These sub-factors are *radioactivity, nuclear energy, working principle of a nuclear plant* and *effects on human health and nature*. The KR-20 and two-tier reliability coefficients calculated for the reliability of the knowledge test were found to be .86 and .85, respectively.

In conclusion, it can be argued that the conceptual understanding test and the knowledge test developed in the present study to ensure that pre-service science teachers' conceptual understanding and knowledge level about nuclear issues are sufficiently reliable and valid. Therefore, it is believed that these tests can be used to evaluate the conceptual understanding and knowledge level of pre-service science teachers about nuclear energy and nuclear plants and they can yield reliable and valid results. Moreover, based on data obtained from a pre-test, instruction can be planned to reduce or eliminate the misconceptions and knowledge deficiencies of students. Critical evaluation of any knowledge requires understanding and internalization of the related basic concepts. Therefore, a holistic measurement that covers a conceptual understanding test and a knowledge test could be helpful to completely understand what the pre-service science teachers know about nuclear issues.

REFERENCES

Abraham, M. R., Williamson, V. M. & Westbrook, S. L. (1994). A cross-age study of the understanding of five concepts. *Journal of Research in Science Teaching*, 31, 147-165.

Abraham, M. R., Gryzybowski, E. B., Renner, J. W. & Marek, A. E. (1992). Understanding and misunderstanding of eighth graders of five chemistry concepts found in textbooks. *Journal of Research in Science Teaching, 29*, 105-120.

Anastasi, A. & Urbina, S. (1997). *Psychological testing.* Prentice Hall.

Atila, B. (2004). Awareness of teachers in secondary education institutions on nuclear issues. Master's thesis, Gazi University, Institute of Educational Sciences, Ankara.

Balcı, A. (2009). *Sosyal Bilimlerde Araştırma Yöntem, Teknik ve İlkeler.* Pegem Akademi: Ankara.

Berberoglu, G. & Tosunoglu, C. (1995). Exploratory and confirmatory factor analysis of an environmental attitude scale (EAS) for Turkish university students. *Journal of Environmental Education, 30*, 40–44.

Buyukozturk, Ş. (2007). *Sosyal bilimler için veri analizi el kitabı.* Pegem Akademik Yayıncılık: Ankara.

Cepni, S. (2007). *Araştırma ve proje çalışmalarına giriş.* Trabzon.

Cohen, L. B. (1998). *Before it's too late.* Nural Matbaacılık: Ankara.

Cokluk, O., Sekercioglu, G. & Buyukozturk, S. (2010). *Sosyal bilimler için çok değişkenli istatistik: SPSS ve LISREL uygulamaları*. Pegem Yayınevi: Ankara.

Demirelli, H. (2003). Yapılandırıcı öğrenme teorisine dayalı laboratuvar aktivitesi: Elektrot Kalibrasyonu ve Gran Metodu. *G.Ü. Gazi Eğitim Fakültesi Dergisi, 23*(2), 161.

Driver, R. & Erickson, G. (1983). Theories-in-action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. *Studies in Science Education, 10*, 37-60.

Gultekin, M. (2002). Eğitim fakülteleri öğretmen yetiştirme programlarının yeniden düzenlenmesi kapsamında ilköğretime öğretmen yetiştirme. *Anadolu Üniversitesi Eğitim Fakültesi Dergisi*, *1*, 49-65.

Haidar, A. F. & Abraham, M. R. (1991). A comparison of applied and theoretical knowledge of concepts based on the particulate nature of matter. *Journal of Research in Science Teaching, 28*, 919-938.

Kabapınar, F. (2003). Kavram yanılgılarının ölçülmesinde kullanılabilecek bir ölçeğin bilgi-kavrama düzeyini ölçmeyi amaçlayan ölçekten farklılıkları. *Kuram ve Uygulamada Eğitim Yönetimi, 35,* 398-417.

Karagoz, C. (2007). Attitutes and interests of pre service chemistry teachers towards nuclear energy. Master's thesis, Gazi University, Institute of Educational Sciences, Ankara.

Kaya, I. S. (2012). Nükleer enerji dünyasında çevre ve insan. *Abant İzzet Baysal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 1*, 71-90.

Kılınç, A., Boyes, E. & Stanisstreet, M. (2013). Exploring students' ideas about risks and benefits of nuclear power using risk perception theories. *Journal of Science Education and Technology*, *22*, 252-266.

Kucukozer, H. (2004). *Yapılandırmacı öğrenme kuramına dayalı olarak geliştirilen öğretim modelinin lise I. sınıf öğrencilerinin basit elektrik devrelerine ilişkin kavramsal anlamalarına etkisi.* (Phd Thesis) Balıkesir University, Instıtute of Science, Balıkesir.

Larsen, K.S. (1993). Attitudes toward the transportation of nuclear waste: the development of a likert-type scale. *The Journal of Social Psychology*, *134*, 27-34.

Maharaj-Sharma, R. (2011). A comparative study of the impact of students' feelings regarding the use of nuclear energy. *Science Education International*, *22*, 18-30.

Martin, C. R. & Newell, R. J. (2004). Factor structure of the hospital anxiety and depression scale in individuals with facial disfigurement. *Psychology Health and Medicine*, *3*, 327-336.

Matsuura, T. & Iırı, Y. (2002). The importance of making right knowledge about radiation popular- activity of “radiation education forum”, *derived from* www.irpa.net/irpa10/cdrom/01306.pdf.

Miles, M. B. & Huberman, A. M. (1994). *Qualitative data analysis: An expanded source book*. Sage Publications.

Ozdamar, K. (2002). *Paket programlar ile istatistiksel veri analizi.* Kaan Yayınları: Eskişehir.

Ozdemir, N. & Cobanoglu, E. O. (2008). Türkiye’de nükleer santrallerin kurulması ve nükleer enerji kullanımı konusundaki öğretmen adaylarının tutumları. *Hacettepe Eğitim Fakültesi Dergisi, 34*, 218-232.

Ozguven, G. E. (1994). *Psikolojik Testler*. Psikolojik Danışma ve Rehberlik Merkezi Yayınları: Ankara.

Sencan, H. (2005). *Sosyal ve davranışsal ölçümlerde güvenirlik ve geçerlilik.* Seçkin Yayıncılık: Ankara.

Simpson, W. D. & Marek, E. A. (1988). Understanding and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. *Journal of Research in Science Teaching*, *25*, 361-374.

Simsek, O. F. (2009). *Yapısal eşitlik modellemesine giriş: Temel ilkeler ve LİSREL uygulamaları.* Ekinoks Yayıncılık: Ankara.

Stephanou, A. (1999). The measurement of conceptual understanding in physics. *The EARLI99*, Gothenburg, Sweden.

Taskın, O. (2004). Postmaterialism, new environmental paradigm and eco-centric approach: A qualitative and quantitative study of environmental attitudes of Turkey senior high school Students. (Unpublished Phd Thesis), Indiana University, Bloomington, IN, United States.

Tavsancıl, E. (2006). *Tutumların ölçülmesi ve spss ile veri analizi.* Nobel Yayınevi: Ankara.

Thompson, B. (2004). *Exploratory and confirmatory factor analysis: understanding concepts and applications.* American Psychological Association: Washington.

Unal Coban, G. *Modellemeye dayalı fen öğretiminin öğrencilerin kavramsal anlama düzeylerine, bilimsel süreç becerilerine, bilimsel bilgi ve varlık anlayışlarına etkisi: 7. sınıf ışık ünitesi örneği* (Phd Thesis). Dokuz Eylül University, Izmir.

Westbrook, S. L. & Marek, E.A. (1991). A cross-age study of student understanding of the concept of diffusion. *Journal of Research in Science Teaching, 28,* 649–660.

Westbrook, S. L. & Marek,E. A. (1992). A cross- age study of student understanding of the concept of homeostasis. *Journal of Research in Science Teaching, 29,* 51–61.

Yalcın, A. & Kılıc, Z. (2005). Öğrencilerin yanlış kavramaları ve ders kitaplarının yanlış kavramalara etkisi örnek konu: Radyoaktivite, *Gazi Üniversitesi Eğitim Fakültesi Dergisi*, *25*, 125-141.

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Türkiye'de Yapılan Bilgisayar Destekli Öğretimin Öğrenci Başarısına Etkisi ve Diğer Ülkelerle Karşılaştırılması: Bir Meta-Analiz Çalışması

Serkan DİNÇER[1]

[1] Arş. Gör., Çukurova Üniversitesi, Eğitim Fakültesi, Adana-TÜRKİYE

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ÖZET

Bu çalışma bir konu, tema ya da çalışma alanı hakkındaki benzer çalışmaların belirli ölçütler altında gruplanıp, bu çalışmalara ait nicel bulguların birleştirilerek yorumlanması olarak tanımlanan meta-analiz yöntemiyle, son 10 yılda yapılan ilgili çalışmaların sonuçlarını değerlendirerek, bilgisayar destekli öğretimin (BDÖ) öğrenci akademik başarısına nasıl bir etkisi olduğunu araştırmaktadır. Bu amaç doğrultusunda üç soruya yanıt aranmaktadır: Türkiye'de yapılan çalışmalarda BDÖ süregelen öğretime (SÖ) göre öğrenci akademik başarısını nasıl etkilemiştir? Akademik başarıyı artırmak için hangi BDÖ yöntemleri kullanılmıştır? Türkiye ve diğer ülkelerdeki BDÖ etkilerini inceleyen çalışmalar arasındaki benzerlikler ve farklılıklar nelerdir? Bu üç araştırma sorusunu cevaplamak için ERIC (2013), Google Scholar (2013) ve Ulakbim (2013) veri tabanlarında ilişkili makaleler taranmıştır. Çalışmanın analizinde Hedges ve Olkin's (1985) ve Thalheimer ve Cook's (2002) etki katsayısı hesaplama formülleri kullanılmıştır. Gerekli analizler sonucunda Türkiye'de yapılan çalışmalarda BDÖ'nün SÖ'ye göre oldukça başarı olduğu; ayrıca hesaplanan etki katsayılarının, diğer ülkelere göre oldukça yüksek olduğu sonucuna ulaşılmıştır.

Anahtar Kelimeler: BDÖ Değerlendirmesi; Bilgisayar Destekli Eğitim; Meta-Analiz.

GİRİŞ

Bilim ve teknolojideki hızlı gelişmeler yaşamın her alanını olduğu gibi eğitim sistemini de etkilemekte ve değiştirmektedir. Teknolojinin eğitimi etkilemesine yol açan en önemli araçlardan birisi şüphesiz ki bilgisayardır. Davranışçı yaklaşımın öncülerinden Skinner (1954) tarafından geliştirilen öğrenme makineleri, geliştirilerek hazırlanan bilgisayarlı eğitim ortamları, ilk olarak 1960'lı yıllarda kullanılmaya başlanmıştır (Morrell, 1992). Bu yıllardan sonra bilgisayarlar, öğretmenlerin öğretim stratejilerini ve öğrencilerin deneyimlerini artırması nedeniyle giderek vazgeçilmez bir araç olarak kabul edilmiştir (Owusu, Monney, Appiah, & Wilmot, 2010). Eğitimde bilgisayarların kullanımı birçok farklı tanımlamayla adlandırılmasına rağmen, genel olarak bilgisayarların eğitimde kullanılmaları, bilgisayar ile öğrenme ve bilgisayar destekli öğrenme olmak üzere iki ana başlıkta ele alınmaktadır (Bybee, Poewll, & Trowbridge, 2008).

Sorumlu Yazar e-mail: dincerserkan@cu.edu.tr

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Bilgisayar ile öğrenme, öğrencinin ev ödevi yazması, interneti kullanarak bilgiye ulaşması, çeşitli yazılımları kullanarak hesap yapması gibi bilgisayarın öğrenimde yardımcı bir araç olarak kullanılmasını içermektedir (Ornstein & Levine, 1993; Owusu et.al., 2010; Thomas, 2001). Buna karşın bilgisayar destekli öğrenme, bilgisayarın bir öğretici olarak doğrudan öğrenciye sunulması olarak tanımlanmaktadır (Ornstein & Levine, 1993; Soe, Koki, & Chang, 2000). Özel öğretici, uygulamayı gösterip alıştırmayı yaptırması ve simülasyonlarla olayı canlandırması özelliklerinden en az birini içeren bu yöntem, davranışçı yaklaşımdan uzaklaşılarak giderek yapılandırmacı yaklaşımın benimsenmesinde önemli bir rol almıştır (Dinçer, 2006). BDÖ'lerin yapılandırmacı yaklaşıma uygun hale gelmesindeki en büyük etkenin, simülasyon tekniği kullanılarak öğrenci ile etkileşimi arttırması olduğu kabul edilmektedir (Owusu et.al., 2010).

Öğretimde içeriğin sağlanması için bilgisayarların kullanılması olarak tanımlanan BDÖ'ler, ABD'de 50 yıldan daha fazladır kullanılmaktadır (Chalmers, 2000; Liao, 2007). ABD'deki kullanımının ardından BDÖ giderek önem kazanarak, gelişmiş ülkelerde başta olmak üzere tüm dünyada hızlıca yayılmaya başlamıştır. ABD'de 2005 yılına kadar okulların hemen hemen hepsine bilgisayar ve internet erişimi sağlanmasına rağmen (Wells & Lewis, 2006), ekonomik nedenlerden dolayı Afrika gibi üçüncü dünya ülkelerinde bilgisayar ve internet erişimi yok denecek kadar azdır (New Partnership for Africa's Development (NEPADs), 2001).Türkiye gibi gelişmekte olan ülkelerde ise bu erişim oranı giderek artmaktadır.

Türkiye'deki BDÖ çalışmalarının etkisini araştırmak için öncelikle Türk Eğitim Sistemi ile bilgisayar kullanımının ilişkisi incelenmelidir. İlk olarak 1967 yılında üniversitelerde öğretimine başlanılan bilgisayar dersleri (Keser, 1988), ortaöğretimde Bilgisayar Eğitimi İhtisas Komisyonu'nun önerileri doğrultusunda, 1985-1986 öğretim yılından itibaren orta öğretim programlarında seçmeli ders olarak verilmesi planlanmıştır (Keser & Teker, 2011); ancak bu uygulamaya 1987 yılında geçilebilmiştir. 1987 ile 1998 yılları arasında bilgisayar okuryazarlık seviyelerinin düşük olması, bilgisayar ve internet erişiminin maliyetli olması gibi nedenlerden dolayı bilgisayarlar, eğitimde verimli bir şekilde kullanılamamıştır. Kişisel bilgisayarın ve internet erişiminin yaygınlaşması ile 1998 yılından itibaren üniversitelerde bilgisayar destekli eğitimler verilmeye başlanmıştır.

Milli Eğitim Bakanlığı Talim ve Terbiye Kurulu tarafından öğretim programlarının geliştirilmesine yönelik çalışmalar kapsamında, 2008 yılından itibaren ilköğretim programlarında "Bilişim Teknolojileri" dersinin dördüncü ve sekizinci sınıflar arasında seçmeli ders olarak öğretim programlarında yer almasına karar verilmiştir. Türk Eğitim Sistemi'nde bilgisayar okuryazarlığının artırılması, BDÖ gelişimine öncülük etmiştir. İlk Türk eğitim yazılımları 1990'lı yıllarda piyasaya sürülmesine rağmen, özellikle 2008 yılından sonra birçok özel firma BDÖ yazılımları geliştirerek, bilgisayarların eğitim ortamlarında aktif olarak kullanılmasına olanak sağlamıştır. 2010 yılından itibaren bilgisayar derslerinin sadece yedinci ve sekizinci sınıfta seçmeli olarak verilme kararından sonra bilgisayar okuryazarlığı ve BDÖ yazılımlarını etkin bir biçimde kullanılamayacağı görüşü öne çıkmıştır. Bu görüş sonrasında bilgisayar okuryazarlığını temel alan derslerin tekrar programa zorunlu ders biçiminde dahil edilme kararı alınmış olsa da bu konu ile ilgili düzenleme2014 yılında yapılmıştır.

Son olarak 2010 yılında, "FATİH Projesi" olarak adlandırılan "Fırsatları Artırma ve Teknolojiyi İyileştirme Hareketi Projesi" kapsamında, Türkiye'deki tüm okulların bilgisayar destekli eğitime geçirilmesi hedeflenmiştir. Bu proje ile tüm sınıflar, akıllı sınıf olarak tasarlanarak, öğrencilere dağıtılan tablet bilgisayarlar ile derslerin desteklenmesine karar verilmiştir. Bu proje ile öğrencilerin, okul dışında eğitim yazılımlarına ulaşmalarını sağlayacak bir nesne havuzu oluşturulması planlanmıştır.

Türkiye'de ve Dünya'da BDÖ'lerin akademik başarıya, tutuma, motivasyona vb. değişkenlere etkilerini araştıran birçok çalışma bulunmaktadır. Bu çalışmaların büyük bir çoğunluğu (Ivers & Barron, 1998; Kausar, Choudhry, & Gujjar; 2008; Kulik & Bangert-Drowns, 1983; Tirosh, Tirosh, Graeber, & Wilson, 1990) BDÖ'lerin SÖ'ye göre daha başarılı olduğunu belirtmesine rağmen, BDÖ'ler ve SÖ'ler arasında sınırlı sayıda çalışmada (Danley & Baker, 1988; Ornstein & Levine, 1993) istatistiki açıdan anlamlı bir farka rastlanmamıştır ya da çok küçük bir etkiye-farka ulaşılmıştır (Bayraktar, 2001). BDÖ'lerin SÖ'ye göre etkisini araştıran birçok çalışmaya ek olarak literatürde SÖ ile BDÖ'nün aynı anda kullanıldığı çalışmalara da ulaşılmıştır. Birçok araştırmacı tarafından öğrenci başarısını en fazla artıran yöntemin, SÖ ile BDÖ ile birlikte kullanılması olarak belirtilmiştir (Akour, 2008; Basturk, 2005; Ornstein & Levine, 1993; Tabassum, 2004).

Bu çalışma deneysel çalışmaların sistematik bir gözden geçirilmesi olarak tanımlanan meta-analiz yöntemi ile son 10 yılda yapılan bilgisayar destekli öğretimin, öğrenmeye katkısını inceleyen çalışmaların, etkisini araştırmaktadır. Bu amaç doğrultusunda üç soruya yanıt aranmaktadır:

- ✓ Türkiye'de yapılan çalışmalarda bilgisayar destekli öğretim (BDÖ) süregelen öğretime (SÖ) göre öğrencilerin akademik başarısına nasıl bir etki göstermiştir?
- ✓ Akademik başarıyı artırmak için hangi BDÖ yöntemleri kullanılmıştır?
- ✓ Türkiye ve diğer ülkelerdeki BDÖ etkilerini inceleyen çalışmalar arasındaki benzerlikler ve farklılıklar nelerdir?

YÖNTEM

a) Çalışmanın Yöntemi

Çalışmanın yöntemi olarak görüş anketleri, ilişkisel çalışmalar, deneysel, yarı deneysel çalışmalar ve regresyon analizleri gibi birçok tipte araştırma bulgularını nicel tekniklerle yordayan, analizlerin analizi olarak adlandırılan meta-analiz yöntemi kullanılmıştır. Meta-analiz ile ilgili bir tanım Dinçer (2014) tarafından "bir konu, tema ya da çalışma alanı hakkındaki benzer çalışmaların belirli ölçütler altında gruplanıp, bu çalışmalara ait nicel bulguların birleştirilerek yorumlanması" şeklinde ifade edilmiştir.

Bu yöntem, daha önceden yapılan deneysel çalışma sonuçlarını ele alarak araştırmacılara nicel veriler sunmakta; tüm çalışmaların sonuçlarını birleştirerek genel bir sonuç ortaya çıkmasını sağlamaktadır. Bir alandaki birden çok çalışmanın sonuçlarının birleştirilerek incelenmesi, benzer sonuçlara ulaşan diğer çalışmaların geçerliliğini arttırabilmesi, meta-analiz çalışmalarının en önemli özelliği olarak ele alınabilmektedir (Abramson & Abramson, 2001; Sağlam & Yüksel, 2007). Bu ifadeye ek olarak meta-analiz çalışmaları, araştırmalarda elde edilen sonuçların tesadüfi olup olmadığı hakkında da araştırmacılara yön göstermektedir. Son olarak meta-analiz çalışmaları ile bir konu hakkında yapılan çalışmaların örneklem büyüklüğü arttırabilir; böylelikle çalışmanın istatistiksel anlamlılık düzeyi artarak sonuçlar hakkında daha net bir ifadeye ulaşmayı sağlayabilmektedir (Dinçer, 2014; Sağlam & Yüksel, 2007).

Birçok olumlu yanı olmasına rağmen, meta-analiz çalışmaları hakkında bazı araştırmacılar olumsuz görüş bildirmektedir. Bu olumsuz görüşlerin başında farklı yöntemlerin, işlemlerin ve değişkenlerin ya da farklı durumlarda toplanan verilerin bir araya getirilmesinin yanlış bir yaklaşım olarak görülmesidir (Eysenck, 1978; 1984; Sağlam & Yüksel, 2007).

Olumsuz yanları belirtilmesine rağmen meta-analiz çalışmaları, gerek literatür taraması gerekse de aynı alanda yapılan çalışmaların geçerliliğinin saptanması açısından oldukça önemlidir. Bu nedenle belirli zaman aralıklarında, belirlenen alanda meta-analiz çalışmaları yapılmasının yararlı olduğu düşünülmektedir. Genel çerçevede belirli bir kuralı olmamasına rağmen meta-analiz çalışmalarının basamakları: Amacın belirlenmesi; hipotez/araştırma sorusunun belirlenmesi; çalışmaya dahil edilecek ölçütlerin belirlenmesi; ilgili literatürün taranması; belirlenen çalışmaların kodlanması; verilerin analizi; yorum/raporlama; olarak kabul edilmektedir (Chambers, 2004; Dinçer, 2014; Hamer & Simpson; 2002).

b) Verilerin Toplaması

Araştırma sorularına cevap verebilmek için ilgili konu ile ilişkili makaleler, ulusal ve uluslararası alandaki tüm makalelere erişimi en iyi şekilde sağlayan üç veri tabanında taranmıştır: ERIC (2013), Google Scholar (2013) ve Ulakbim (2013). Belirtilen veri tabanları ilk olarak 15 Kasım 2012 tarihinde taranmış; 03 Ocak 2013 tarihinde tekrar taranarak gerekli kontroller yapılmıştır. Makaleler "BDÖ değerlendirmesi", "bilgisayar destekli öğretim/öğrenme" ve "bilgisayar tabanlı/temelli öğretim/öğrenme" anahtar kelimeleri kullanılarak taranmıştır. Bulunan çalışmalar son 10 yılda (2003-2012) ve hakemli dergilerde yayımlanma kriterine göre sınıflandırılarak analize dahil edilmiştir. Bu sınıflamaya göre sempozyum, kongre vb. bilimsel etkinliklerde sunulan bildirilere çalışmada yer verilmemiştir. Bulunan 108 adet makale içinden deneysel çalışmalara odaklanılarak özellikle ön-son test uygulanan ve gruplar arasında karşılaştırma yapılan makaleler, ilgili çalışma için seçilmiştir. Meta-analiz çalışmaları için gerekli olan değişkenlere (n, $\bar{x}$, t, F, ss, vb.) sahip olmayan çalışmalar elenmiştir. Sonuç olarak belirlenen seçim özelliklerine göre çalışmaya 26 makale dahil edilmiştir.

c) Verilerin Analizi

Çalışmanın istatistiği için etki büyüklüğü (EB) hesaplanmıştır. Bu etki büyüklükleri Thalheimer ve Cook (2002) tarafından önerilen Cohen's *d* ve Hedges ve Olkin (1985) tarafından önerilen Hedges' *g* hesaplamasına göre hesaplanmıştır. Çalışmaların etkisi sınıflandırılırken, ölçeğin geniş olması nedeniyle Thalheimer ve Cook (2002) tarafından aşağıda belirtilen düzey sınıflamasına yer verilirken, genel EB (etki büyüklüğü) ve homojenlik testi için Hedges' *g* kullanılmıştır.

- Etki büyüklüğü ≤ 0.15 önemsiz düzeyde
- 0.15 < Etki büyüklüğü ≤ 0.40 küçük düzeyde
- 0.40 < Etki büyüklüğü ≤ 0.75 orta düzeyde
- 0.75 < Etki büyüklüğü ≤ 1.10 geniş düzeyde
- 1.10 < Etki büyüklüğü ≤ 1.45 çok geniş düzeyde
- 1.45 < Etki büyüklüğü mükemmel düzeyde

Bir makalede etki büyüklükleri hesaplanmış olmasına rağmen, diğer makalelerle tutarlılık gösterilmesi için ayrıca Hedges' *g* katsayısı tekrar hesaplanmış, teknik farlılığından dolayı 0.02 ile 0.10 oranında değişim tespit edilmiştir. Ancak bu oranların küçük olmasından ve araştırmanın doğasını etkilemeyeceğinden, değişim dikkate alınmamıştır. Kullanılan hesaplama formülleri Tablo 1' de gösterilmiştir.

Tablo 1. *Etki Büyüklükleri Hesaplama Formülleri.*

Cohen's *d*	$d = \frac{\bar{x}_t - \bar{x}_c}{S_{pooled}}$ $d = t\sqrt{\left(\frac{n_t + n_c}{n_t n_c}\right)\left(\frac{n_t + n_c}{n_t + n_c - 2}\right)}$	$S_{pooled} = \sqrt{\frac{(n_t - 1)s_t^2 + (n_c - 1)s_c^2}{(n_t + n_c)}}$	s = standart sapma n = örneklem sayısı t = *t*-testi $\bar{x}$ = aritmetik ortalama t: deney grubu c: kontrol grubu
Hedges' *g*	$g = \frac{\bar{x}_t - \bar{x}_c}{S_{pooled}}$	$S_{pooled} = \sqrt{\frac{(n_t - 1)s_t^2 + (n_c - 1)s_c^2}{(n_t + n_c - 2)}}$	

BULGULAR ve YORUMLAR

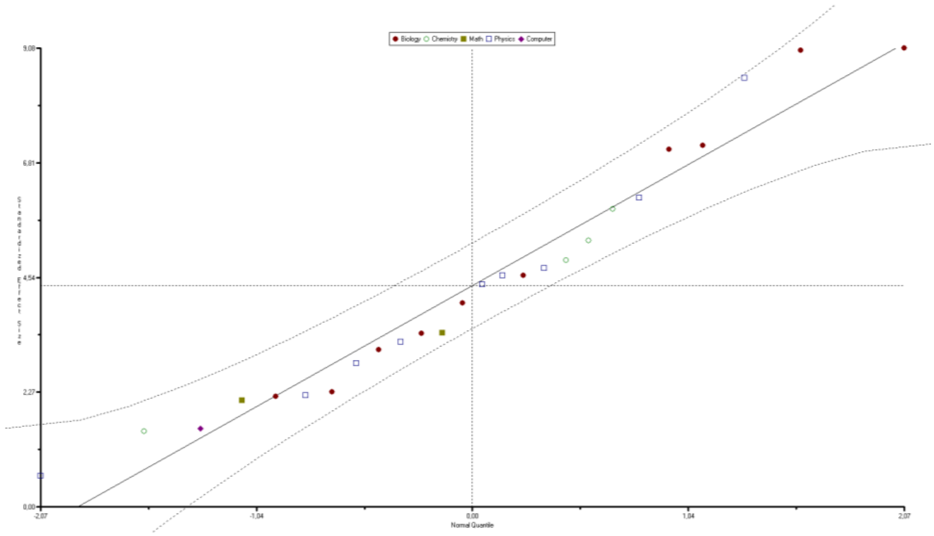
Türkiye'de BDÖ ile yapılan çalışmaların etkilerini incelemek için etki büyüklükleri (EB) hem Cohen's *d* hem de Hedges' *g* ile hesaplanmış, sonuçlar Tablo 2'de gösterilmiştir. Araştırmaya dâhil edilen 26 çalışmanın toplam katılımcı sayısı 1669 olarak hesaplanmıştır. Bu çalışmaların hepsinin etki büyüklüklerinin pozitif ve BDÖ gruplarının lehine bir sonuca ulaştığı tespit edilmiştir. Hesaplanan etki büyüklükleri 0.34 ile 2.66 (Hedges' *g*'sine göre) arasında olduğu tespit edilmiştir.

Tablo 1. *Meta-Analiz Çalışması Etki Katsayıları ve Çalışma Özetleri.*

Yazar (yayın yılı)	Disiplin	Kavramsal Konu	Teknik	n	Cohen's *d*	Hedges' *g*
Akçay vd. (2005)	Biyoloji	Bitkiler	1-2	50	0.69	0.66
Akçay vd. (2007)	Kimya	Radyoaktivite	1	100	1.16	1.14
Akgün (2005)	Kimya	Tepkimeler	1-2	37	0.52	0.5
Aktümen vd. (2003)	Matematik	4 işlem	1	24	0.98	0.9
Atam vd. (2010)	Fizik	Isı	3	72	0.71	0.69
Aykanat vd. (2005)	Biyoloji	Hücre	1	92	1.79	1.76
Baltacı vd. (2011)	Bilgisayar	Hesaplamalar	1-2	86	0.34	0.34
Bozkurt vd. (2008)	Fizik	Elektronik	3	85	2.48	2.43
Daşdemir vd. (2012)	Fizik	Hareket	3	37	1.96	1.86
Efe vd. (2006)	Biyoloji	Üreme	1	90	1.79	1.75
Güneş vd. (2010)	Biyoloji	Hücre	1-2	88	2.71	2.66
Güven vd. (2012)	Kimya	Madde	1	63	1.8	1.75
Hançer vd. (2009)	Fizik	Hareket	1	58	2.02	1.95
Kara vd. (2007)	Biyoloji	Hücre	1	48	1.55	1.49
Kiraz (2006)	Biyoloji	Hücre	2	46	1.01	0.97
Korkmaz vd. (2012)	Fizik	---	3	67	0.15	0.15
Morgil vd. (2004)	Kimya	İyon	1-3	84	1.29	1.26
Pektaş vd. (2009)	Fizik	Işık	3	78	1.14	1.11
Pektaş vd. (2006)	Biyoloji	Boşaltım Sistemi	1	42	0.72	0.69
Saka vd. (2005)	Fizik	Madde	1	44	1.57	1.5
Selçik vd. (2011)	Matematik	Geometri	1-3	32	1.43	1.35
Sünbül vd. (2002)	Fen	---	1	60	0.6	0.58
Şan (2010)	Fizik		3	61	0.9	0.88
Taşçı vd. (2008)	Biyoloji	Hücre	3	58	0.98	0.95
Yakışkan vd. (2009)	Biyoloji	Hücre	3	97	2.46	2.41
Yenice vd. (2003)	Biyoloji	Genetik	1	70	1.05	1.03

*** 1: Özel öğretici; 2: Gösterip yaptırma; 3: Simülasyon**

Meta-analitik yöntemler normalliği kabul etmektedir. Grafik 1' de gösterilen etki büyüklüklerinin x=y doğrusu boyunca ve güven aralıkları olması dağılımın normal olduğunu göstermektedir. Dağılımın normal olması, çalışma verilerinin toplam etki büyüklüğünün hesaplanmasında kullanılabileceğini göstermektedir (Rosenberg, Adams, & Gurevitch, 2000).



Grafik 1. *Etki büyüklüklerinin genel dağılımı.*

Elde edilen etki büyüklükleri sabit etkiler modeline göre % 95’lik güven aralığının 1.01 ile 1.23 sınırları arasında, genel etki büyüklüğü değerinin 1.11 olduğu belirlenmiştir. Bu sonuç Türkiye’de BDÖ yöntemi ile yapılan çalışmaların SÖ yöntemine göre akademik başarıyı arttırma açısından daha başarılı olduğunu ve etki büyüklüğü açısından çok geniş bir düzeyde etkisi olduğunu göstermektedir. Ancak çalışmaların *Q* istatistiğine bakılarak homojenliğinin sorgulanması, buna göre normal dağılım olduğunun kabul edilmesi ve sonuç olarak buna göre hangi etki modelinin kullanılması gerektiğine karar verilmesi gerekmektedir.

Homojenlik testi için *Q*= 146.084 bulunmuştur. χ^2 kritik değer aralığı tablosundan % 95 anlamlılık düzeyinde 25 serbestlik derecesi değeri için *Q*= 46.928 olması, etki büyüklüğü dağılımının heterojen olduğu göstermektedir. Bu nedenle çalışmada rastgele etkiler modeli kullanılarak genel etki tekrar hesaplanmış, genel etki büyüklüğü % 95’lik güven aralığının 1.10 ile 1.33 sınırları arasında, 1.21 olarak bulunmuştur.

Türkiye’de yapılan BDÖ çalışmaları konularına göre incelendiğinde, çalışmaların genel olarak fen eğitiminde yapıldığı görülmektedir. Bu çalışmalar alt bilim dallarında incelendiğinde en fazla çalışmanın biyoloji (% 38.46) ve fizik (% 30.77) alanında yapıldığı dikkati çekmektedir. Alanlarına göre BDÖ etkilerinin belirlenmesi için alanlar sınıflandırılarak etki katsayıları tekrar hesaplanmış, bu sınıflandırmaya göre etki büyükleri Grafik 2’de gösterilmiştir.

Grafik 2. *Çalışma alanlarına göre etki büyüklükleri ve güven aralıkları.*

Grafik 2'de de görüldüğü gibi çalışmaya dahil edilen 26 araştırmanın % 38.46'si biyoloji (n=10), % 30.77'si fizik (n=8), % 19.23'ü kimya (n=5), % 7.69'u matematik (n=2), % 3.85'i bilgisayar (n=1) alanında yapılmıştır. Alanlara göre genel etki büyüklükleri ve homojenlik testi için yapılan sonuçlar Tablo 3'de gösterilmiştir.

Tablo 3. *Alanlara Göre Etki Katsayısı ve Homojenlik Test Sonuçları.*

Alan	n	EB	Q	df	95% CI	χ^2 kritik değer aralığı
Biyoloji	10	1.48	54.465	9	1.275 - 1.674	23.589
Fizik	9	1.10	56.317	8	0.884 - 1.312	21.955
Kimya	4	1.20	7.964	3	0.771 - 1.619	12.838
Matematik	2	1.15	0.599	1	-2.531 - 4.823	7.879
Bilgisayar	1	Çalışma sayısı az olduğu için hesaplanamamıştır				

Alanlara göre tekrar hesaplanan etki katsayıları incelendiğinde biyoloji alanı ile ilgili BDÖ'nün diğer alanlardaki BDÖ'ye göre daha etkili olduğu sonucuna ulaşılmıştır. χ^2 kritik değer aralığı tablosundan % 95 anlamlılık düzeyinde çalışmalar incelendiğinde biyoloji, fizik alanında yapılan çalışmaların heterojen olduğu; kimya ve matematik alanlarında yapılan çalışmaların homojen olduğu tespit edilmiştir.

Türkiye'de BDÖ ile yapılan çalışmalarda kullanılan yöntemler incelendiğinde, genel olarak çalışmalarda özel öğretici kullanıldığı tespit edilmiştir. Bunun yanı sıra çalışmalarda simülasyonların kullanıldığı ve sadece bir çalışmada uygulamayı gösterme, alıştırmayı yaptırma yönteminin kullanıldığı belirlenmiştir. Çalışmaların hepsinde kontrol ve deney grubu ile deneysel çalışma yapıldığı; analizler için genel olarak *t*-testi ve ANOVA tekniklerinin kullanıldığı tespit edilmiştir. Özellikle çalışmaya dahil edilmeyen, elenen çalışmalarda istatistiki yöntem hataları yapıldığı dikkati çekmiştir. Bu hataların başında kontrol ve deney gruplarının ön-son test sonuçları gruplar arasında karşılaştırılmadığı, eşleştirilmiş *t*-testi ile grupların kendi içlerinde test edildiği belirlenmiştir.

TARTIŞMA VE SONUÇ

Gelişmiş ülkelerde uzunca bir süredir kullanılan BDÖ, Türkiye'de 1990'lı yılların ilk yarısında kullanılmaya başlamasına rağmen, aktif olarak ancak 2000'li yılların başında kullanılmaya başlanmıştır. 2010 yılından itibaren FATIH Projesi başlatılarak, tüm okullarda BDÖ ile eğitim verilmesi hedeflenmiştir.

Son 10 yıllık zaman diliminde Türkiye'de BDÖ ile yapılan çalışmaların etkisini araştıran bu çalışmanın sonucunda; incelenen çalışmaların büyük bir çoğunluğunun (n= 10; % 38.46) mükemmel düzeyde bir etki katsayısı olması ve genel etki büyüklüklerinin çok geniş bir düzeyde etki etmesi nedeniyle, Türkiye'de yapılan BDÖ'lerin SÖ'ye göre daha etkili olduğu sonucuna ulaşılmıştır. Diğer bir deyişle, Türkiye'de yapılan BDÖ'ler, SÖ'ye göre ortalama 1.21 standart sapma kadar daha başarılıdır. Bu sonuç Yeşilyurt (2011) tarafından yapılan çalışma ile örtüşmektedir. Hem bu çalışmanın hem de Liao (2007) tarafından yapılan çalışmaların sonuçları incelendiğinde öğretmenlere derslerinde sağlanan teknolojilerin, öğretime olumlu bir etkide bulunduğu görülmektedir. Bu sonucu destekleyici başka çalışmalar olmasına rağmen (de Jong & van Joolingen, 1998; de Jong, Martin, Zamarro, Esquembre, Swaak, & van Joolingen, 1999; Trey & Khan, 2008), Clark (1983) tarafından yapılan çalışmaların sonuçları ile örtüşmemektedir. Clark (1983), medyanın sadece öğrenme üzerinde tek başına etkisinin olmadığını, özellikle kullanılan yöntemin BDÖ'ler ile düzgün bir şekilde entegre edilerek yararlı olabileceğini belirtmektedir (Liao, 2007).

İncelenen çalışmaların hemen hepsinde BDÖ'nün öğrencilerin motivasyonlarını ve tutumlarını arttırdığı sonucu birçok çalışmayla desteklenmektedir. Ancak Smith (1968) tarafından belirtilen motivasyonların, tutumların çok kısa zaman aralığında oluşamayacağı ifadesinden yola çıkılarak BDÖ'lere karşı özellikle tutumun incelenmesinin aynı gruplarla zamana yayarak yapılması önem taşımaktadır. Öğrenenlere sunulan yeniliklerin (araç, yöntem, vb.) genel olarak dikkati çekmesi ve bu nedenle tutumda olumlu bir etki göstermesine rağmen, zamanla bu yeniliklerin sıradanlaşması motivasyonun ve tutumun azalma olasılığının bulunduğu unutulmamalıdır.

Çalışmaya dahil edilen araştırmalar alanlarına göre incelendiğinde, genel olarak çalışmaların fen bilgisi eğitiminde kullanıldığı dikkati çekmektedir. Etki büyüklükleri sıralamasında BDÖ'nün biyoloji eğitiminde en etkili olduğu görülmesine rağmen, fizik alanındaki çalışma etki büyüklüklerinin normale daha yakın olduğu dikkati çekmektedir. Biyoloji alanında yapılan çalışmaların etki büyüklerinin yüksek oluşu, kullanılan yöntemle ilişkili olduğu düşünülmektedir. Bu çalışmalardaki BDÖ yöntemleri sınıflandırıldığında, genel olarak simülasyonların kullanıldığı dikkati çekmektedir. Özellikle soyut kavramların öğretiminde başarılı sonuç veren simülasyon kullanımı (de Jong & van Joolingen, 1998; Trey & Khan, 2008), öğrencilerin canlandıramadıkları soyut kavramları, somutlaştırarak başarılarını artırdığı düşünülmektedir.

Türkiye'de yapılan BDÖ'lerin diğer ülkelerde yapılan BDÖ'ler ile karşılaştırmasını yapmak için ilgili literatür taranmış ancak sınırlı sayıda BDÖ ile ilgili meta-analiz çalışmasına ulaşılmıştır. Örneğin Bangert-Drowns, Kulik ve Kulik (1985), Kulik, Kulik, ve Bangert-Drowns (1985) ve Kulik, Kulik, ve Cohen (1980) tarafından ABD'de yapılan çalışmalarda BDÖ'lerin öğrencilerin akademik başarılarını SÖ'ye göre daha olumlu etkilediği sonucuna ulaşılmıştır. Buna ek olarak Liao (2007) tarafından Taiwan'da yapılan çalışmaların meta-analizinde BDÖ'lerin SÖ'ye göre daha etkili olduğu ve bu etkinin orta düzeyde olduğu belirtilmiştir. Bu çalışmalara ek olarak Rutten, van Jooloingen, ve van der Veen (2012) tarafından simülasyonların fen eğitimindeki etkisini inceleyen meta-analiz çalışmasının sonuçları da bu çalışmanın sonuçlarını desteklemektedir. Buna karşın Bayraktar (2001) tarafından genel bir tarama meta-analizinde, BDÖ'lerin küçük düzeyde bir etkisi olduğu sonucuna ulaşmıştır. Türkiye'de yapılan çalışmaların etki büyüklükleri incelendiğinde diğer ülkelerdeki çalışmalara göre oldukça yüksek çıkması dikkati çekmektedir. Örneğin Yeşilyurt (2011) tarafından fizik alanındaki BDÖ araştırmalarının meta-analizinde, 25 çalışmaya yer vermiş ve genel etki büyüklüğü 3.17 olarak bulmuştur. Türkiye'de yapılan bu iki çalışmanın diğer ülkelere göre yüksek bir etki katsayıya sahip olması ve homojen bir dağılım olmamasının nedeni, araştırmacı tarafından açıklanamamıştır. Ayrıca güven aralığı geniş olan bir çalışmanın güvenilirliğinin düşük olduğu gerçeğinden yola çıkarak, çalışmaların yayın yanlılığına maruz kalmış olabileceği sonucuna ulaşılmıştır (Borenstein, Hedges, Higgins, & Rothstein,2013).

Sonuç olarak bu çalışma sonucunda Türkiye'de yapılan BDÖ'lerin genel olarak fen eğitiminde yapıldığı, ve etkisinin SÖ'ye göre daha yüksek olduğu sonucuna ulaşılmıştır. Oldukça popüler olan bu konu hakkında Türkiye'de yeterli çalışmaya ulaşılamaması Dinçer (2014) ve Özdemirli-Çapar (2011) tarafından da belirtildiği gibi, ulusal alandaki çalışmalara yeterince ulaşılamaması olarak değerlendirilmiştir. Bu sınırlılığın nedenleri: Birçok derginin hiçbir indekste taranmaması, doküman halinde ulaşılabilmesine rağmen sayfa başlarında tanıtıcı yayın bilgisinin/künyesinin olmaması nedeniyle, makale-bildiri ayrımının yapılamaması olarak iki başlıkta sınıflandırılmıştır. Bu nedenle akademik dergilerin tanıtım yazılarını/künyelerini makale başlarına eklemeleri ve daha geniş ulusal bir veri tabanının hazırlanmasının yararlı olacağı düşünülmektedir. Bu konuda yapılan çalışmalarda etki katsayısı hesaplanmasında gerekli olan istatistikî verilerin ($\bar{x}$, n, SS, t, F, MSE vb.) eksik verilmesi, meta-analizi zorlaştırdığı için çalışmalarda eksiksiz olarak verilmesi; gelecek çalışmalar için ilgili konunun tezler boyutunda tekrar incelenmesi, özellikle kullanılan teknikler ile sınıflandırma yapılarak karşılaştırılması önerilmektedir.

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Effects of Computer-Assisted Learning on Students' Achievements in Turkey: A Meta-Analysis

Serkan DİNÇER[1]

[1] Research Asst., Çukurova University, Faculty of Education, Adana-TURKEY

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Key Words: Assessment of CAL; Computer-Assisted Learning; Meta-Analysis.

SYNOPSIS

INTRODUCTION

Rapid developments in science and technology has been influencing and changing education systems as well as many other areas. Undoubtedly, computer is one of the most influential tools for technology to affect education. The learning machines first developed by Skinner, one of the leading figures in behaviorism, were first put into use in classes in 1960's (Morell, 1992). Following this advent, computers has increasingly been utilized to maximize teachers' strategies and students' experiences and thus become an indispensable tool (Owusu, Monney, Appiah, & Wilmot, 2010). Although the use of computers in education has been called with various terms, on general terms, the use of computers in education is divided into learning with computers and learning through computers (Bybee, Poewll, & Trowbridge, 2008).

Learning with computers involves using computers as a tool to do homework, access information through internet, make calculations with the use of various software (Ornstein & Levine, 1993; Owusu et. al. 2010; Thomas, 2001). Despite learning through computers is defined, computers have been mis-conceptualized as a teacher for students (Ornstein & Levine, 1993; Soe, Koki, & Chang, 2000). In time, this method, using at least one of the following tutorials, drill & practice, simulations has significantly helped trends to grow away from behaviorist approach and gain a constructivist approach (Dinçer, 2006). The most crucial factor for learning through computers to take a constructivist approach is considered that this method has increased student interaction using simulation technique (Owusu et. al. 2010).

Learning through computers or computer-assisted learning (CAL), identified as use of computers to provide content, has been in use in USA for the last 50 years (Chalmers, 2000; Liao, 2007). Following the advent of educational use of computers in USA, CAL has first spread to the developed countries and then the rest of the world.

Corresponding Author e-mail: dincerserkan@cu.edu.tr © ISSN:1304-6020

According to Wells & Lewis (2006), By 2005, nearly all schools in USA had access to computers and internet connection while in third-world countries such as the ones in Africa, computers and internet connection were almost non-existent (New Partnership for Africa's Development (NEPADs), 2001). On the other hand, the accesses to both in developing countries such as Turkey have been gradually increasing. In order to investigate the effects of CAL, the relationship between Turkish Education System and computer use has to be analyzed. Started first in 1967 in universities, computer courses (Keser, 1988), were planned to be a selective course in secondary schools starting from 1985-1986 school year by recommendations of the Commission of Computer Education Expertise (Keser & Teker, 2011); however, it was put into practice in 1987. Between 1987 and 1998, computers were not used effectively in education due to such problems as the low computer literacy levels, the high costs of computer and internet access. After 1998 with the spread of personal computers and internet access, computer assisted education started to be provided in universities.

Within the scope of studies to develop education programs by Turkish Education Board in Ministry of Education, it was decided to offer "Information Technologies" selective course to students between 4^{th} to 8^{th} grade starting from 2008. The increase in computer literacy in Turkish Education System has significantly helped CAL flourish. Although first Turkish educational software was released in 1990's, especially after 2008 many private companies have developed CAL software and have made it possible for computers to be utilized in classrooms. It was speculated that the amendment that computer courses would be given to 7th and 8th graders as a selective course starting from 2010, would prevent computer literacy and CAL software to be effectively used, a study to investigate the possible outcomes of this change worked in 2014.

Lastly, in 2010 it was aimed to exclusively equip all public schools with CAL environment within the scope of FATIH Project (standing for "Improving Opportunities and Developing Technologies Movement). With this project, classrooms will be designed as smart classes and lessons will be followed using the tablet computers distributed to students. With this project, an object pooling is designed for the students to access educational software out of school.

PURPOSE of the RESEARCH

In Turkey and in the world, various studies have been implemented on the effects of CAL on such variables as academic success, attitude, motivation, and so on. Although most of these studies (Ivers & Barron, 1998; Kausar, Choudhry, & Gujjar; 2008; Kulik & Bangert-Drowns, 1983; Tirosh, Tirosh, Graeber, & Wilson, 1990) indicate that CAL is more fruitful than traditional learning (TL) method, a limited number of studies (Danley & Baker, 1988; Ornstein & Levine, 1993), did not indicate a significant difference between these two. In addition to many studies on the effects of CAL in relation to TL, studies which include both approaches to be used at the same time can be found in the literature. The best method to increase student success was seen to be a combination of both CAL and TL (Akour, 2008; Basturk, 2005; Ornstein & Levine, 1993; Tabassum, 2004).

This study takes a meta-analysis approach to systematically review experimental studies of the past decade on the learning effects of computer-assisted learning. The focus is on three questions:

- ✓ What is the effect of computer-assisted learning (CAL) versus traditional learning (TL) on students' achievements in Turkey?
- ✓ Which CAL's methods are used in order to enhance learning processes?

- ✓ What are the differences and similarities of CAL's effects between Turkey and other countries?

METHODOLOGY

The method of the study include opinion surveys, correlational studies, experimental, semi-experimental studies and regression analysis and the results were analyzed with meta-analysis method, which predicts results with quantitative techniques, and is called as the analysis of analyses. This method reaches results by first considering the results of the previously conducted experimental studies and provides researchers with quantitative data and thus draws a general conclusion by combining the results of all studies. Examining the results of all the studies in a field, improving the validity of other studies with similar results are some of the crucial features of meta-analysis (Abramson & Abramson, 2001; Sağlam & Yüksel, 2007). In addition, meta-analysis studies provide researchers with confirmations whether the results they gather are accidental or not. Lastly, Meta-analysis studies provide a clearer picture for results of studies by increasing the statistical significance level of a study (Dinçer, 2014; Sağlam & Yüksel, 2007).

Despite many of its benefits, some researchers have negative opinions of meta-analysis. A common counter-view is that data that was gathered with different methods, calculations and variables or in different situations is not suitable (Eysenck, 1978; Eysenck, 1984; Sağlam & Yüksel, 2007).

Although negative sides have been pointed out, meta-analysis studies is of great importance for both literature review and pinpointing validity of studies carried out in the same field. This is the reason it is considered that meta-analysis studies are expected to be useful for certain time intervals and in certain fields. In general terms, there is not a rule; however, the steps of meta-analysis are as follows: identifying the purposes, identifying the hypothesis/research questions, identifying the criteria in the study, identifying the time intervals of the investigations, reviewing the related literature, coding the selected studies, analyzing the data, discussion/reporting (Chambers, 2004; Hamer & Simpson; 2002).

a) Data Collection Tools and Analysis

Related articles are searched within four databases in order to answer research questions: ERIC (2013), Google Scholar (2013), Ulakbim (2013). The very first date of search the mentioned databases is November 15, 2012; it is re-searched in January 03, 2013 for necessary controls. The articles are searched through using the keywords: "assessment of CAL", "computer-aided learning/teaching", and "computer-assisted learning/teaching". The found articles are categorized with the criteria of being published in last ten years (2003-2012) and in referred journal.

According to this categorization, the proceedings which were presented in symposiums, congress, and scientific activities, and etc. are not included in this study. Within one-hundred and eight found articles, it is focused on experimental studies, and specifically the studies adapting pre-posttest design and making comparison between/among groups are selected for this study. The studies that do not embody the variables necessary for meta-analysis (n, $\bar{x}$, t, F,ss, etc.) are excluded. As a result, according the selection criteria, 26 articles are included in this study.

Effect size (Es) for statistical analysis of the study is calculated. These Ess, Cohen's *d* proposed by Thalheimer and Cook (2002) and Hedges' *g* proposed by Hedges and Olkin's (1985) calculations, are calculated for 26 articles.

Thalheimer and Cook's (2002) classification mentioned above is used due to its scale being large while limiting the effect of studies, and Hedges' *g* is used for mean Es and homogeneity test.

- Effect size ≤ 0.15 — negligible effect
- 0.15 < Effect size ≤ 0.40 — small effect
- 0.40 < Effect size ≤ 0.75 — medium effect
- 0.75 < Effect size ≤ 1.10 — large effect
- 1.10 < Effect size ≤ 1.45 — very large effect
- 1.45 < Effect size — huge effect

Although the Es is calculated in one paper, Hedges' *g* Es of it is re-calculated for being consistent with other papers, and change between 0.02 and 0.10 is detected because of technical differences. However, this change is not noticed due to its being too small and not affecting the nature of the study. The used calculation formulas are seen in Table 1.

Table 1. *Using Formulas for Calculating Effect Size.*

Cohen's *d*	$d = \frac{\bar{x}_t - \bar{x}_c}{s_{pooled}}$ $d = t\sqrt{\left(\frac{n_t + n_c}{n_t n_c}\right)\left(\frac{n_t + n_c}{n_t + n_c - 2}\right)}$	$s_{pooled} = \sqrt{\frac{(n_t - 1)s_t^2 + (n_c - 1)s_c^2}{(n_t + n_c)}}$	s = standard deviation n = number of subjects t = t statistic $\bar{x}$= mean t refers to the treatment group c refers to the control condition.
Hedges' *g*	$g = \frac{\bar{x}_t - \bar{x}_c}{s_{pooled}}$	$s_{pooled} = \sqrt{\frac{(n_t - 1)s_t^2 + (n_c - 1)s_c^2}{(n_t + n_c - 2)}}$	

FINDINGS

Ess are calculated with both Cohen's *d* and Hedges' *g* in order to investigate the effect of studies done with CAL in Turkey, and the results are shown in Table 2. The total participants of twenty-six papers, which are included in this study, are computed as 1669. It is found out that all articles' Ess are positive and they result in CAL groups' favor. The calculated Ess of these studies is between 0.34 and 2.66 (according to Hedges' *g*), and their general Ess are computed as 1.11

Meta-analytical methods accept normality. The effect size's being along x=y axis and confidence intervals presented in Figure 1 show that the distribution is normal. Normal distribution enables to use these studies' data for calculating total effect size (Rosenberg, Adams, & Gurevitch, 2000).

Q= 146.084 is found for homogeneity test. It is concluded that the effect size distribution is heterogenic since freedom of degree value is *Q*= 46.928 at 95% significance level in critical values of $\chi 2$. According to random effect models, the obtained effect size is between 1.10 and 1.33 limits of 95% confidence interval; average effect size is found as 1.21. This result shows that computer assisted learning is more successful in terms of increasing academic success as compared to general learning, and it shows that it has a large effect in terms of an effect size.

When CAL studies are illustrated according to their scopes, it is seen that most studies are conducted within science education. When these studies are looked more closely for sub-branches, it is noticed that most of the studies are conducted in biology (38.46%) and physics (30.77%). Effect sizes are re-calculated by classifying fields in order to determine the effect of CAL according to fields, and the effect size is shown in Figure 2 according to this classification.

Table 2. *Effect Size and Summary of Studies.*

Author(s) (Year)	Field	Topic	Technique	n	Cohen's *d*	Hedges' *g*
Akçay et al. (2005)	Biology	Plants	1, 2	50	0.69	0.66
Akçay et al. (2007)	Chemistry	Radioactivity	1	100	1.16	1.14
Akgün (2005)	Chemistry	Reactions	1, 2	37	0.52	0.5
Aktümen et al. (2003)	Mathematics	Operations	1	24	0.98	0.9
Atam et al. (2010)	Physics	Thermo	3	72	0.71	0.69
Aykanat et al. (2005)	Biology	Cell	1	92	1.79	1.76
Baltacı et al. (2011)	Computer	Calculate	1, 2	86	0.34	0.34
Bozkurt et al. (2008)	Physics	Electronics	3	85	2.48	2.43
Daşdemir et al. (2012)	Physics	Motion	3	37	1.96	1.86
Efe et al. (2006)	Biology	Breeding	1	90	1.79	1.75
Güneş et al. (2010)	Biology	Cell	1, 2	88	2.71	2.66
Güven et al. (2012)	Chemistry	Material	1	63	1.8	1.75
Hançer et al. (2009)	Physics	Motion	1	58	2.02	1.95
Kara et al. (2007)	Biology	Cell	1	48	1.55	1.49
Kiraz (2006)	Biology	Cell	2	46	1.01	0.97
Korkmaz et al. (2012)	Physics	---	3	67	0.15	0.15
Morgil et al. (2004)	Chemistry	Ion	1,3	84	1.29	1.26
Pektaş et al. (2009)	Physics	Light	3	78	1.14	1.11
Pektaş et al. (2006)	Biology	Urinary apparatus	1	42	0.72	0.69
Saka et al. (2005)	Physics	Material	1	44	1.57	1.5
Selçik et al. (2011)	Mathematics	Geometry	1, 2	32	1.43	1.35
Sünbül et al. (2002)	Science	---	1	60	0.6	0.58
Şan. (2003)	Physics	Motion	3	61	0.9	0.88
Taşçı et al. (2008)	Biology	Cell	3	58	0.98	0.95
Yakışkan et al. (2009)	Biology	Cell	3	97	2.46	2.41
Yenice et al. (2003)	Biology	Genetic	1	70	1.05	1.03

*** 1: Tutorial; 2: Drill and practice; 3: Simulation**

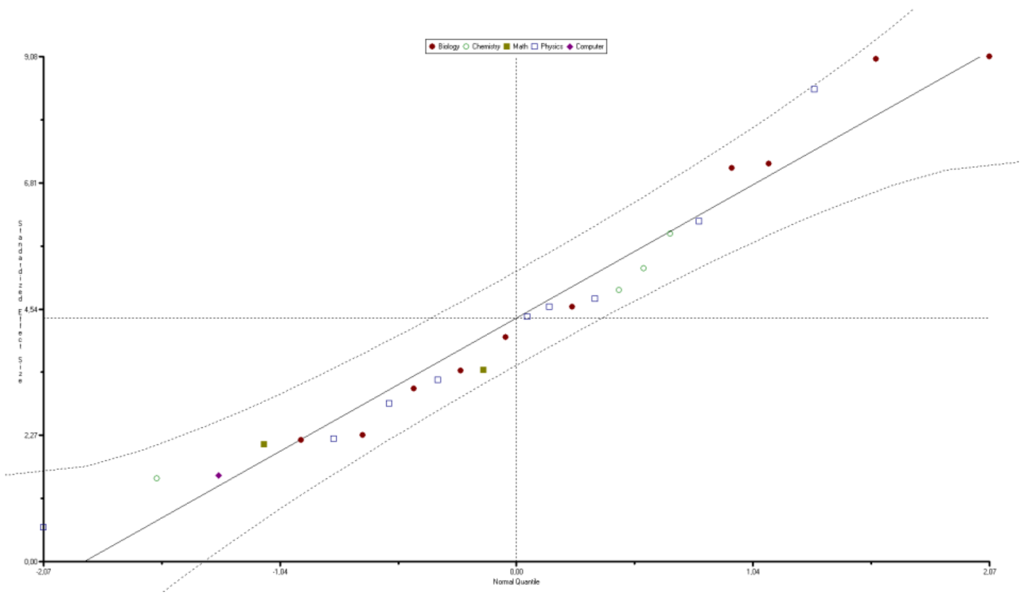

Figure 1. *Effect sizes' normal distribution.*

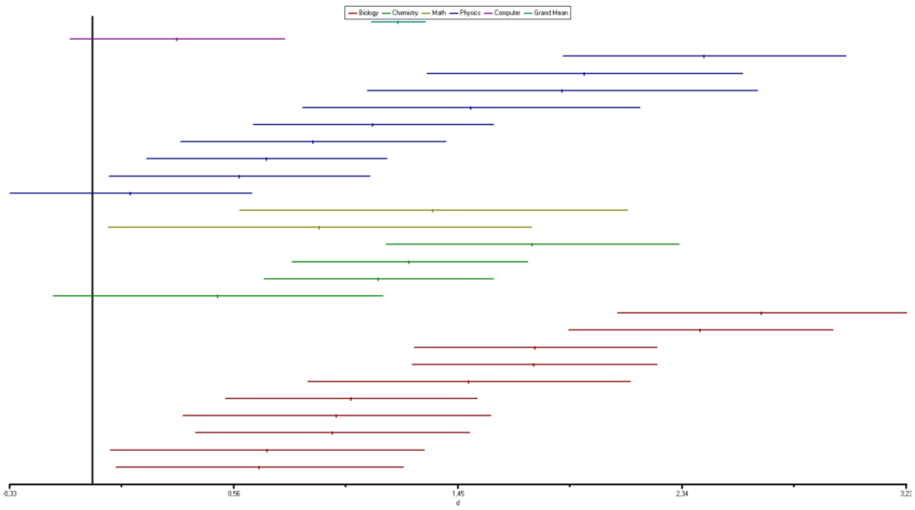

Figure 2. *Effect sizes and confidence intervals for field .*

As seen in Figure 2, 38.46 % of 26 studies included in the study are conducted within the field of biology (n=10), 30.77 % of them are conducted in physics (n=8), 19.23% of them are conducted in chemistry (n=5), 7.69 % of them are conducted in mathematics (n=2), and 3.85% of them are conducted in computer (n=1). Average Ess and the results of homogeneity test according to fields are shown in Table 3.

Table 3. *Results of The Effect Size and The Homogeneity Test According to Fields Of Study*

Field	n	Es	Q	df	95% CI	critical values of χ^2
Biology	10	1.48	54.465	9	1.275 to 1.674	23.589
Physics	9	1.10	56.317	8	0.884 to 1.312	21.955
Chemistry	4	1.20	7.964	3	0.771 to 1.619	12.838
Mathematics	2	1.15	0.599	1	-2.531 to 4.823	7.879
Computer	1	not calculate for little sample				

When the re-calculated Ess according to fields is investigated, it is concluded that studies conducted within CAL is effective in the field of biology. When the studies in critical values of χ^2 table at 95% significance level are examined, the studies done in biology and physics are heterogenic, however, the studies conducted in the field of chemistry and mathematics are homogenous.

When the methods used in CAL studies in Turkey are searched, it is detected that tutorial is generally used in the studies. Moreover, simulation method and drill and practice in one study are noticed as used methods.

It is found out that all studies are based on control and experimental group and they are experimental studies; *t*-test and ANOVA are the statistical analysis used generally. Specifically, it is noticed that the studies excluded from this study has methodological problems. Mainly among these methodological problems it is determined the results of pre - posttests of control and experimental study groups are not compared among groups, it is only used dependent-samples *t*-test within groups.

DISCUSSION and CONCLUSION

Even though CAL, which has been used in developed countries for a long time, was started to be used in Turkey in the beginning of 1990s, it could only be started to be used actively in the beginning of the 2000s. 2010 onwards, instruction with CAL in every school was aimed with the FATIH Project.

As a result of this research which investigates the effect of studies conducted with CAL in Turkey in the last decade, compared to TL, the result that CAL is more effective (n= 10; % 38.46) was reached due to the fact that most of the researches have an ideal effect parameters and the average of Ess make a large influence. In other words, CALs made in Turkey are more successful than TL by 1.21 in standard deviation. This result is in parallel with the study of Yesilyurt (2011). When the results of this study and the ones of Liao's (2007) are analyzed, technologies offered to teachers has a positive effect on the teaching. Although there are other supportive studies in addition to this (de Jong & van Joolingen, 1998; de Jong, Martin, Zamarro, Esquembre, Swaak, & van Joolingen, 1999; Trey & Khan, 2008), it is in parallel with the results of Clark's (1983) study. He offers the it is not media only that affects learning, but also the method used can be useful by integrating with CALs (Liao, 2007).In almost all of the researches which are studied, it is supported that CAL increases the motivation and the attitudes of the students. However, based on the idea offered by Smith (1986) that motivations and attitudes cannot be generated in a short time, it is significant that the study of attitude should be done with the same groups in a long period. Advances offered to the learners attract the students and make a positive effect on the attitudes, yet the prospect of decrease in motivation and attitude can be led to by these advances become old-fashioned in time

When the researches included in the study are examined by their ranges, they are mostly placed in science lessons. In the average of effect co-efficiency CAL is considered as the most effective, Ess of the studies in physics field is more closer to normal. Being high of the average Ess of studies carried out in the field of biology is thought to be relevant to the method used. When the CAL methods used in this research are classified, that simulations are generally used attract attention. Especially, the successful use of simulations in teaching absract concepts (de Jong & van Joolingen, 1998; Trey & Khan, 2008) is thought to increase the success of the students by materializing the abstract concepts.

The relevant literature was studied in order to compare the CAL studies carried out in Turkey with the CAL studiesin other countries, yet limited number of meta-analysis researches about CAL were reached. For instance, in the studies carried out in the USA by Bangert-Drowns, Kulik and Kulik (1985), Kulik and Bangert-Drowns (1985) and Kulik, Kulik and Cohen (1980), CAL has a more positive on the academic success of the students when compared to the TL. In addition, meta-analyses of the researches carried out in Taiwan by Liao (2007) it is found that CAL are more effective than the TL and this effect is medium. In addition to these studies, the results of meta-analyses researches by Rutten, van Jooloingen and van der Veen (2012) which deal with the effect of simulations in teaching science support the results of this research. However the Ess in the studies carried out in Turkey outnumbers the ones conducted in other countries is striking. For example, in the meta-analysis of the studies of CAL in Turkey by Yeşilyurt (2011), 25 studies took place and the average Es is found as 3.17. These two studies' having a high Es and the reason for the not homogeneous distribution weren't able to be explained by the researcher.

As a result of this study, the CALs done in Turkey are mostly in science field and its effect is greater than the TL. The reason why adequate number of researches could not be reached about this issue which is highly popular is due to the fact that studies cannot be reached in the national grounds noted by Özdemirli-Çapar (2011). The reasons for this limitation are: few journals can be searched in indices and that they can be reached as in the form of document, there is no such information as identification of publications such as article-memo distinction, so they are classified in two different categories. For this reason, academic journals should add identification tag to the top note and a larger national database must be prepared. As the lack of statistical data ($\bar{x}$, n, SS, t, F, MSE, etc.) needed in Es' calculation in the researchers conducted make the meta-analyses more difficult, they must be given as full; the relevant subject area must be studied in terms of theses for further studies and they must be compared via classification by making use of techniques specially used.

KAYNAKLAR/REFERENCES

Abramson, J. H. & Abramson, Z. H. (2001). *Making sense of data. A self instruction manual on the interpretation of epidemiological data.* New York: Oxford University Press.

Akçay, S., Aydoğdu, M., Yıldırım, H. I., & Şensoy, Ö. (2005). Fen öğretiminde ilköğretim 6. Sınıflarda çiçekli bitkiler konusunun öğretiminde bilgisayar destekli öğretimin öğrenci başarısına etkisi. *Gazi Üniversitesi Kastamonu Eğitim Dergisi, 13*(1), 103- 116.

Akçay, H., Tüysüz, C., Feyzioğlu, B., & Uçar, V. (2007). Bilgisayar destekli kimya öğretiminin öğrenci başarısı ve tutumuna etkisine bir örnek: "Radyoaktivite". *Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Dergisi, 22*, 98-106.

Akgün, Ö.E. (2005). Bilgisayar destekli ve fen bilgisi laboratuvarında yapılan gösterim deneylerinin öğrencilerin fen bilgisi başarısı ve tutumları üzerindeki etkisi. *Yüzüncü Yıl Üniversitesi Elektronik Eğitim Fakültesi Dergisi, 2*(2), 1-18.

Akour, A. (2008). The effects of computer-assisted instruction on Jordanian college students' achievements in an introductory computer science course. *Electronic Journal for the Integration of Technology in Education, 5*, 16–23.

Aktümen, M. & Kaçar, A. (2003). İlköğretim 8. sınıflarda harfli ifadelerle işlemlerin öğretiminde bilgisayar destekli öğretimin rolü ve bilgisayar destekli öğretim üzerine öğrenci görüşlerinin değerlendirilmesi. *Kastamonu Eğitim Dergisi,11*(2), 339-358.

Atam, O., &Tekdal, M. (2010). Fen ve teknoloji dersi ısı-sıcaklık konusunda hazırlanan simülasyon tabanlı bir yazılımın ilköğretim 5.sınıf öğrencilerin akademik başarılarına ve kalıcılığa etkisi. *Eğitim ve Teknolojileri Araştırma Dergisi, 1*(2), 1-18.

Aykanat, F., Doğru, M., & Kalender, S. (2005). Bilgisayar destekli kavram haritaları yöntemiyle fen öğretiminin öğrenci başarısına etkisi. *Kastamonu Eğitim Dergisi,13*(2), 391-400.

Baltacı, M. & Akpınar, B. (2011). Web tabanlı öğretimin öğrencilerin akademik başarısına etkisi. *Fırat Üniversitesi Sosyal Bilimler Dergisi, 21*(1), 77-88.

Bangert-Drowns, R., Kulik, J., & Kulik, C.-L. (1985). Effectiveness of computer-based education in secondary schools. *Journal of Computer-Based Instruction, 12*(3), 59–68.

Basturk, R. (2005). The effectiveness of computer-assisted instruction in teaching introductory statistics. *Educational Technology and Society*, *8*(2), 170–178.

Bayraktar, Ş. (2001) A meta-analysis of the effectiveness of computer-assisted instruction in science education. *Journal of Research on Technology in Education*, *34*(2), 173-188

Borenstein, M., Hedges, L. V., Higgins, J.P., & Rothstein, H. R. (2013). *Meta-analize giriş*, (Trans. S. Dinçer). Ankara: Anı Yayıncılık.

Bozkurt, E. & Sarıkoç, A. (2008). Fizik eğitiminde sanal laboratuvar, geleneksel laboratuvarın yerini tutabilir mi?. *Selçuk Üniversitesi Ahmet Keleşoğlu Eğitim Fakültesi Dergisi*, *25*, 89 -100.

Bybee, R. W., Poewll, J. C., & Trowbridge, L. W. (2008). *Teaching secondary school: Strategies for developing scientific literacy*. USA: Pearson Prentice Hall.

Chalmers. P. A. (2000). User interface improvements in computer-assisted instruction the challenge. *Computers in Human Behavior. 16*(5). 507–517.

Chambers, E. (2004). An introduction to meta-analysis with articles from The Journal of Educational Research (1992–2002). *The Journal of Educational Research. 98*(1), 35–44.

Clark, R. E. (1983). Reconsidering research on learning from media. *Review of Educational Research, 53*(4), 445–459.

Danley, W. E. & Baker, C. (1988). Comparing a pre-service mainstreaming class taught by traditional methods with a similar class taught by computer assisted instruction. *Computers in the Schools, 5*(12), 151–255.

Daşdemir, İ. & Doymuş, K. (2012). 8. Sınıf kuvvet ve hareket ünitesinde animasyon kullanımının öğrencilerin akademik başarılarına, öğrenilen bilgilerin kalıcılığına ve bilimsel süreç becerilerine etkisi. *Eğitim ve Öğretim Araştırmaları Dergisi, 1*(1), 77-87.

de Jong, T. & van Joolingen, W. R. (1998) Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research, 68*(2), 179–202.

de Jong, T., Martin, E., Zamarro, J.-M., Esquembre, F., Swaak, J., & van Joolingen, W. (1999). The integration of computer simulation and learning support: An example from the physics domain of collisions. *Journal of Research in Science Teaching, 36*(5), 597–615.

Dinçer, S. (2014). *Eğitim bilimlerinde uygulamalı meta-analiz.* Ankara: Pegem Akademi.

Dinçer. S. (2006). *Bilgisayar destekli eğitim ve uzaktan eğitime genel bir bakış. Proceedings of Akademik Bilişim 2006,(*pp 65-76). Denizli: Pamukkale Üniversitesi.

Efe, N., & Bakır, S. (2006). İlköğretim 8. sınıfta üreme konusunun bilgisayar destekli öğretiminin öğrenci başarısına etkisi. *Kazım Karabekir Eğitim Fakültesi Dergisi, 13*, 271-284.

ERIC. (2013). *Education Resources Information Center*. Retrieved January 03, 2013 from http://eric.ed.gov/

Eysenck, H.J. (1978). An exercise in mega-silliness. *American psychologist, 33*(5), 517–517.

Eysenck, H.J. (1984). Meta-analysis: an abuse of research integration. *The journal of special education, 18* (1), 41–59.

Google Scholar. (2013). *Google Akademik*. Retrieved January 03, 2013 http://scholar.google.com.tr/

Güneş, M. H. & Çelikler, D. (2010) .The investigation of effects of modelling and computer assisted ınstruction on academic achievement. *The International Journal of Educational Researchers. 1*(1), 20-27.

Güven, G. & Sülün, Y. (2012). Bilgisayar destekli öğretimin 8.sınıf fen ve teknoloji dersindeki akademik başarıya ve öğrencilerin derse karşı tutumlarına etkisi. *Türk Fen Eğitimi Dergisi, 9*(1), 68-79.

Hamer, R. M. & Simpson, P. M. (2002). *SAS tools for meta-analysis.* SAS SUGI Proceedings: Statistics, Data Analysis and Data Mining.

Hançer, A.H. & Yalçın, N. (2009). Fen eğitiminde yapılandırmacı yaklaşıma dayalı bilgisayar destekli öğretimin akademik başarı ve kalıcılığa etkisi. *Cumhuriyet Üniversitesi Sosyal Bilimler Dergisi, 33*(1), 75-88.

Hedges, L. & Olkin, I. (1985). *Statistical methods for meta-analysis.* Orlando, Fla: Academic Press.

Ivers, K. S. & Barron, A. E. (1998). Using paired learning conditions with computer-based instruction to teach preservice teachers about telecommunications. *Journal of Technology and Teacher Education, 6*(2–3), 183–191.

Kara, Y. & Yeşilyurt, S. (2007). Hücre bölünmeleri konusunda bir ders yazılımının öğrencilerin başarısına, kavram yanılgılarına ve biyolojiye karşı tutumlarına etkisi üzerine bir araştırma. *Çukurova Üniversitesi Eğitim Fakültesi Dergisi, 3*(34), 41-49.

Kausar, T., Choudhry, B. N., & Gujjar, A. A. (2008). A comparative study to evaluate the effectiveness of computer assisted instruction (CAI) versus classroom lecture (CRL) for computer science at ICS level. *The Turkish Online Journal of Educational Technology, 7*(4), 11–21.

Keser, H. (1988). *Bilgisayar destekli öğretim için bir model önerisi.* Unpublished doctoral dissertation, Ankara Üniversitesi Sosyal Bilimler Enstitüsü, Ankara.

Keser, H. & Teker, N. (2011). Türkiye'de bilgisayar eğitiminde 1960-1988 yılları arasındaki gelişmelerin incelenmesi. *İlköğretim Online, 10*(3), 1010-1027.

Kiraz, N. (2006). İköğretim fen bilgisi öğretiminde BDÖ yazılımlarının öğrenci başarısına etkisi. *Eğitim Dergisi, 10*(2), 25-46.

Korkmaz, A. & Yıldız, A. (2012). Ortaöğretim okullarında cinsiyet farklılıklarının, fizik dersinde interaktif ve klasik eğitiminde başarısının karşılaştırılması. *International Journal of New Trends in Arts, Sports & Science Education, 1*(3), 44-50.

Kulik, J. A. & Bangert-Drowns, R. L. (1983). Effectiveness of technology in precollege mathematics and science teaching. *Journal of Educational Technology Research, 12*(2), 137–158.

Kulik, J., Kulik, C.-L., & Bangert-Drowns, R. L. (1985). Effectiveness of computer-based education in elementary pupils. *Computers in Human Behavior, 1*(1), 59–74.

Kulik, J., Kulik, C.-L., & Cohen, P. (1980). Effectiveness of computer-based college teaching: a meta-analysis of findings. *Review of Educational Research, 50*(4), 525–544.

Liao, Y.C. (2007). Effects of computer-assisted instruction on students’achievement in Taiwan: A meta-analysis. *Computers & Education, 48*(2), 216-233.

Morgil, İ., Erökten, S., Yavuz, S., & Oskay, Ö. (2004). Computerized applications on complexation in chemıcal education. *The Turkish Online Journal of Educational Technology, 3*(4), 3-8.

Morrell. P. D. (1992). The effects of computer-assisted instruction and students. Achievement in high school biology. *School Science and Mathematics, 92*(4), 177–181.

New Partnership for Africa’s Development. (2001). *New partnership for Africa’s development.* South Africa: Pretoria.

Ornstein, A. C. & Levine, D. U. (1993). *Foundations of educations* (5th ed.). Boston: Houghton Mifflin Co.

Owusu, K. A., Monney, K. A., Appiah, J. Y., & Wilmot, E. M. (2010). Effects of computer-assisted instruction on performance of senior high school biology students in Ghana. *Computer & Education, 55*(2), 904-910.

Özdemirli-Çapar, G. (2011). *İşbirlikli öğrenme yönteminin öğrencinin matematik başarısı ve matematiğe ilişkin tutumu üzerindeki etkililiği: Bir meta-analiz çalışması.* Unpublished master thesis, Çukurova Üniversitesi, Adana.

Pektaş, H. M., Çelik, H., Katrancı, M., & Köse, S. (2009). 5. sınıflarda ses ve ışık ünitesinin öğretiminde bilgisayar destekli öğretimin öğrenci başarısına etkisi. *Kastamonu Eğitim Dergisi, 17*(2), 649-658.

Pektaş, M., Türkmen, L., & Solak, K. (2006). Bilgisayar destekli öğretimin fen bilgisi öğretmen adaylarının sindirim sistemi ve boşaltım sistemi konularını öğrenmeleri üzerine etkisi. *Kastamonu Eğitim Dergisi, 14*(2), 465-472.

Rosenberg, M.S., Adams, D.C. & Gurevitch, J. (2000). *MetaWin.* Sunderland, MA: Sinauer Associates.

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers and Education, 58*(1), 136–153.

Sağlam, M. & Yüksel, İ. (2007). Program değerlendirmede meta-analiz ve meta-değerlendirme yöntemleri. *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi, 18,* 175-188.

Saka, A.Z. & Yılmaz, M. (2005). Bilgisayar destekli fizik öğretiminde çalışma yapraklarına dayalı materyal geliştirme ve uygulama. *Turkish Online Journal of Educational Technology, 4*(3), 120-131.

Soe, K., Koki, S., & Chang, J. (2000). *Effects of computer-assisted instruction (CAI) on reading achievement: a metaanalysis*. Honolulu, HI: Pacific Resources for Education and Learning (ERIC Document Reproduction Service No. ED 443 079).

Selçik, N. & Bilgici, G. (2011). Geogebra yazılımının öğrenci başarısına etkisi. *Kastamonu Eğitim Dergisi, 19*(3), 913-924.

Skinner, B. F. (1954). The science of learning and the art of teaching. *Harvard Educational Review,24*, 56-97.

Smith, M. B. (1968) A map for the analysis of personality and politics. *Journal of Social Issues, 24*(3), 15–28.

Sünbül, A.M., Gündüz, Ş., & Yılmaz, Y. (2002). The effect of 'computer assisted instruction' prepared according to 'Gagne's instruction theory' on students' achievement. *Selçuk University Journal of Education, 14,* 379-404.

Şan, A. (2010). Bilgisayar destekli fizik eğitiminin akademik başarıya etkisi. *IJTA, 2*(3), 64-70.

Tabassum, R. (2004). *Effect of computer assisted instruction (CAI) on the secondary school student achievement in science*. Unpublished doctoral dissertation, University of Arid Agriculture, Rawalpinda, Pakistan.

Taşçı, G. & Soran, H. (2008). Hücre bölünmesi konusunda çoklu ortam uygulamalarının kavrama ve uygulama düzeyinde öğrenme başarısına etkisi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 34*, 233-243.

Thalheimer, W. & Cook, S. (2002). *How to calculate effect sizes from published research articles: A simplified methodology*. Retrieved November 25, 2012 from http://work-learning.com/effect_sizes.htm

Thomas, G. P. (2001). Toward effective computer use in high school science education: where to from here? *Education and Information Technologies, 6*(1), 29–30.

Tirosh, D., Tirosh, C., Graeber, A., & Wilson, J. (1990). Computer-based intervention to correct preservice teachers' misconceptions about the operators of division. *Journal of Computers in Math and Science Teaching, 10*(2), 71–78.

Trey, L. & Khan, S. (2008). How science students can learn about unobservable phenomena using computer-based analogies. *Computers & Education, 51* (2), 519-529.

Ulakbim. (2013). *Ulakbim Sosyal ve Beşeri Bilimler Veri Tabanı*. Retrieved January 03, 2013 from http://uvt.ulakbim.gov.tr/sbvt/

Wells. J. & Lewis. L. (2006). *Internet access in U.S. public schools and classrooms: 1994–2005 (NCES 2007–2007).* U.S. department of Education. Washington. DC: National Centre for Education Statistics.

Yakışan, M., Yel, M., & Mutlu, M. (2009). Biyoloji öğretiminde bilgisayar animasyonlarının kullanılmasının öğrenci başarısı üzerine etkisi. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi, 10*(2), 129-139.

Yenice, N., Sümer, Ş., Oktaylar, H. C., & Erbil, E. (2003). Fen bilgisi derslerinde bilgisayar destekli öğretimin ders hedeflerine ulaşma düzeyine etkisi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 24,* 152-158.

Yeşilyurt, M. (2011). Meta-analysis of the computer assisted studies in physics: A sample of Turkey. *Energy Education Science and Technology Part B: Social and Educational Studies, 3*(2), 173-182.