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Understanding Pre-service Elementary School Teachers' Mental Models about Seasonal Change

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ABSTRACT

The objectives of this study are to develop an abductive procedure that students construct their alternative models, and help teacher to construct their scientific models from initial model to them about seasonal change. The data collected from the paper-pencil test and individual interview with students. For this study, 30 pre-service elementary school teachers(1st grade) were participated. The results of this study show that the students had apparent alternative conceptions, and that the 'distance theory' had most important effects on their alternative conceptions. In order to find the origin of structure of their alternative conceptions about seasonal change, we reconstructed the forming process of their alternative concepts according to the inference patterns of abduction. The revision types of main hypothesis as a their alternative models is done through their early age perceptions of typical celestial bodies rather than the acquired specific knowledge, and have the expansion, contraction, and revision of main theory. Implications for pre-service teachers' science education and related research were discussed. For teachers to successfully guide elementary school students in scientific activities, teachers must possess both the appropriate scientific knowledge and the necessary abductive inference skills.

Keywords: Alternative Models; Seasonal Change; Distance Theory; The Inference of Abduction; Pre-Service Teachers' Science Education.

INTRODUCTION

Scientific theories explain regularities in nature by describing their causes. Scientific laws are statements about the relations between observable phenomena, whereas a theory explains the properties of a phenomenon that cannot be observed. When a generalization hypothesis or an explanatory hypothesis is proven, it becomes a law or a theory, respectively. Facts and laws are discovered in nature, whereas concepts and theories are constructed in the abstract. Current scientific theories are, in fact, just explanatory hypotheses (McComas, 2000). Therefore, the key to scientific advancement may lie in developing explanatory hypotheses.

Peirce (1839-1914) was one of the first to claim that abduction is a process that eventually yields explanatory hypotheses (Eames, 1977). He stated that "all of the well-established scientific theories of today are due to abduction" (*PC 5, 172*). In addition,

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researchers who study the hypothesis formation process have claimed that this process is guided by abduction (Magnani, 2001; Walton, 2004) rather than taking place within the inductive or the hypothetico-deductive system (Lawson, 1995)

Normally, the generation of a preliminary explanatory hypothesis is the third stage of abduction. However, scientists and philosophers recognize that it is difficult to accept a hypothesis unless it is evaluated against competing hypotheses based on all available evidence. Philosophers have referred to this stage as "Inference to the best explanation" and consider it as the fourth stage in the process of abduction (Harman, 1973; Thagard, 1988). During the problem-solving process, abductive reasoning can play an important role in scientific discoveries and creative reasoning (Magnani, 2001).

In the field of astronomy, students have reported constructing a few limited mental models. Understanding these explanatory mental models can provide important information about the students' knowledge structure, based on questions' responses (Vosniadou, 1994). In other words, if we do not understand students' mental models, we cannot know the basis from which the students will form theoretical models in the future.

Therefore, the main objective of this study is to explore the types of models developed by pre-service elementary school teachers who are not scientists when they were asked to form their own models about seasonal changes and to develop hypotheses about how they develop. To accomplish this objective, the abduction process was followed in stages to explore the types of alternative conceptions of seasonal changes among pre-service elementary teachers.

Through many surveys (Atwood & Atwood, 1996; Oh & Kim, 2005; Trumper, 2006), many people, especially Pre-service elementary teachers believe that the seasons are the result of the changing distance between the Earth and the Sun.

Mental Models and Concepts

Learning theories that science educators have interest in since 1980c can be divided into concept-learning and problem-solving (Eylon & Linn 1988). They are classified into studies on the contents and structures of knowledge areas of beginners and experts during conceptual changes and studies on kinds of knowledge acquired in process of problem solving. The former is called to be a "Conceptual Change Model" and the latter is called "Model Building Problem Solving."

In the research of Conceptual Changes, the unit of learning is concepts, and learning science is defined as changes in the concepts of learners about the nature world. In a conflict situation of concepts, according to status of concepts, conceptual changes occur or existing concepts are maintained. Learners acquire concepts through inquiries with existing conceptions, or form knowledge as conceptual exchange about anomalies (Hewson 1981, Posner, et al., 1982).

In the tradition of Model Building Problem Solving, abilities to solve problems can show that learning was immediately conducted (Stewart & Van Kirk 1990). In this tradition, Learner is compared to a scientist who solves given-problems in a class environment compared to a science laboratory (Peterson & Jungck 1988).

The Conceptual Change Model and Model Building Problem Solving deal with concepts and a mental model as units of learning respectively. Concept and the mental model have something in common in that they play functional roles as means and objects of thinking at the same time. Also, the mental model has private characteristics and is different from a received model prescribed in the society of scientists.

According to Hewson and Hewson (1988), they said that science is shown as a sequent course of conceptual changes. Posner at al (1982) propose that science suggests problems and what things should be decided based on using of paradigms.

These views of science were originated form Kuhn and Lakatos. Accumulations of anomalies are linked with changes of paradigms and progression or degeneration of research programs. In the tradition of Conceptual Change Model, paradigm and core of research program become the foundations for epistemic belief of learners which realize inner consistency and generalization.

On the other hand, in the tradition of Model Building Problem-Solving, science is regarded as activities of problem solving. Science exists as a procedure for theories to be formulated. The tradition of Model Building Problem Solving considers the mental model as conceptual knowledge. As concepts, the mental model is a mental construct on some aspects of the environments (objects) of learners.

The mental model is causal as a unit of problem-solving and can be defined functionally in the meaning that solvers for problem explain, and predict them. In science classrooms or textbooks, the most important approved models among models made by scientists in the past are proposed. Therefore, learners apply to existing concepts and form harmonized models. These may not be profitable to the aims suggested by teachers. The individual and diverse types of model by learners are called the mental model.

Concepts and the mental model have similarity in structural and functional aspects. But, in this research, we use the mental model from accepting the suggestion of Vosniadou (1994) that students infer causally about problem solving with theories and premises of their own, in the process of problems solving, though they are imperfect circumstantially and contextually, especially in the process of knowledge development for astronomical phenomena. And dynamic, physical models are abundant in Earth & Space Science education, at all levels from elementary through college (Kastens & Rivet, 2010).

Abduction and an Inquiry Process

Peirce called this a "reasoning abduction." Charniak and McDermott (1985) characterized abduction as a form of looking back to infer the cause of something and to generate explanations for things we see around us and infer the best explanation. In these views, abduction is inference in which the observed evidence is presented first and the related hypothesis is presented later, as shown in the following general format (Hanson, 1972, p. 86):

The surprising, C. is observed;
But if H [an explanatory hypothesis] were true, C would be a matter of course,
Hence, there is reason to suspect that H is true.

"Abduction can be understood as a mode of inference that seeks explanations for anomalous or surprising phenomena. Here, A might be a general theory (or, using the earlier terminology, it might include both a rule and a case). The conclusion is not A in and of itself but is rather the assertion that there is reason to suspect A is true" (Niiniluoto 1999, p. 439).

Peirce stated the following:

(1) Every inquiry whatsoever takes its rise in the observation…of some surprising phenomenon… (CP, 6.469).

(2) The inquiry begins by pondering these phenomena in all their aspects, in the search for some point of view whence the wonder may be resolved. At length, a conjecture arises that furnishes a possible explanation, by which I mean a syllogism exhibiting the surprising fact as necessarily consequent upon the circumstance of its occurrence together with the truth of the credible conjecture, as Premises (CP, 6.469). "The very phrase '**as a matter of course**' indicates a degree of intuitiveness, a point underscored by the fact that an explanatory conditional conveys a connection of necessity or high probability" (8.231, 7.36). (Kapitan,

1992)
(3) Based on this explanation, the inquirer is led to regard his conjecture, or hypothesis, with favor. As I phrase it, he provisionally holds it to be "plausible" (CP, 6.469).

Thus, we propose that premise one (1) in [PA] corresponds to the "**surprising observations.**" Premise two (2) in [PA] corresponds to the "**conjecture and invention of hypotheses**" and the conclusion (3) in [PA] corresponds to the "**selection of hypotheses**."(Oh, 2012; Oh, 2013)

1**. Generation of Hypotheses Phase:** According to Peirce, we study science for the purpose of understanding reality, and the first phase of reasoning that needs to be performed for this purpose is abduction. In turn, abduction is classified as the observation of unusual phenomena and the speculation about what was observed. Observation of an unusual phenomenon makes us seek a hypothesis to explain that phenomenon. Following Hanson's suggestions, the reasoning process was specifically adjusted as follows. Although Hanson himself did not develop these ideas in this exact manner, these points can be viewed as strategic principles (Paavola, 2004).

Oh (2012, 2013)'s suggestions was referred to individually as "**Surprising Observation (1)", "Conjecture and Invention of Hypothesis (2)**", and "**Selection of the Hypothesis (3)**."

"Surprising Observation" refers to a rather unexpected phenomenon. In other words, it refers to a phenomenon that cannot readily be explained by ordinary experience or existing knowledge because it is a phenomenon that does not normally occur. When new knowledge is required to solve a difficult problem, beginning with unusual or little facts and attempting to discover a solution or hypothesis is a good strategy (Niinluoto, 1996b).

"Conjecture and Invention of Hypothesis" refers to developing hypotheses in our minds. At first, we begin our conjecture from inconclusive and varying data, but eventually, we can make reliable inferences from well-organized evidence. The transition from poorly understood data collected by a person making an inference to rich and well-documented evidence based on well-developed theories is continuous. These endpoints differ only in degree, not in logical pattern. Initially, of course, good evidence is lacking (Hanson, 1965).

"Selection of Hypothesis" refers to expressing and adhering to preferences for one hypothesis out of several possible hypotheses. An abduction is completed with the selection of a hypothesis. The reasoning process involves analogical reasoning and eliminative induction (Laudan, 1987).

A characteristic of the abduction process is that the initial process of developing explanatorily useful hypotheses and the subsequent choice of one hypothesis takes place during the process of critically evaluating the best explanation (Josephson & Josephson, 1996). Therefore, this study considers not only the hypothesis-generation phase but also the process of evaluating the selected hypothesis as follows.

Testing of Hypotheses Phase

Preliminary testing of Hypotheses: When considering a new, inconsistent event as part of the preliminary evaluation of a hypothesis, it may be necessary to determine the explanatory consistency of the hypothesis. Let us resume the kinds of change considered in the original **belief revision framework** (see Figure 1) (Magnani, 2001, p.31-32). The ***expansion*** of a set of beliefs ***K*** taken from some underlying language (considered to be the closure of some finite set of premise ***KB***. The addition happens "regardless" of whether the larger set is *consistent*.

The case of ***revision*** happens when the new ***A*** is inconsistent with ***K*** and we want to maintained consistency: some beliefs in ***K*** must be withdrawn before A can be accommodated

(Gärdenfors, 1988). Hence, *inconsistent resolution* in belief revision framework is captured by the concept of revision.

Another way of belief change is the process of ***contraction***. When a belief set ***K*** is contracted by ***A***, the resulting belief set K + A is such that A is no longer held, without adding any new fact. Aliseda (2000) makes use of the belief revision framework to construct a theory of the epistemic transmission between the states of doubt and belief revision dynamics in data bases and abduction.

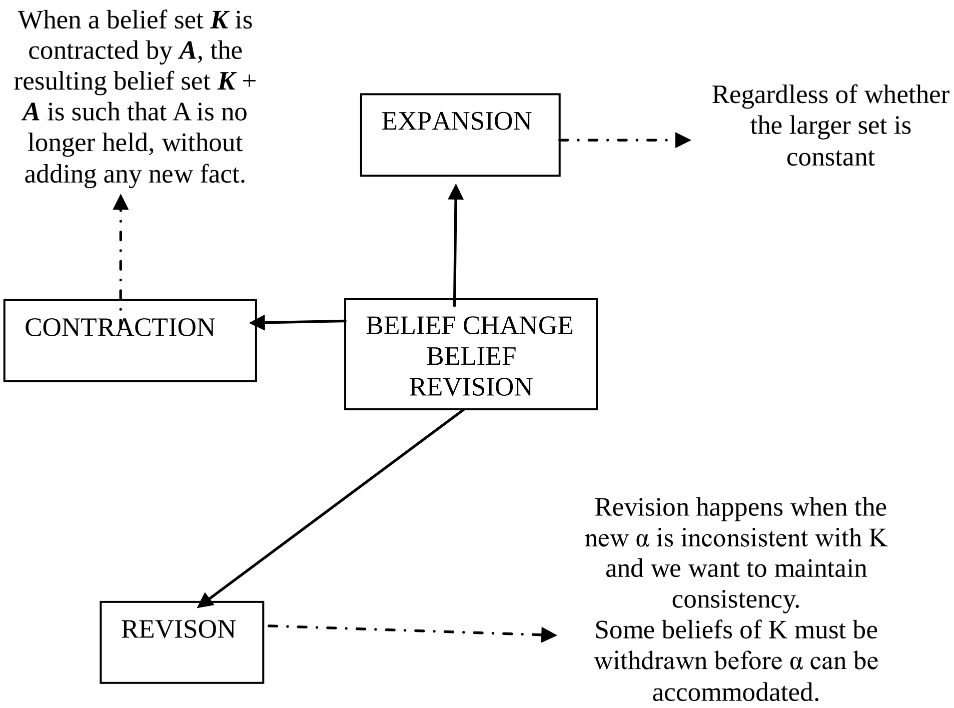


Figure 1. *Belief Change (Aliseda, 2000)*

In this study, to understand the development of students’ theories, it is necessary to examine the changes in the patterns of the students’ **existing main concepts (K)** when an **inconsistent event (A)** is presented. This approach assumes that such changes are analogous to the changes in scientific theories in response to anomalies for the generation and development of scientific theories that emphasize existing background knowledge (see Figure1).

Explanatory Coherence/Consistency: The degree of explanatory coherence, or the explanatory power, of a model must be relatively high (Thagard, 1992).This standard was used to evaluate the structures and types of the students’ explanatory model sand their explanatory consistency.

First, many students have a theoretical basis (an underlying rationale) for their explanation. The students’ explanations differ from the scientific viewpoints, but from the perspectives of the students themselves, they appear consistent. In our study, we refer to the students’ explanations as the **main theory (K)** (Watson et al., 1997).

Second, the degree of explanatory coherence is said to be high as the number of primary theories among the students’ explanations is low, as is the number of auxiliary (ad-hoc) hypotheses (number of ad hoc) based on one primary theory. The number of auxiliary hypotheses related to the main theory is found during the process of forming a scientific theory. Strictly speaking, the one of the auxiliary hypotheses are ad-hoc hypotheses, which have the sole purpose of avoiding refutation. For the main theories, when an anomaly is presented, the initial theory is considered to be on hold temporarily, even if it is modified, and the initial and modified theories are provisionally considered to coexist.

This process of establishing and evaluating the hypothesis can be summarized as follows. Surprising observations, conjecture and invention of hypotheses and the selection of hypotheses together constitute abduction. Preliminary testing of a hypothesis involves "inference to the best explanation", and abduction ends when the individual is mentally satisfied. However, the hypothesis test provides a more accurate evaluation in the form of a "hypothetico-deductive" process.

"**Hypothetico-Deductive Method**": The hypothetico-deductive method, HD, is a process that starts with established hypotheses and initial conditions and proceeds to form testable statements. In summary, plausible hypotheses are generated through abduction, and generated hypotheses are tested through HD. Preliminary hypothesis testing is the first stage. After the predictions are deduced from the hypothesis, an experiment is performed to obtain evidence to support the hypothesis. The inquiry begins with observation and ends with experiments. (See Figure 2)

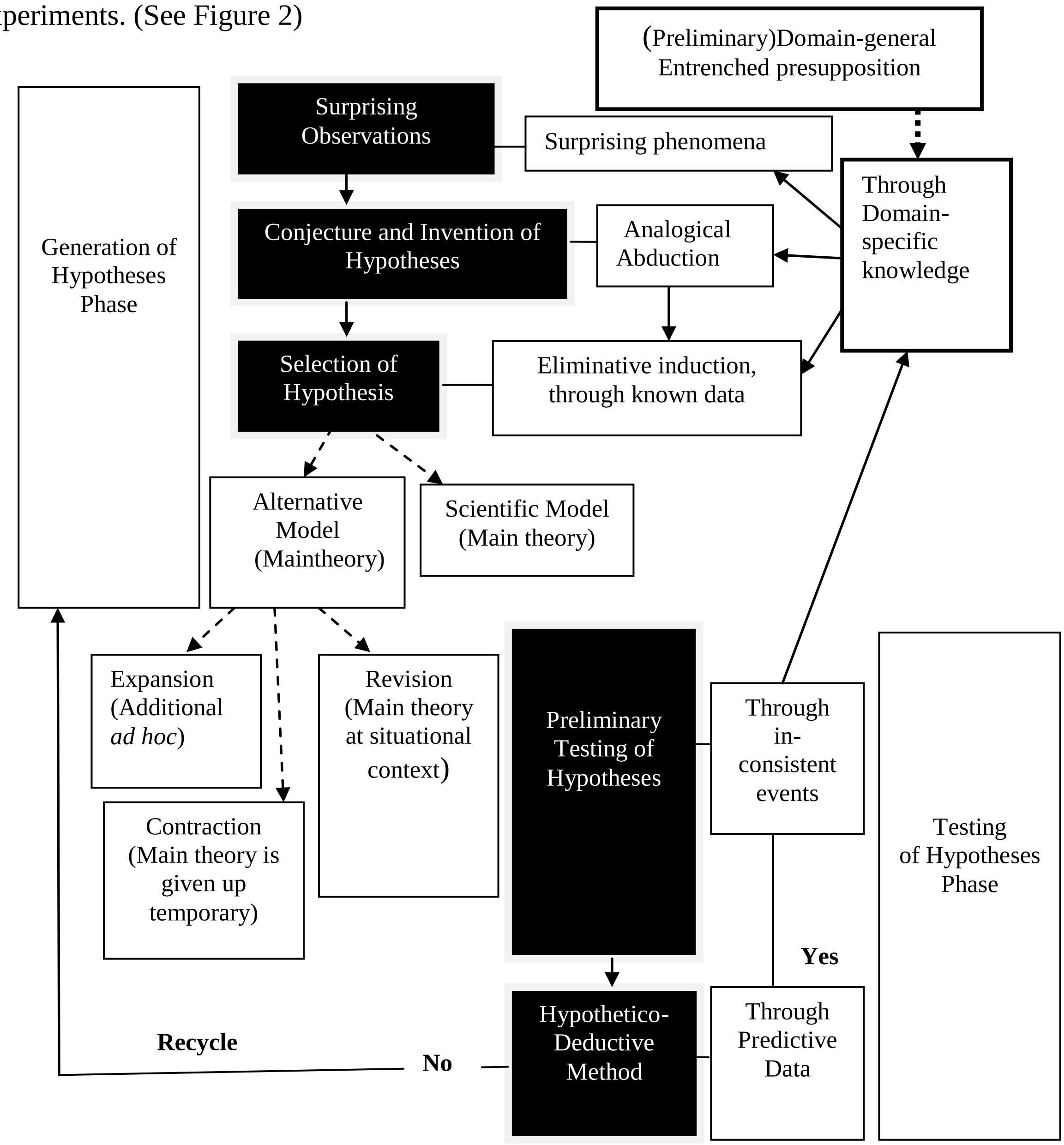


Figure 2. *Abductive Process Involving Testing Process of Hypotheses*

METHODOLOGY

a) Participants

30 first-year students of J. National University of Education (South Korea) participated in this research. First-year students were selected because we determined that scientific knowledge acquired from high school classes would be utilized the most for generating explanatory hypotheses that explain astronomical phenomena. All students had completed physics and earth science courses during high school and consented to participate in the study.

b) Testing Instruments and Interview

Understanding the growth of scientific knowledge has been one of the main goals of the philosophy of science for the past 30 years (for example, see Kuhn, 1970; Toulmin, 1972; Lakatos, 1970; Laudan, 1977). Another new approach is to view science as a problem-solving method. Domain-general and domain-specific knowledge are used as background to solve novel problems (Nickles, 1987; Thagard, 1988).Therefore, students' domain-general and domain-specific knowledge was considered to be a source of possible hypotheses. In this study, interviews were conducted by utilizing the following testing tools to find out how pre-service elementary school teachers use their existing background knowledge to explain the astronomical phenomenon of seasonal changes.

1) Domain-general entrenched presupposition background knowledge: Questions (Questions 1, 2) developed by Feigenberg et al. (2002) were used and expanded upon throughout the interviews.

2) Domain-specific background knowledge of specific astronomical phenomena: The questionnaire (Questions 3, 4) developed by Kikas (1998a,b) was used, and the interview was conducted to elicit more detail about the students' thoughts.

3) Interview Stages

Preliminary Stage (Domain-general background knowledge, entrenched presupposition): Draw a diagram in the survey to illustrate your thoughts.

First Stage (Unexplained phenomena, Surprising phenomena): Seasonal temperature changes occur in Korea, which lies at a middle latitude. Describe the phenomena accompanying seasonal temperature change.

Second Stage (Domain-specific background knowledge, Conjecture and invention of hypotheses):List the possible explanations for the phenomena you identified. Use as much of your existing knowledge as possible.

Third Stage (Domain-specific background knowledge, the selection of hypotheses): Check to see if the explanations of the observed phenomena proposed are adequate. What is the most plausible explanation?

Fourth Stage (suggesting anomalies):How is your explanation affected by the fact that the distance between the Sun and the Earth is slightly greater during summer than in the winter?

Fifth Stage (Hypothetico-deductive Method, justification of selected hypothesis) If your hypothesis is correct, then what happen?

c) Classification of the Pre-service Elementary School Teachers' Alternative Models through Belief Revision based on Abductive Process

Construction of the Explanatory Alternative Models

Preliminary Stage *(Domain-general entrenched presupposition background knowledge)*

After exploring students' knowledge related to astronomical phenomena based on their responses to the questions developed by Feigenberg et al. (2002), we interviewed students about the concept of celestial bodies that are far from Earth. We investigated whether they understood sunlight as rays emitted from a nearby heat source (the "lamp theory") or as a nearly parallel ray from a distant celestial body. We selected six people who proposed the lamp theory and conducted the interviews according to an abduction strategy. We assumed that all six students generated this theory on their own.

The question about the shadow of a tree in the appendix (Appendix1, Question 2) was used only as a reference. This is because the lamp theory is rarely proposed when considering a narrow range and is more often shown when the range is large, as in (Appendix1, Question 1) As shown in Figure 3 below, the responses for the two cases were tied in to the "lamp concept". Similarly, in Figure 4 (b), the light of the lamp is in close proximity to the ground, so it spreads everywhere and illuminates everything nearby.

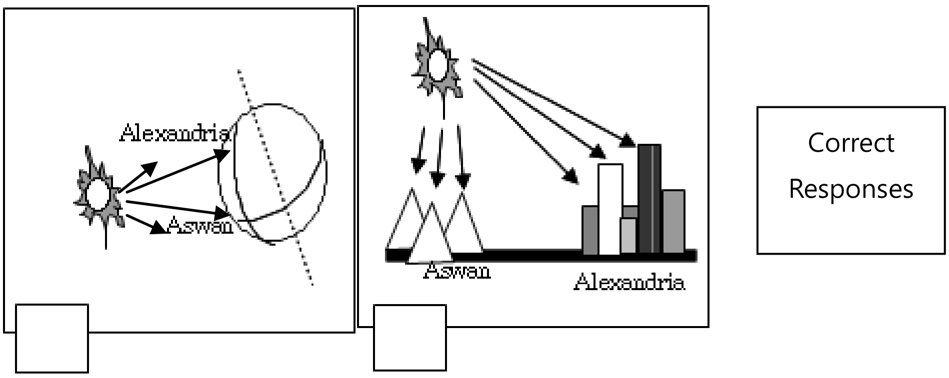
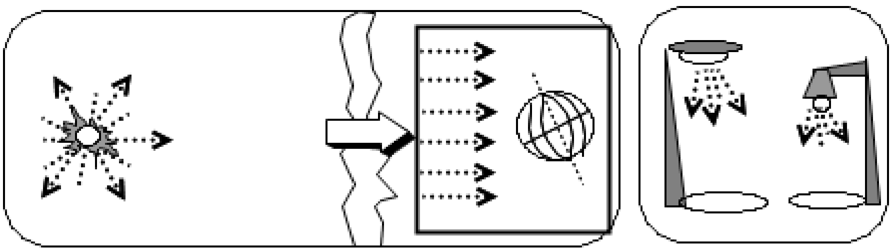


Figure 3. *Students' Explanations About Sun's Position At Noon*



(a) (b)

Figure 4. a) Correct understanding b) every day experiences

For this preliminary interview stage, we used the diagrams by Feigenberg et al. (2002).They show that light radiates in all directions when close to the Sun, as in Figure 4 (a), but once the light reaches the Earth, it is approximately parallel because the distance between the Sun and the Earth is very great. Therefore, it is not externally apparent but is deeply latent.

Surprising Phenomena (domain-specific background knowledge):

Students were given the following prompt: *Seasonal temperature changes occur in Korea, which lies at a middle latitude. Describe the phenomena accompanying seasonal temperature change.* The main strategy in this stage is to emphasize that the phenomenon occurs only in the middle latitudes, as in Korea.

Conjecture and Invention of Hypotheses:

This step involves identifying the key explanatory hypothesis for explaining a certain astronomical phenomenon. First, the students' main thoughts were investigated using the questionnaire (Appendix 3, 4) developed by Kikas (1998a, 1998b). The interviews were based on this questionnaire to understand their thoughts more clearly. The interviews were tape recorded. The interviews began with the following instructions: *List all possible explanations and how they explain the phenomena observed around us.*

Development of possible hypotheses determines which background knowledge will be used. In other words, we first consider whether the background knowledge being used is based on life experience, existing scientific knowledge, or both. Thus, the hypotheses generated can be grouped according to their source.

Selection of Hypotheses:

This phase involves selecting the most plausible explanation out of the possible explanatory hypotheses generated. The students were given the following instructions:

Of the explanations you have proposed, determine if there is any explanation that is not adequate for explaining the observed phenomena based on your background knowledge. Additionally, identify the most plausible explanation.

In abductive reasoning, eliminating the explanations that contradict background knowledge or the observed phenomena is an important strategy. At least one hypothesis with a relatively high probability of survival should be selected.

Preliminary Testing: In this phase, students evaluate the selected hypothesis in terms of consistency with the presentation of an inconsistent event. The anomaly that was presented varied according to each student's thought process.

Preliminary hypothesis testing is usually defined as the selection of the hypothesis, but the two phases can be distinguished from each other. If a hypothesis is selected based on what is believed to be plausible, preliminary hypothesis testing is an evaluation of the probability and truth of the hypothesis itself.

In epistemology, hypotheses that become laws are called generalization hypotheses, and hypotheses that become theories are called explanatory hypotheses (McComas, 2000). Theories are developed based on the laws of nature, and they explain the laws by presenting their causes. Furthermore, a law is a statement about the relationship between observable phenomena, whereas a theory is a system explaining the properties that cannot be observed (McComas, 2000).

Consistency, an important element of coherence, is a form of epistemological commitment that shows the reasoning between the concepts. Students organize existing concepts, and in the process of validating them, they display a pattern of explanatory consistency. Here, explanatory consistency does not refer to reasoning about scientific concepts but rather to the students' individual consistency. In conflicting situations, explanatory consistency is important for the maintenance and protection of the existing concepts or for developing temporary hypotheses (Watson et al., 1997, p.426).

In this study, the explanatory hypotheses were considered to be incomplete as they explain only some phenomena, despite being developed for use as theories. In the preliminary evaluation stage, we examined how the students' explanatory hypotheses changed based on their explanatory consistency.

■ **Revision**: Participants with an in-depth **(entrenched presupposition)** lamp conception were selected, and their process of explaining the seasonal changes was reconstructed through interviews as follows. The following is an excerpt from the interviews with pre-service teachers who hypothesized a visibly elliptical orbit and placed summer at the perihelion.

Researcher: Seasonal temperature fluctuations occur only at middle latitudes, as in Korea. Describe the phenomena that accompany seasonal temperature changes.

Respondent 1: The Sun gets weaker and then stronger. [After thinking for a while] In Korea, the Sun is low during winter and high during summer. **(Additional observations**)

Researcher: List all possible explanations for these phenomena.

Respondent 1: If we think that the Sun is an object that gives off heat, it would be the changes within the Sun itself, and the changes in the distance between the Sun and the Earth. Um… the tilt of the rotation axis based on before knowledge… **(Conjecture and invention of hypotheses)**

Researcher: Of the explanations you have proposed, is there any explanation that did not explain the observed phenomena adequately? In contrast, what is the most plausible explanation?

Respondent 1: As I understand, change within the Sun itself is unlikely. That is because the Sun is known as a very stable star. If the Earth is closer to the Sun due to the elliptical orbit, then wouldn't it be summer, while at a far distance it would be winter? Additionally, in Korea, um… if the axis of rotation is tilted this way, then it can be explained with the meridian altitude. **(Selection of a hypothesis)**

Researcher: Then, if it is summer in the Northern Hemisphere, would the Southern Hemisphere also be the same summer season? **(Anomalies 1)**

Respondent 1: [Appearing embarrassed] No.[Appearing to be thinking carefully] As I told you a moment ago, the Southern Hemisphere would be further from the Sun due to the tilt of the rotational axis, so it would be a different season.

Researcher: Actually, summer in the Northern Hemisphere corresponds to the aphelion of the Earth's elliptical orbit, so how would you explain that? **(Anomalies 2)**

Respondent 1: [Flustered] Then, it is certain that the elliptical orbit has no effect.

Researcher: Then, can you explain why the meridian altitude is higher and the daytime is longer during the summer compared to other seasons? **(Additional observations)**

Respondent 1: [Confidently] I think that is because the rotational axis is tilted. Obviously, if the meridian altitude is higher, then the day is longer. Additionally, it is natural that a large amount of the Sun's energy comes to the Earth. **(Preliminary Testing of Hypotheses)**

After presenting multiple anomalies, the initial lamp conception and the consistent initial belief in the effect of the changing distance from the Earth to the Sun were discarded. An additional anomaly was presented to illustrate the revision or change in the student's hypothesis.

When suggested hypothesis is more comprehensive, it can be justified as follow:

Reconstruction based on hypothetico-deductive method procedure

(If .....)The reasons of the seasonal change are the tilt of Earth's axis to the plane of its orbit around the Sun is correct (**Tilt of sun's lay hypothesis**),

(and..)Approximately plane wave arrive at surface, and have learned that Earth is nearly circular revolution (**test conditions**)

(then..) the amount of light at same surface we receive from the sun will be varied (expected Results)

(And......) students have learned that Earth is nearly circular revolution, the variation of a amount of sun's light intensity by the Earth's axis tilt are explained(**observation results**).

(Therefore...) the causes of the seasonal change owing to the tilt of Earth's axis to the plane of its orbit around the Sun are correctare supported (**conclusion**).

■**Expansion**: In this step, the addition happens regardless of whether the larger belief set is consistent.

Researcher: Seasonal temperature fluctuations occur only at middle latitudes, as in Korea. Describe the phenomena that accompany seasonal temperature changes.

Respondent 2: The Sun gets weaker and then stronger. The wind blows from the north during winter, and the wind blows from the south during summer. [After thinking further] In Korea, it seems that the altitude of the Sun during winter is low and high in the summer. Is this correct?**(Observation of phenomena)**

Researcher: List all possible explanations for these phenomena.

Respondent 2: If you compare the Sun to an object that gives off heat, I think the reason may be the changes in the Sun's latitude, as well as the changes in the distance between the Sun and the Earth based on life.**(Hypothesis generation)**

Researcher: Of the explanations you have proposed, is there any explanation that did not explain the observed phenomena adequately? In contrast, what is the most plausible explanation?

Respondent 2: If the Sun is at a close distance, wouldn't it be summer, and if the Sun is at a far distance, wouldn't it be winter? Wouldn't the Earth's elliptical orbit of revolution explain it? And, um… also, if the Earth's rotational axis is tilted, the meridian altitude can also be explained. I don't know exactly, but the changes in the latitude do not explain it, except for the effect of the wind.**(Hypothesis selection)**

Researcher: Then, if it is summer in the northern hemisphere, would the southern hemisphere also be the same summer season?

Respondent 2: [Stumped] No, it wouldn't be. [Thinking for a while] In my opinion, the seasons are different because the energy that the southern hemisphere receives from the Sun is different due to the tilt of the rotational axis.

Researcher: Then, can you explain why the meridian altitude is higher and the daytime is longer during the summer compared to other seasons?

Respondent 2: I think that is due to the tilt of the rotational axis. If the meridian altitude is high, then the day would obviously be long. Additionally, a lot of the Sun's energy comes to the Earth.

Researcher: Are you saying that the distance from the Sun and the tilt of the rotational axis have effects?

Respondent 2: [Hesitant again, but appearing satisfied] Yes, I think the tilt of the rotational axis has an effect, but the effect of the distance must also be present. (**Preliminary evaluation of the hypothesis**)

Pre-service teachers who initially had an in-depth **(entrenched presupposition)** lamp conception were interviewed according to the abduction strategy. The transcript below illustrates that when a new tilt theory was simply added without changing the distance variation; the inconsistent event was not recognized as above and instead was used to justify the distance theory.

Reconstruction based on hypothetico-deductive method procedure

(If .....)the reasons of the seasonal change are the distance between Earth and Sun and the tilt of Earth's axis to the plane of its orbit around the Sun are correct **(distance variation hypothesis),**

(and..) Spherical wave (lamp conception)arrive at surface, and have learned that Earth is elliptical revolution**(test conditions)**

(then..)the amount of light at same surface we receive from the sun will be varied owing to ecliptic revolution around the sun **(expected Results**)

(And......)students have learned that Earth is nearly circular revolution rather than extreme ecliptic revolution **(observation Results).**

(Therefore...)the reasons of the seasonal change owing to distance between the sun and Earth is not supported (**conclusion).**

Thus teacher show the need of a new hypothesis generation procedure to students.

■ **Contraction:** In this process, the initial belief set became so small that it could no longer be maintained without adding any new facts.

Researcher: Seasonal temperature fluctuations occur only at middle latitudes, as in Korea. Describe the phenomena that accompany seasonal temperature changes.

Respondent 3: It seems that the Sun's altitude is low during winter and high during summer. Am I correct? The Sun becomes weaker and then stronger. **(Observation of phenomena)**

Researcher: List all possible explanations for these phenomena.

Respondent 3: If you compare the Sun to an object that gives off heat, I think the reason would be the changes in the Sun's latitude, as well as the changes in the distance between the Sun and the Earth based on the intensity variation of lamp light.**(Hypothesis generation)**

Researcher: Of the explanations you have proposed, is there any explanation that did not explain the observed phenomena adequately? In contrast, what is the most plausible explanation?

Respondent 3: If the Sun is at a close distance, wouldn't it be summer, and if the Sun is at a far distance, wouldn't it be winter? Wouldn't the Earth's elliptical orbit of revolution explain it? And, um… also, if the Earth's rotational axis is tilted, the meridian altitude can also be explained. There is a change due to the distance, but wouldn't the changes in energy due to the tilt of the rotational axis be a more likely possibility?**(Hypothesis selection)**

Researcher: Can you explain the reason for indicating the position of the Earth on the orbit for each season and the cause of seasonal changes? Additionally, why is it wintertime when the Earth is closest to the Sun? **(Presentation of anomaly)**

Respondent 3: I knew even before this interview that it is winter when the Sun is close and summer when it is far. However, couldn't the reason for this be that …… the change in the distance caused bythe elliptical orbit is small?

Researcher: Then, can you explain why the meridian altitude is higher and the daytime is longer during the summer compared to other seasons?

Respondent 3:[Awkwardly] I just know that the Earth's rotational axis does not stand straight but is tilted. Now that I think about it, I think I learned in the past that it has an effect of changing the meridian altitude and so there is a change in the energy received. Um…. Um… Perhaps the seasonal changes may be caused more by the tilt in the rotational axis rather than the effect of the Earth's elliptical orbit …probable the elliptical orbit seem to be more explored.**(Confirmation of the hypothesis through preliminary evaluation of the hypothesis)**

Participants had an in-depth**(entrenched presupposition)**plane wave, but they did not explicitly endorse the distance theory (main hypothesis).

Evidence of eccentricity challenges the distance theory, leading students who hold this theory to question their chosen explanation.

However, additional effort (data) is required because emotional uncertainty is expressed to some extent. And then, teachers must show that justification of hypothesis was completed after additional data suggestion to students

(If .....) the cause of the seasonal change are the tilt of Earth's axis to the plane of its orbit around the Sun rather than Earth's ecliptic revolution around the Sun is correct **(tilt of sun's lay Theory)**, (and..) Approximately plane wave arrive at surface, and have learned that Earth is nearly circular revolution(**test conditions**)

(then..)the amount of light at same surface we receive from the sun will be varied (**expected results**)

(And......)students have learned that Earth is nearly circular revolution, the variation of a amount of sun's light intensity by the Earth's axis tilt are explained (**observation Results**).

(Therefore...) If students have learned that Earth is nearly circular revolution, the reasons of the seasonal change owing to the tilt of Earth's axis to the plane of its orbit around the Sun are correct are supported **(conclusion**).

The pre-service teachers with an in-depth lamp conception who explained the seasonal changes with distance theory, Respondent 1(6/30)demonstrates a case of withdrawing the distance theory when a type of inconsistent event was present and accepting a new theory

Respondent 2 (10/30)demonstrates case of partially accepting the tilt theory while continuing to adhere to the distance theory. Respondent 3(5/30)initially held the distance variation but later partially withdraw it, with a doubt for his initial conceptions, leaving this student in a transitional stage in which the abduction process is not complete. Additional information is necessary for this student to complete the abduction process.

No classification, Respondent (7/30) demonstrates a case of different types of hypothesis with Respondent 1 and Respondent 2(see The Table 1).

Table 1. *Classification Of Belief Variation Of Pre-Service Elementary Teachers About Seasonal Change Through Abductive Strategies*

Phase	Stage	**Revision <respondent 1>**	**Expansion <respondent2>**	**Contraction <Respondent3>**		**Correct**
Prelimina ry exploratio	entrenched presupposition	**Spherical wave** at lamp at near heating	**Spherical wave** at lamp at near heating	**Nearly plane wave** of the sun's ray arriving at Earth's surface		**Nearly plane wave** of the sun's ray arriving at Earth's surface
Generation of Hypotheses Phase	Surprising observations	Sun's Intensity and , Altitude variation of meridian passage	Intensity of Sun and Wind, and , Altitude variation of meridian passage	Sun's Intensity and , Altitude variation of meridian passage		Altitude variation of meridian passage
	Conjecture and Invention of Hypotheses	Sun's intrinsic energy variation, and the earth's distance variation to the sun **based on everyday experiences**	Earth's Latitude variations of Sun and, distance variation between Sun and Earth **based on everyday experiences**	Earth's Latitude variations of Sun and, distance variation between Sun and Earth **based on everyday experiences**		Earth's revolution about Sun and Earth's axis rotation based on tilt of earth's rotational axis **based on scientific knowledge**
	Selection of Hypothesis	the earth's **distance** variation to the sun	**distance** variation between Sun and Earth	distance variation between Sun and Earth, and **tilt of earth's rotational axis**		Main theory
Testing of Hypotheses Phase	Preliminary Testing of Hypotheses	Give up of distance variation: Altitude variation of meridian passage owing to tilt of earth's rotational axis	The consistent holding of distance variation between Sun and Earth	Through give up of distance variation, tilt of earth's rotational axis-- need to additional data		Classification criteria By suggestion of anomalies
	Hypothetico-Deductive Method	Justification	Falsification	Conditional justification	Expected Results	No classification
Numbers of pre-service teachers (n/30)		6	10	5	2	7

First, what is the abduction strategy for explaining surprising phenomena?

In the first stage of the abduction strategy, by stressing that surprising phenomena only occur in middle-latitude countries like Korea, we were able to naturally draw out the tilt of the rotational axis in interviewees' explanations of the seasonal change.

Second, what background knowledge is used for generating and selecting hypotheses in the abduction process?

During hypothesis generation, which is the second stage in the abduction strategy, the generated hypotheses are not completely different hypotheses but rather hypotheses of the same type (Hanson, 1965). This means that the same elements of background knowledge were used to develop all of the possible hypotheses.

Excluding the transitional period in the model formation, the lamp theory developed from domain-general background knowledge acquired during childhood is found to constitute the core of the current model. Figure 5 shows that a new theory develops gradually based on domain-general background knowledge.

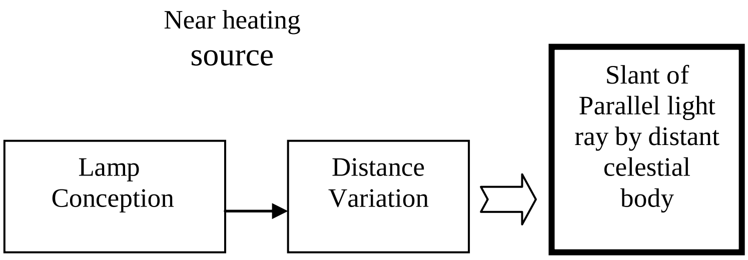


Figure 5. *Pre-Service Elementary Teachers' Conceptual Change Aspects*

Third, what is the students' preliminary evaluation of their main theory and hypotheses?

The fourth stage of the abduction strategy, which concerns the consistency or inconsistency of students' responses during the process of justifying the initially selected hypothesis, asks how the initially introduced point of view changed. To protect their unclear explanation, students may have one theory that becomes the basis for their explanations, and the students may explain the phenomena within the scope of their limitations or enter a transitional state from one theory to another.

With more auxiliary hypotheses, the degree of consistency is lower, and if a new hypothesis was implemented but had little effect on the initial theory, then consistency decreases. Nevertheless, there is consistency because the auxiliary hypotheses within the theory are adjusted. At first, the students believed that the perihelion in an exaggerated elliptical orbit corresponded to summer. When presented with the information that summer in the Northern Hemisphere does not occur concurrently with summer in the Southern Hemisphere, they explained this anomaly with the tilt of the Earth's rotational axis without weakening the distance theory. This alternative model has consistency, albeit less than the scientific model. In sum, students tended to move towards a lower consistency of their beliefs during the process of justifying the hypothesis they selected.

Furthermore, at first, the students believed that the Earth follows an exaggerated elliptical orbit and that the perihelion took place during the summer, but then they began to explain the seasonal changes only with the tilt of the light. Therefore, the distance theory was limited or temporarily suspended and logically incomplete, and the consistency of the explanation was low. We categorized this step of the process as a "transitional mental model."However, the students' thought processes may not have changed completely.

Fourth, Lawson (1995) said that the hypothetico-deductive process and the abduction process have a recursive relationship. Tracing the main hypothesis that constitutes the pre-service teachers' alternative models through HD would obviously result in its dismissal. Therefore, using HD with the abduction process is a good strategy to show that the hypothesis selected by the students is ineffective.

CONCLUSION and SUGGESTIONS

In this study, we examined pre-service elementary school teachers' process of forming alternative models explaining seasonal changes according to abductive reasoning. In addition, based on these results, we constructed an alternative model development process based on the abduction process to understand how the pre-service elementary school teachers generate and justify hypotheses that explain seasonal changes to develop their own alternative mental models.

First, In response to the question of whether seasonal changes occur only in middle-latitude countries like Korea, most pre-service teachers considered the tilt of the Earth's rotational axis, although insufficiently.

Second, Most students demonstrated the lamp theory of a close heat source to explain the Sun's behavior rather than considering it to bea celestial body. They limited the number and structure of their alternative models and used domain-general background knowledge for generating their models. This result is consistent with the suggestion that the hypotheses generated from the students' background knowledge by the abduction strategy are ultimately of the same type

Third, As an explanation for seasonal changes, the pre-service teachers believed that the Sun's energy changed due to the Earth's revolution within the exaggerated elliptical orbit. This explanation strongly supports the "distance theory", which is an offshoot of the "lamp conception". It is more appropriate to discuss the process of belief changes as the "maintenance of the hypothesis (belief) by additional concepts" rather than as "changes in hypothesis (belief)" or "revision of hypothesis (belief)".

The results illustrate the process of using only nonscientific hypotheses while using only one theory consistently without modification. As the beliefs contributing to the model change, "maintenance of the hypothesis (belief) by additional concepts" is shown. Moreover, pre-service teachers who are in the intermediate stage of moving toward a scientific understanding of the phenomenon were found to undergo a transitional period of doubting the belief without showing any change in the belief (theory). Although the existing hypothesis (belief) is significantly restricted in its relevance, additional evidence and learning are necessary to accept the new hypothesis.

Fourth, It is possible to have more than one competing hypotheses to explain a phenomenon. However, teachers can be help their students to know whether their hypothesis is correct or falsified through the hypothetico-deductive method from the students' perspective.

Finally, abduction strategies can trace the students' process of generating hypotheses during problem solving. Because the abduction process emphasizes hypothesis generation via discovery, it is possible to identify the process and the source of hypothesis generation.

Our study used the abduction strategy to describe the stages of the students' alternative model formation, but research identifying more detailed stages of the abduction strategy is necessary. Additionally, seasonal change is a very difficult process to understand when it is taught in elementary school. Hence, we propose that pre-service elementary school teachers learn how to explain seasonal change through abductive reasoning. For teachers to successfully guide elementary school students in scientific activities, teachers must possess both the appropriate scientific knowledge and the necessary abductive inference skills. Therefore, the educational courses for pre-service teachers must recognize problems in scientific inquiry situations and create process to resolve those problems.

Finally, future research should compare the research process of actual scientists to the research process of teachers. This suggestion is based on the assumption that scientists and students use similar processes to develop scientific knowledge.

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Exploring Attitudes Towards Science Among Malay and Aboriginal Primary Students

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ABSTRACT

This study aims to explore the gender, grade level and ethnicity differential in attitudes towards science. Using a 3-point Likert scale 8-item unidimensional Attitudes Towards Science Questionnaire with appropriate validity and reliability, the questionnaire was administered to 84 respondents from two national primary schools in Temerloh District in Pahang comprising 29, 25 and 30 primary students from years 4, 5 and 6 respectively. The dataset was analysed using a two-way (gender and grade level) factorial ANOVA and an independent samples t-test for ethnicity. The findings indicated that while there were no significant two-way interactional effect and main gender effect, the grade level effect was significant in which Year 5 and 6 students were having more positive attitudes than Year 4 students. Additionally, the Malay students have a markedly higher level of attitudes towards science as compared to the Aboriginal students. The results are discussed in the context of science teaching and research.

Keywords: Attitudes towards Science; Malay; Aboriginal; Primary Students.

INTRODUCTION

Scientific literacy, probably the most commonly use terms in science education today (Roberts, 2007), has been one of the main goals of science education in many countries across the globe. The National Philosophy of Science Education in Malaysia embodies the aspiration to develop scientific literacy among Malaysians by fostering “a culture of Science and Technology, focusing on the development of an individual who is competitive, dynamic, agile and resilient, and is able to master the knowledge of science and technological competence” (Ministry of Education, 2010, p. v). While there is virtually no consensus on the definition of scientific literacy and it has been hailed as “an ill-defined and diffuse concept” by Laugksch (2000, p.71), the characteristics of a scientifically literate person, as described in the Twenty First Century Science (u.d.) – a suite of science courses offered at GCSE in the UK, encompass the ability to appreciate and understand the impact of science and technology on everyday life; take informed personal decisions about things that involve science, such as health, diet, use of energy resources; read and understand the essential points of media reports

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about matters that involve science; reflect critically on the information included in, and (often more important) omitted from, such reports; and take part confidently in discussions with others about issues involving science.

Accordingly, scientific literacy involves not only the cognitive domain, but also the affective or attitudinal domain which deals with appreciation, taking informed personal decisions, and taking part confidently in discussions on scientific issues. Hence, scientific literacy is affected by a student's attitudes towards science, which in turn, contributes to how well he or she performs in a science class (Dalgety, Coll & Jones, 2003; George, 2000). Research also indicates that prior learning of, and past exposure to, science-based subjects do have an impact on science achievement and attitudes (Baldwin, Ebert-May, & Burns, 1999; Wandersee, Mintzes, & Novak, 1994).

Research in academic achievement reveals that there is a strong association between science achievement and attitudes towards science (e.g., Nuttall, 1971; Simpson & Oliver, 1990; Papanastasiou & Zembylas, 2002; 2004). In TIMSS 2011 International Science Report (Martin, Mullis, Foy, & Stanco, 2012), students' attitudes towards science was one of the ways to elicit information that could provide an educational context for interpreting the science achievement results. The work by Germann (1988) indicates that students who have more positive attitudes towards science show increased attention to classroom instruction and participate more in science activities. The development of attitudes towards science in schools, particularly among elementary school children, is regarded as important because positive attitudes may contribute to the increased uptake of science and the sufficiency of scientists. Osborne, Simon, and Collons (2003) opine that "educating more children in mathematics and science is, at the very least, very unlikely to have a negative effect on the economic well-being of any society" (p. 1053) and research indicates that many latent scientists appear to make early decisions about their careers in the elementary years (Blatchford, 1992; Wellington, 1990; Woolnough, 1990).

Therefore, the development of positive attitudes towards science is one of the legitimate goals of science education globally. Although attitudinal research has been conducted amongst students at secondary and pre-university levels in Malaysia (e.g., Ahmad Nurulazam, Mohd Ali, Rohandi, & Azman, 2010; Aziz & Lin, 2011; Kamisah, 2013; Kamisah, Zanaton, & Lilia, 2007; Ong & Ruthven, 2009; Zanaton, Lilia, & Kamisah, 2006), there is still a scarcity in attitudinal research amongst students at the elementary level.

Aims

This study aims to investigate the attitudes towards science among elementary school students, looking at the differences by gender, grade level, and ethnicity. Ethnicity difference is worth investigating given that there are some aboriginal (indigenous) students among the predominantly Malay students in the selected schools. Accordingly, this study seeks to answer the following questions:-

(a) Is there any difference in attitudes towards science between the girls and the boys?
(b) Are there any differences in attitudes towards science among the students in grades 4, 5 and 6?
(c) Is there a difference in attitudes towards science between the aboriginal and the Malay students?

Attitudes towards science: A literature review

The concept of attitude and its relation to academic achievement has been the targeted area of educational research since 1920s when Thurstone declared in an article that attitudes were measurable (Simpson, Koballa, Oliver, & Crawley, 1994). From 1920s till the early

1970s, the scope of attitudinal research was in one of the three areas, namely measurement of student attitudes; measurement of change in student attitudes resulting from various interventions or treatment methods; and identification of relationship in support of student attitudes and science-related behaviours (Simpson et al., 1994). In the late 1970s and early 1980s, attitudinal research “focused on documenting student attitudes and their relationship to science achievement” (Koballa & Glynn, 2007, p.77). While there seemed to be a pause in attitudinal research in the 1990s, possibly due to uncharted direction, the first decade of the 21st Century displayed an uptrend in attitudinal research which looks into “a variety of student attitudes and beliefs that shape and are shaped by student classroom experience” (Adams, Perkins, Podolefsky, Dubson, Finkelstein, & Wieman, 2006, p. 1). Such growth in attitudinal research was due, in part, to the concern among science educators and researchers regarding the decreasing uptake of science post-16, which correspondingly, causing a significant decline in the number of students in the scientific career pipeline (Osborne, Simon, & Collins, 2003) which was described as “a murky pool of talent” by The Royal Society (2006, p.3).

Gardner (1975) acknowledges the broad nature of the term attitude that takes on different meanings in discussions about science education. He distinguishes two broad categories of attitude. The first category, "attitudes towards science" (e.g., interest in science, attitudes towards scientist, attitudes towards social responsibility in science) shows some distinct attitude object such as science or scientist, to which the respondent is invited to react favourably or otherwise. Viewed as an emotional reaction of students, Gardner (1975, p.2) regards attitudes towards science as "learned disposition to evaluate in certain ways objects, actions, situations or propositions involved in the learning of science". The second category, "scientific attitudes" (e.g., open-mindedness, objectivity, honesty, and skepticism), by contrast, are best described as styles of thinking which scientists are presumed to display. In a similar vein of differentiating, Simpson et al. (1994) reckon scientific attitudes as “ways in which scientists believe in and conduct their work” (p.212), while attitudes towards science represent “a person’s positive or negative response to the enterprise of science ... [or] refer specifically to whether a person likes or dislikes science” (p.213). Osborne, Simon, and Collins (2003) subscribe to Gardner's distinction between "attitudes towards science" and "scientific attitudes", reckoning such distinction as not only clear, but "fundamental and basic" (p.1053) in an otherwise "nebulous, …poorly articulated and not well understood" (p. 1049) concept of attitudes in science educational research.

The review of research into attitudes towards science by Osborne, Simon, and Collins (2003, p.1054) indicate that the attitudes towards science are multidimensional in terms of construct, and that the subconstructs, which contribute in varying proportions towards an individual’s attitudes towards science, consist of the combination of these measures: the perception of the science teacher; anxiety toward science; the value of science; self-esteem at science; motivation towards science; enjoyment of science; attitudes of peers and friends towards science; attitudes of parents towards science; the nature of the classroom environment; achievement in science; and fear of failure on course.

Nevertheless, the problem of interpreting the significance of these subconstructs or sub-dimensions of attitudes towards science has been pertinently pointed out by Gardner (1975) when he comments: “An attitude instrument yields a score. If this score is to be meaningful, it should faithfully reflect the respondent’s position on some well-defined continuum. For this to happen, the items within the scale must all be related to a single attitude object. A disparate collection of items, reflecting attitude towards a wide variety of attitude objects, does not constitute a scale, and cannot yield a meaningful score” (p. 12). Accordingly, Gardner (1975) strongly advocates that when measuring attitudes toward science, the instrument used needs to be internally consistent and unidimensional. While internal consistency is commonly determined through the use of a measure known as Cronbach’s alpha, the unidimensionality of scales are tested using an appropriate statistical technique such as factor analysis. Osborne, Simon, and Collins (2003) reinforced Garner's (1975) advocacy by cautioning that "while unidimensional scales will be internally consistent (since they all measure the same construct), it does not follow that internally consistent scales will be unidimensional" and reminding researchers that "if a scale does measure what it purports to measure, then the variance should be explained by a loading on a unitary factor" (p. 1058).

A clear feature of the attitudinal research is the decline in attitudes towards science from age 11 onwards. Yager and Penick (1986) found that students in elementary schools perceived science to be enjoyable, interesting and useful. However, a decline in attitude occurs throughout junior high and high school, resulting in young adults who do not feel positive about their school science. Osborne, Driver, and Simon (1998) noted that positive attitudes towards school science appear to peak at, or before, the age of 11 and decline thereafter by quite significant amounts, especially for girls. Lowery (1967) found that at the age of 10 to 11, science in children's mind was associated with difficult words, monsters, precious metals and jewels, and that science was unsafe. The results of the national survey in Australian schools undertaken by Rennie, Goodrum, and Hackling (2001) indicate that a significant number of adolescents view science as a difficult and boring subject.

Another clear feature of the attitudinal research, supported by meta-analyses of Schibeci (1984), Becker (1989), and Weinburgh (1995), and by subject preference study of Lightbody and Durndell (1996) in one school is that boys have a consistently more positive attitudes towards school science than girls. The plausible thesis offered to explain this finding is that it is a consequence of "stereotype threat" (Hill, Corbett, & St. Rose, 2010, p. 38) whereby boys are generally being perceived as better suited and possessing higher ability for science careers than girls. Such thesis is supported by Corell (2004) whose study indicates that fewer girls than boys are interested in becoming scientists or engineers, and by Jovanovic and King (1998) who contend that girls' antipathy towards science is explained by their own comparative judgments across academic domains, perceiving that they are better at other subjects (i.e., English) and, therefore, not as good at science.

However, while boys' attitudes towards science are significantly more positive than girls, the effect is stronger in physics than in biology. Such a bifurcation of interest in physical and biological science between boys and girls (i.e., Harvey & Edwards, 1980) has been given additional salience by the work of Ormerod, Rutherford, and Wood (1989) where boys were found to be far more interested in "space" and girls far more interested in "nature study". Meanwhile, by employing the use of focus groups to explore 16-year-old student's views and attitudes towards science, Osborne and Collins (2000) found that, to their surprise, chemistry was perceived as less appealing than physics, although the analysis by gender in Osborne, Simon, and Collins (2003) shows that the male to female ratio is approximately equal in chemistry as compared to 3.4:1 in physics, favoring the males, and 1.6:1 in biology, favoring the females.

The work of Jarvis and Pell (2005) suggests that an intervention of visiting UK National Space Centre had positive significant effects on Year 10 and 11 children's attitudes towards science in terms of interest in space, science in a social context, and lowering anxiety. However, there was no significant effect on attitudes with regard to science enthusiasm. As to its long-term effect, while the space interest was not sustained, the attitudes towards science in a social context continued to remain at a high level and that the anxiety levels which showed a much lower score after the visit continued to decline for the remainder of the year. In terms of the impact on attitudes towards science deriving from intervention using student-centered strategies, the results seem to be mixed. While some studies suggest that the use of inquiry-based teaching does have positive impact on students' attitudes towards science (Gibson & Chase 2002; Jones, Gott, & Jarman, 2000; Lord & Orkwiszewski 2006; Sesen &

Tarhan, 2013), other studies concluded that there was no significant impact of activity-based teaching or programmes (e.g., Gantreau & Binns, 2008; Turpin, 2000; Wideen, 1975) on students' attitudes towards science.

Studies reviewed in this section support four conclusions of research on attitudes towards science. Firstly, age is related to attitude (i.e., as a student advances to higher levels of schooling, attitude declines). Secondly, gender is related to attitude (i.e., boys have more positive attitudes towards science than girls). Thirdly, gender is also related to biological science relative to physical science (i.e., boys are more interested in physical science while girls are more interested in biological science). Finally, students' attitudes towards science are related to the pedagogical approach employed by the teachers (i.e., inquiry-based teaching and outdoor science may have positive impact on attitudes towards science). Nevertheless, the review of the literature in this section indicates that, while there is an abundance of attitudinal research conducted among secondary and post secondary students, the research on elementary (primary) students' attitudes towards science is relatively scant and inadequate.

METHODOLOGY

a) Research Design

In view of the aim of this research which is to gauge the level of attitudes towards science among elementary school students, comparing it by gender, grade level, and ethnicity in a natural, intact ecological school setting, and subsequently, providing possible reasons and explanations for the findings, the appropriate methodology used was a causal-comparative research design. This is in line with the principles in the causal-comparative design where "investigators attempt to determine the cause or consequences of differences that *already exist* between or among groups of individuals" (Fraenkel, Wallen, & Hyun, 2012, p. 366).

b) Instrumentation

The instrument used in this study, a modified version of the Attitudes Towards Science Inventory (m-ATSI), was adapted from the Attitude Toward Science Inventory or ATSI (Gogolin & Swartz, 1992). While the multidimensional ATSI has 48 items measuring six constructs, namely perception of the science teacher, anxiety towards science, value of science in society, self-concept in science, enjoyment of science, and motivation in science, using a 5-point Likert scale of which some items are worded negatively, the m-ATSI is basically an 8-item unidimensional inventory measuring only the construct of enjoyment in science using a 3-point Likert scale where each item is worded in a positive manner. The adaptation took into consideration the age range, reading ability and the concentration time span of upper primary students, and hence it is pre-determined as unidimensional with 8 items using a 3-point Likert scale (1=Disagree, 2=Undecided, 3=Agree). Despite the fact that ATSI was developed in the 90s, the construct measuring students' attitudes towards science in terms of their enjoyment in learning science is still relevant to the Malaysian context as evident in the study by Kamisah (2013).

In order to establish its unidimensionality, a factor analysis was run with the dataset collected from a sample of 84 students. The value of Kaiser-Meyer-Olkin (KMO) obtained was 0.740, suggesting good sampling adequacy (Hutcheson & Sofroniou, 1999) and that factor analysis is appropriate (Field, 2005). Bartlett's test of spherity has a significant value, $p < .001$, indicating that the R-matrix is not an identity matrix, having some relationship between variables, and therefore, factor analysis is appropriate (Field, 2005). The unidimensionality, established through a factor analysis with varimax rotation, was evident in one factor solution with factor loadings that ranged from 0.49 to 0.74 and an eigenvalue of 3.03 which accounted for 37.92 per cent of the total variance. The Cronbach's alpha for m-

ATSI was 0.76, suggesting that the instrument has sufficient internal reliability. Accordingly, the use of the 8-item m-ATSI justifies the use of summated-ratings procedure to measure students' attitudes towards science. Table 1 presents the items in the unidimensional scale for the modified Attitudes Towards Science Inventory (m-ATSI).

Table 1. *Unidimensional Scale for the Modified Attitudes towards Science Inventory (m-ATSI)*

Attitudes Towards Science Inventory (m-ATSI) (α = 0.76)		Factor Loading
1.	Doing science labs or hands-on activities is fun (#6) *Aktiviti dalam makmal sains menyeronokkan*	.646
2.	Science is something that I enjoy very much (#2) *Saya sangat suka sains*	.533
3.	I do not like anything about science (#18)* *Saya tidak suka apa-apa juga yang berkaitan dengan sains*	.589
4.	I enjoy watching a science program on television (#29) *Saya seronok menonton program sains di TV*	.605
5.	I enjoy talking to people about science (#28) *Saya seronok bercakap mengenai sains dengan orang lain*	.742
6.	Working with science upsets me (#34)* *Kerja-kerja berkaitan dengan sains menggembirakan saya*	.699
7.	Science is one of my favourite subjects (#45) *Sains merupakan salah satu mata pelajaran yang saya gemari*	.581
8.	I would like to spend more time in school studying science (#13) *Saya ingin menghabiskan lebih masa untuk mempelajari sains di sekolah*	.492

Note: * reverse-coded item

c) Sampling

A convenience sampling was used in this study given that the second author and her friend taught science in the participating schools. While we acknowledge the criticism of bias and non-representativenes in convenience sampling, such sampling technique, nevertheless, has the benefit of obtaining preliminary data for understanding of attitudinal trend among upper primary students without the complications of using a randomized sample. There were 84 students, drawn from Year 4, 5 and 6 intact classes of two national primary schools in Temerloh, participated in this study. Analisis by gender, there were 49 boys (32 Malay, 17 Indigeneous) and 35 girls (29 Malay, 6 Indigenous). The two participating schools are classified as rural schools by the Ministry of Education and the total number of Year 4, 5 and 6 students as gleaned from the official records was 116, with the Malay and Aboriginal ratio of approximately 3:2. This suggests a high absenteeism, particularly among the aboriginal students who regularly skip school for various reasons which include helping parents in farming. Table 2 presents the number of students by gender and grade level for ethnicity.

Table 2. *Sample Distribution*

	Malay			Indigenous			
Grade Level	Boys	Girls	Total	Boys	Girls	Total	Grand Total
Year 4	11	7	18	8	3	11	29
Year 5	5	12	17	6	2	8	25
Year 6	16	10	26	3	1	4	30
Total	32	29	61	17	6	23	84

d) Data Collection Procedures

The m-ATSI was administered to the students in each class by the second author in school time. Before responding to the items, a moderation session was held with the students in which they were tuned to what it means to agree, undecided, and to disagree by means of a simulation. To simulate or walk through what "agree" means, students were presented a hypothetical situation in which they have just eaten a sumptous lunch till they are really full, and then they were presented with the statement, "I want to have a bowl of noodle". In the same fashion, undecided and disagree responses were simulated through a partially full and hungry (or starving) hypothetical situations respectively. Once students were accustomed or tuned to the three responses, the first item in the m-ASTI was then audibly read to the class, clarifing any question and explaining any meaning of a problematic word or phrase. The students then picked their self-perceived most suitable response by checking the corresponding box. This process was repeated for each of the eight items.

e) Data Analysis Procedures

With the significance level set at 0.05, the scores on m-ATSI were analysed using a 2 x 3 (gender x grade level) ANOVA. The reason for using factorial design was to ensure that the interpretation of gender and grade level differences was not spurious as measure had been taken to establish if there was any two-way interaction effect. Should the interaction effect is significant, then the moderating effect of one independent variable on the other independent variable would be judiciously considered; otherwise, the main effects of gender and grade level could be interpreted in a straightforward manner. Additionally, ethnicity was not entered into the equation for three-way factorial ANOVA simply because the number of Aboriginal students was small and should it be entered into a three-way factorial analysis, some cells would have less than 5 cases as indicated in Table 2, thus rendering the analysis as non-robust. As such, the difference in attitudes towards science by ethnicity would be analysed separately using an independent samples t-test.

FINDINGS

A two-way ANOVA for attitudes towards science was carried out. The results are presented in Table 3.

Table 3. *2 x 3 (Gender x Grade Level) between-subjects Analysis of Variance for attitudes towards science*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Gender (A)	13.575	1	13.575	1.151	.287	.015
Grade Level (B)	185.339	2	92.669	7.856	.001	.168
A * B	5.744	2	2.872	.243	.784	.006
Error	920.038	78	11.795			
Total	29243.000	84				
Corrected Total	1119.560	83				

One-Way Gender Effect

Based on Table 3, the main effect of gender was not significant, $F(1, 78) = 1.151$, $p = .287$. Table 4 shows the means and standard deviations by gender for attitudes towards science.

Table 4. *Means and Standard Deviations by Gender for Attitudes towards Science*

	Boys (n=49)		Girls (n=35)		Difference
	M_m	SD	M_f	SD	$M_m - M_f$
attitudes towards science	18.49	4.13	18.03	2.96	0.46

One-Way Grade Level Effect

Based on Table 3, the main effect of grade level was statistically significant, $F(2, 78) = 7.856$, $p = .001 < .05$, and accounted for 16.8% of the total variance in the attitudes towards science. Table 5 presents the means and standard deviations by grade level for the attitudes towards science.

Table 5. *Means And Standard Deviations by Grade Level for Attitudes towards Science*

	Year 4 (n=29)		Year 5 (n=25)		Year 6 (n=30)		Differences		
	M_4	SD	M_5	SD	M_6	SD	$M_4 - M_5$	$M_4 - M_6$	$M_5 - M_6$
attitudes towards science	16.28	4.11	19.36	2.69	19.37	3.17	-3.08* p=.004	-3.09* p=.002	-0.01 p=1.000

* Significant at $p < .05$

When the statistically significant grade level effect was followed up with the Bonferroni Post Hoc Tests for attitudes towards science, significant differences were found between the attitudes of Year 4 and 5 students favouring Year 5, and of Year 4 and 6 students, favouring Year 6. However, the attitudes towards science between Year 5 and 6 students were not statistically significant.

Two-Way Gender and Grade Level Interaction Effect

Based on Table 3, there was no statistically significant effect of interaction between gender and grade level, $F(2, 78) = 0.243$, $p = .784 > .05$, for attitudes towards science. The descriptive statistics by gender and grade level for attitudes towards science are given in Table 6.

Table 6. *Means and Standard Deviations by Group and Grade Level for Attitudes Towards Science*

	Boys (n=49)						Girls (n=35)					
	Year 4 (n=19)		Year 5 (n=11)		Year 6 (n=19)		Year 4 (n=10)		Year 5 (n=14)		Year 6 (n=11)	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
attitudes towards science	16.58	4.51	20.18	3.63	19.42	3.36	15.70	3.37	18.71	1.49	19.27	2.97

Ethnicity Effect

The attitudes towards science between the Malay and the Aboriginal students were investigated by performing an independent samples t-test. As shown in Table 7, the analysis of independent samples t-test yielded a $t(83)$ of 3.22 that was statistically significant ($p < .05$). This indicates that the level of attitudes towards science among the Malay students is statistically significantly higher than the level of attitudes among the Aboriginal students.

Table 7. *Results Obtained from İndependent Samples T-Test for Attitudes towards Science*

Malay			Aboriginal				
N	Mean	SD	N	Mean	SD	t	p
61	19.05	3.24	23	16.30	4.06	3.22	.002

DISCUSSION and CONCLUSION

The aims of this research were to explore the differences in attitudes towards science among the Malay and Aboriginal Year 4, 5 and 6 primary students, specifically by gender, grade level, and ethnicity. Since there was no two-way interactional effect between gender and grade level, the main effects for gender as well as grade level could therefore be interpreted in a straightforward manner without any concern of moderating effect. The findings indicated that, while there was no significant difference in attitudes towards science between the boys and the girls, there was a statistical significant difference by grade level in which Year 5 students had more positive attitudes towards science than Year 4 students, and that Year 6 students had more positive attitudes towards science than Year 4 students. However, there was no significant difference in attitudes towards science between Year 5 and Year 6 students. In terms of ethnicity, the Malay students have more favorable attitudes towards science as compared to the Aboriginal students.

The findings of this study in which Year 4 (aged 10 in Malaysia) students' level of attitudes towards science seems to increase as they progress to Year 5 (aged 11) and subsequently hovering around or rather plateuring at similar level in Year 6 (aged 12), provide credence to Osborne, Driver, and Simon's (1998) observation that positive attitudes towards school science appear to peak at, or before, the age of 11. Such parallel findings were rather accidental because the participants in Osborne, Driver, and Simon's (1998) study were geographically, culturally, and socially dissimilar, albeit similar in age. Accordingly, this may suggest similar trend in students' attitudes towards science at ages 10-12 across boundaries, and that such attitudinal trend is not idiosyncratic to Malaysian students. Further study is required to determine if similar trend in attitudes towards science can be found should a more representative sample be used. Morever, this trend in attitudes towards science among the Malay and Aboriginal students can be explained within the context of primary science teaching in Malaysia. One of the possible explanations is that science is introduced as a subject in Year 1 with simple hands-on, minds-on, and hearts-on classroom activities, and these activity-based lessons increase in numbers and complexity in tendem to the cognitive demand as stipulated in the syllabuses. At Years 5 and 6, the teaching and learning of science in the primary classrooms is characterized by note-copying and drilling in preparation for the National Standardised "Primary School Evaluation Test" or its acronym UPSR (*Ujian Penilaian Sekolah Rendah*), and this may contribute towards a stagnated level of attitudes towards science among these Year 5 and 6 students.

The finding in this study which shows no difference in attitudes towards science between the girls and the boys is not consistent with the study of Lightbody and Durndell (1996) and meta-analyses of Schibeci (1984), Becker (1989), and Weinburgh (1995) which indicate that boys have consistently more positive attitudes towards science. The no-gender-difference phenomenon could be explained from a sociocultural perspective. While boys and girls at the primary ages see themselves as members of a group, the group membership seems to be gender inclusive, rather than gender exclusive where the boys see themselves in a masculine group and the girls, feminine group. Gender exclusive perception has been propounded to explain the differences in achievement where boys more than girls reckon that excelling in education as not "cool" (Francis, 2000; Warrington, Younger, & Williams, 2000; Whitelaw, Milosevic, & Daniels, 2000) and that displaying a positive attitudes towards science as not being the "done thing" (Osborne, Simons, & Collins, 2003, p. 1054). By similar vein, it can be theorized that gender inclusive perception which is more dominant among non-adolescent boys and girls, may explain for the non-statistical difference in attitudes towards science by gender. This has implications for science teaching, particularly in structuring group activity, where teachers should make a conscious effort and preparation to ensure that heterogeneous grouping is used in activity-based lessons; heterogeneity not only in terms of academic achievement, but also in terms of gender and ethnicity.

In relation to ethnicity in which the Malay students have more positive attitudes towards science than the Aboriginal students, we were not able to find any previous studies done with which this finding could be directly compared, thus explaining the novelty and distinctiveness of the ethnicity effect of this study. However, there is a cause for concern as the Aboriginal students who responded to the attitudinal questionnaire in this study were the students who did not play truant on that day. What about the level of attitudes towards science among those Aboriginal students who were absent? As such, it would contribute significantly to the research and literature if the future research could determine whether such level of attitudes towards science is reflective of the Aboriginal students through a more representative sampling at the district, state and national levels.

The data collected in this study were based on students' self-rating on the questionnaire, and hence subjective in nature. While the validity and reliability of students' self-ratings are no longer a bone of contention (Meece, Anderman, & Anderman, 2006; Ramsden, 1997) and that the use of self-ratings has been widespread even among highly respected researchers who used self-ratings of students (Fraser, 1981; Hofstein & Lazarowitz, 1986; Kempa & Orion, 1989), a more balanced, comprehensive, and triangulated view is advocated by considering the views of teachers and parents.

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Application of Multiple Representation Levels in Redox Reactions among Tenth Grade Chemistry Teachers

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ABSTRACT

Utmost important is students should be able to understand chemistry concepts at multiple representation levels and integrate between these levels. However, previous research showed that students face difficulty in this aspect. Thus, this study embarked into investigating how chemistry teachers apply these multiple representation levels in teaching redox reactions through verbal interaction. Ten chemistry secondary school teachers in Kuala Lumpur, Malaysia were involved in this study. Data were collected using observation and semi-structured interview. Analysis of data was done quantitatively to determine the percentages of verbal interaction at multiple representation levels. Data were also analyzed qualitatively to determine the pattern of application of multiple representation levels. Findings showed that teachers emphasized more on macroscopic level compared to submicroscopic and symbolic levels. It was found that students' statement on multiple representation levels dominates interaction that occurred during chemistry lessons observed. Furthermore, there were three types of patterns of integration between multiple representation levels illustrated by chemistry teachers. Eighty percent of the respondents showed incomplete integration between these multiple representation levels. In conclusion, chemistry teachers should be aware and understand the application of these multiple representation levels in order to produce chemically literate students.

Keywords: Multiple Representation Levels; Macroscopic; Submicroscopic; Symbolic; Verbal Interaction.

INTRODUCTION

In Malaysia, students start learning chemistry as a subject in tenth grade. The students will learn many concepts in chemistry in two years before they are required to sit for the public examination prepared by Malaysian Education Certificate at the end of Form Five (Year 11). In Curriculum Specifications Chemistry for Secondary Schools developed by Curriculum Development Centre, there are nine chapters in Tenth Grade (Year 10) and five chapters in Form Five (Year 11) (Curriculum Development Centre, 2005; Bahagian Pembangunan Kurikulum [Curriculum Development Centre, 2012). Allocation of time for chemistry lessons specified by the Ministry of Education (1990) is 160 minutes per week. With so many concepts to be learned and being a novice learner in scientific community, this

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subject is considered as difficult. This is supported by Johnstone (2000); Sirhan (2007); Tsaparlis, Koliulis and Pappa (2010) and Noor Dayana et al. (2010) which stated that chemistry is considered as one of the tough subject.

Chemistry involves understanding and application of chemical concepts. Chemistry concept or knowledge can be represented at multiple representation levels which are also known as chemistry triplet (Talanquer, 2011) or triplet relationship (Gilbert and Treagust, 2009). These multiple representation levels are the observable world (macroscopic), model (submicroscopic world) and symbolic level (Johnstone, 1991, 2000; Treagust, Chittleborough and Mamiala, 2003; Jaber and BouJaoude, 2012). Johnstone (1993) stated that chemistry which was often discussed in terms of macro and symbolic level, which excludes the submicro part. Therefore, this study attempts to study the verbal interaction at multiple representation levels in redox reactions lessons. These forms of the subject are the macro and tangible: what can be seen, touched and smelt; the submicro: atoms, molecules, ion, structures; and symbolic: the representational symbols, formulae, equations, molarity, mathematical manipulation and graphs (Johnstone, 2000). He added that in order to 'fully understand' chemistry, more emphasis should be given to submicro and symbolic levels (Johnstone, 2000). Jaber and BouJaoude (2012) pointed that failure to understand chemistry at multiple representation levels could lead to alternative conception and prevent students to learn and appreciate chemistry. Not only understanding at these levels are important, students should also link between one level to the other or integrate these levels as these chemical representations complement each other (Johnstone, 2000; Treagust, Chittleborough and Mamiala, 2003) (see Figure 1).

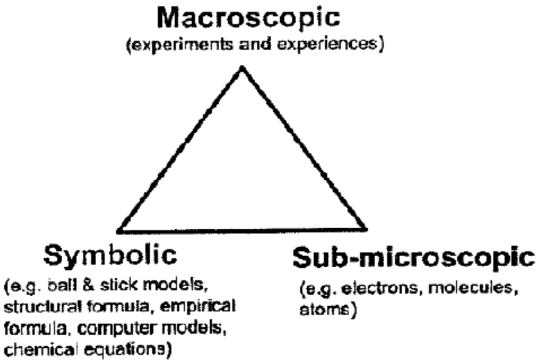


Figure 1: *Three Levels of Representation in Chemistry (Johnstone, 1991; Treagust, Chittleborough and Mamiala, 2003)*

In other words, to understand chemistry, it needs a deep and thorough understanding of a concept. This is the key component in learning chemistry. There is evidence which showed that chemistry students often face difficulty with regards to this chemistry triplet (Gilbert and Treagust, 2009). Students unable to relate observations made (macroscopic) to submicroscopic and symbolic world. Understanding at submicroscopic level involves understanding particulate nature of matter. However, due to students' inability to visualise the particles, unable to make connection between macro and submicroscopic add to the challenge for students to learn chemistry. Eventually, due to the complexity of these multiple representation levels, which is the nature of chemistry itself left the students fell bored, frustrated and ended up with memorising the facts. They 'learn' chemistry through rote learning as reported by Nurfaradilla et al. (2010). This rote learning acts as barrier to meaningful learning as stated by Dori and Hameiri (2003).

The application of these multiple representation levels in redox reactions is as follows. For example, a reaction between zinc and copper (II) sulphate solution, students could do some observation at the end of the reaction. The students could have observed that, for example, a brown solid is deposited. That observation represents the macroscopic level. In order to understand what actually happens in the reaction, we have to look at submicroscopic and symbolic level, which is the type of particles, took part in the reaction. In the example of displacement reaction, zinc metal which is all in atom form will displace copper two ions from its salt solution (submicroscopic). The reaction can be represented by the following chemical and ionic equation (symbolic).

$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$ (chemical equation)
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$ (ionic equation)

Sadly, in many experiments, students were being taught to write 'standard' answer (Tan et al., 2009). If the teacher did not explain what happens in the reaction occurred and by writing chemical and ionic equation, obviously the students' understanding was merely at macroscopic level.

Redox reactions concepts were mainly interaction between macroscopic and submicroscopic world, which is the source of difficulty for many chemistry learners as reported by Garnett and Treagust (1992); De Jong, Acampo and Verdonk (1995); Sanger and Greenbowe (1997); Tsaparlis (2007), and also difficult for teacher to teach (De Jong, Acampo and Verdonk, 1995). Furthermore, there is lack empirical studies on this topic (De Jong and Treagust, 2002) in terms of student's difficulties in learning. This topic was chosen also as it is related to oxidation and reduction which students will learn in Year 11 (Curriculum Development Centre, 2005; 2012). Therefore it is of utmost important that these students grasp and master the concepts in this topic. Nevertheless, explanation of relevant concepts in textbooks were found to be insufficient to provide students with adequate conceptual knowledge of the topic (Ozkaya, 2002). This is where teacher plays an important role here. The way teacher explain the concept is more important than the quantity of concepts impart to the students. Sirhan (2007) mentioned that information delivered to students is not always learned. If teacher fails to explain chemistry concepts at multiple representation levels, it may leads to misconceptions.

Classroom learning involves interaction, between teacher and students (Suchman, 1966; Brown, 1975; Chamberlain and Llamzon, 1982), or between student and other students (Suchman, 1966). According to Shahabuddin, Rohizani and Mohd. Zohir (2003), there are two types of interaction which occur in classroom; verbal interaction and non-verbal interaction. This study focused on verbal interaction as verbal interaction is the common type of interaction that occurred in classroom claimed by Chamberlain and Llamzon (1982). Furthermore, verbal interaction could be used to investigate the process of teaching and learning in classroom as stated by Flanders, 1970; Eggleston, Galton and Jones, 1975; Malamah-Thomas, 1987; Mohamed Najib, 1997; Brandon *et al.*, 2008). Three main components of verbal interactions are teacher's talk, student's talk and silence (Flanders, 1970; Eggleston, Galton and Jones, 1975; Malamah-Thomas, 1987) or confusion (Mohamed Najib, 1997). Teacher's talk could be either teacher's question or teacher's statement; and student's talk could represents either student's question or student's statement. Although research suggest the integration of these three aspects and the importance of these aspects (De Jong and Taber, 2007; Gilbert and Treagust, 2009; Tan et al., 2009), yet there is lack empirical research on how chemistry teachers at secondary schools apply multiple representation levels during chemistry lesson. Hence, this study addresses this issue to provide insight into application of triplet relationship in chemistry lesson.

This study was designed to describe and provide explanation on application of multiple representation levels among chemistry teachers. In specific, research questions are as follows:

1) What are the verbal interactions at multiple representation levels emphasised by chemistry teachers in teaching redox reactions?
2) How do chemistry teachers link between these multiple representation levels in teaching redox reactions?

METHODOLOGY

The following section discuss about setting and participants, instrument and data analysis.

a) Settings and participants

This mixed method study involves seven urban secondary schools, in Kuala Lumpur, Malaysia. Quantitative data was first collected, analysed, followed by qualitative data. Qualitative data was used to explain findings of quantitative data as stated by Creswell (2009). Therefore, these two types of data were needed as they complement each other to enhance understanding of the application of multiple representation levels among chemistry teachers.

This study involved ten chemistry teachers with teaching experience ranging between one to twenty five years of teaching chemistry. The students were of mixed ability. General information about the background of these teachers, who were the focus in this study (see Table 1).

Table 1: *Participant Information*

Participant	Gender	Academic Qualification	Specialisation	Teaching experience (year(s))	Academic Responsibilities
R01 (SMK A)	Female	Bachelor of Education	Chemistry	5	Chemistry teacher
R02 (SMK B)	Male	Bachelor of Education	Biology/Chemistry	2	Chemistry teacher
R03 (SMK C)	Female	Bachelor of Education	Biology/Chemistry	3	Chemistry teacher
R04 (SMK D)	Male	Bachelor of Education	Mathematics/Chemistry	7	Chemistry teacher
R05 (SMK E)	Female	Bachelor of Education	Chemistry	8	Head of Chemistry Panel
R06 (SMK E)	Female	Bachelor of Education	Chemistry	3	Head of Chemistry Panel
R07 (SMK F)	Female	Bachelor of Education	Biology/Chemistry	15	Head of Science and Mathematics Division
R08 (SMK G)	Female	Bachelor of Education	Chemistry	1	Head of Chemistry Panel
R09 (SMK G)	Female	Bachelor of Education	Chemistry	25	Head of Science and Mathematics Division
R10 (SMK H)	Female	Master of Education	Chemistry	10	Chemistry teacher

R: Respondent

The data was collected over six months and involved two major data collection tools, which are observation instrument and semi-structured interview. Each teacher was observed four times. Duration of each lesson lasted between 70 to 80 minutes. Observations were done based on date agreed between the researchers and the respondent. Field note was also used to complement data obtained from the two major data collection methods. The researchers explained the purpose, instruments that will be used and the nature of the study which involved recording the observations. Researcher also emphasised that observations will be recorded and these recordings are only done to cater the purposes of this study and the participants are ensured of confidentiality and anonymity of the participants. Only the researchers have access to the recordings. As this study involved video and audio recording of lessons observed, teachers are selected based on their consent given to participate in this study.

b) Instrument

An observation instrument, known as Observation Instrument in Inquiry Teaching through Verbal Interaction (OIITVI) was built to identify the verbal interaction of teacher and students at multiple representation levels in chemistry lessons (see Appendix 1). This instrument was built based on modification of previous existing classroom observation instruments developed by Flanders (1970), Eggleston, Galton and Jones (1975); Mohamed Najib (1997), Brandon et al. (2008) and Tay (2010). Time sampling was every three seconds as used by other researchers (Flanders, 1970; Mohamed Najib, 1997 and Tay, 2010). Face validity and content validity has been obtained from two senior lecturers specialised in chemistry education and one Master chemistry teacher to ensure that this instrument (OIITVI) able to determine the inquiry teaching practices in chemistry lessons. In terms of reliability of this observation, inter-rater reliability was applied as suggested by Creswell (2008). Hence, the researcher and two other chemistry lecturers categorise a recorded chemistry lessons of 30 minutes using the instrument (OIITVI). Kappa value which measures the agreement between observers was used to express the agreement between observers. Calculated kappa values obtained were .977 and .808 for the first and second lecturer respectively. These values showed high agreement between observers (Viera and Garrett, 2005). Besides that, to ensure the reliability of data obtained from the OIITVI, recorded chemistry lessons were listened twice.

These teachers were then interviewed based on the result obtained from the observation. The interviews were conducted in order to explore and understand in detail about chemistry teacher's inquiry teaching practices (Bennett, 2003). Example of questions asked were "Are you aware of macroscopic, submicroscopic and symbolic terminology?", "Based on observations, you tend to focus more on macroscopic aspect compared to submicroscopic and symbolic levels. Why?" and "How do you emphasise on these multiple representation levels aspect in teaching chemistry?".

Protocol of the interviews was as suggested by Creswell (2008).

Date of interview:
Time :
Venue :
Interviewer :
Respondent :

These interviews were audio recorded after respondents' consent was obtained and transcribed verbatim.

c) Data Analysis

Process of analysing data was done concurrently with the collection of data. Chemistry lessons observed was first categorised based on categories in the observation instrument, Observation Instrument in Inquiry Teaching through Verbal Interaction (OIITVI) (see

Appendix 1). Categories 1a until 1p represent teacher's questions and 2a until 2w represents teacher's statement. On the other hand, student's question categories and student's statement categories were represented by categories 3a, 3b, 3c; and 4a, 4b, 4c respectively. Descriptive statistics in terms of percentage of verbal interaction at multiple representation levels were then calculated. The results were reported according to four main categories of verbal interaction observed (teacher's question, teacher's statement, student's question and student's statement). Data were analysed using Statistical Package for Social Sciences PASW Version 18.0.

Analysis on how teachers integrate these multiple representation levels was done manually. All recorded chemistry lessons and interviews were transcribed verbatim. In order to ensure validity of the findings, the participants were showed the transcribed classroom observation lessons and interviews made. Overall, the participants agreed with the transcribed lessons and interviews made by the researcher.

FINDINGS and DISCUSSION

This part discusses findings on distribution of multiple representation levels in redox reactions and how teachers apply multiple representation levels in teaching.

What Are The Verbal Interactions of Multiple Representation Levels Emphasised by Chemistry Teachers in Teaching Redox Reactions?

Overall distributions of multiple representation levels are stated in terms of percentage which is shown in Figure 1. Chemistry teachers in this study tend to focus on macroscopic level, followed by symbolic level and the least were submicroscopic level. Teacher's focus on macroscopic level was also reported by Tan *et al*. (2009). This finding differed from findings from previous researchers, Garnett and Treagust (1992), Sanger and Greenbowe (1997) whom stated that electrochemistry topic, which also includes redox reactions deals mainly with macroscopic and submicroscopic levels. This showed that chemistry teachers showed a slight deviation from the common teaching practice in this topic. Submicroscopic level is very important, especially in this topic, as it explains the macroscopic aspect (observations made during the laboratory sessions) and explain a chemical concept in detail as mentioned by Johnstone (2000).

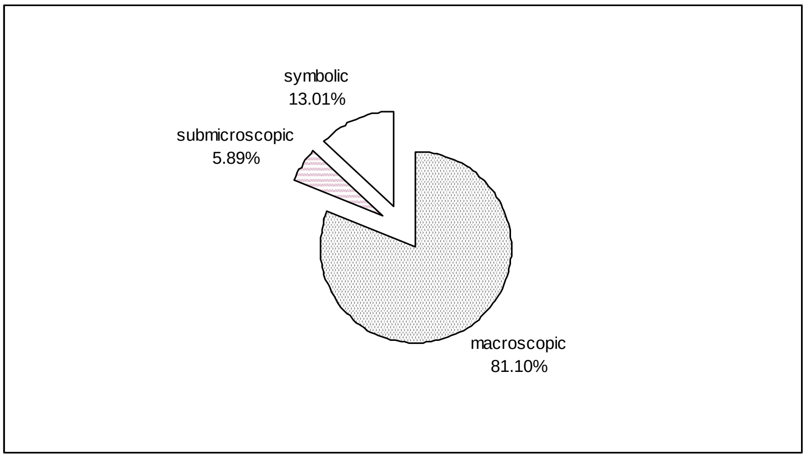


Figure 2: *Overall Distribution of Multiple Representation Levels in Redox Reactions*

Figure 3 shows a detail analysis of distribution of multiple representation levels in terms of teacher's question, teacher's statement, student's question and students' statement.

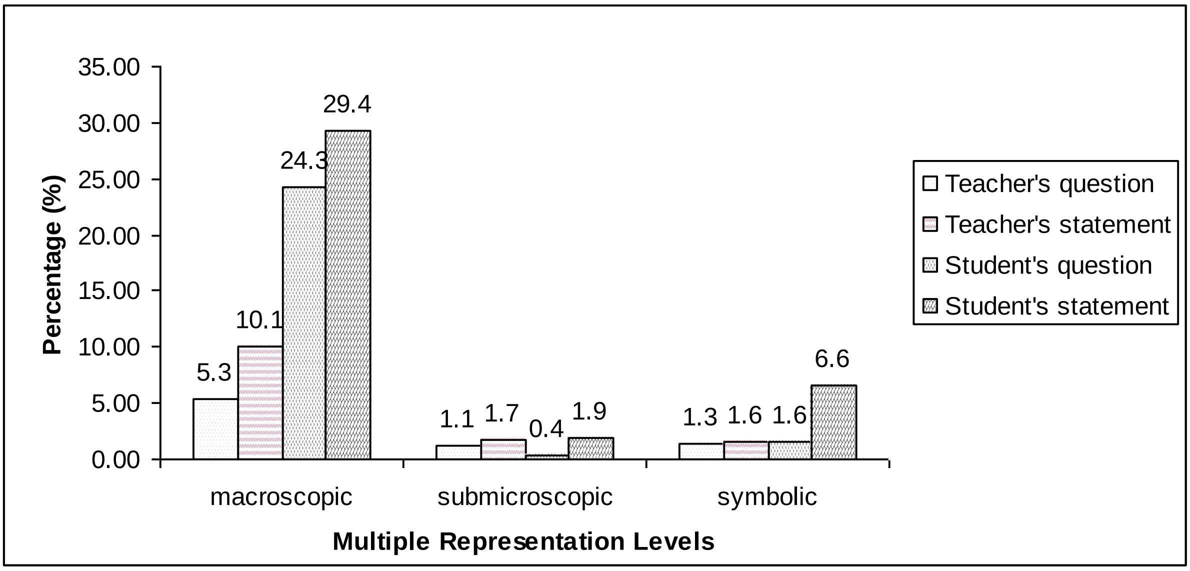


Figure 3: *Distribution of Multiple Representation Levels in Redox Reactions according to Categories of Verbal Interaction*

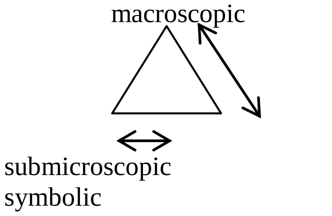
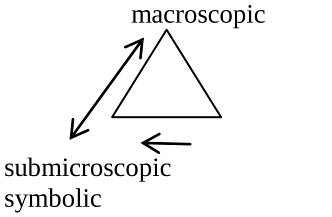
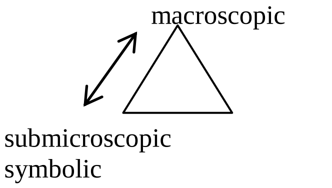
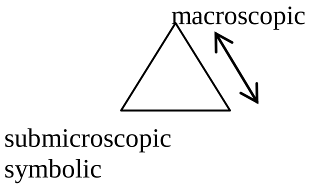
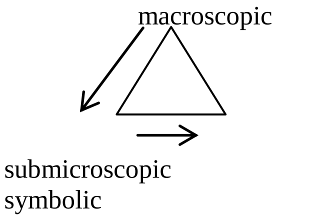
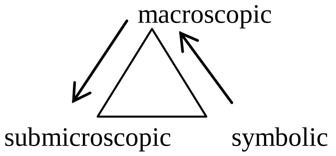
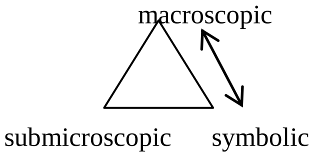
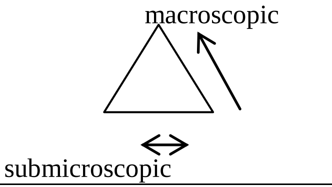
Surprisingly, finding from this study showed that the teaching and learning process is student-centred as percentage of student' talk, either questions or statements are higher than percentage of teacher talk. Student's statement dominates the interaction that occurred in the classroom which is 37.9%. Domination of students' verbal interaction was mostly due to respondents' encouragement and positive attitudes towards students' involvement during teaching and learning process. Students were seen giving response to teachers' questions or statements.

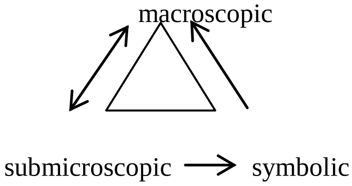
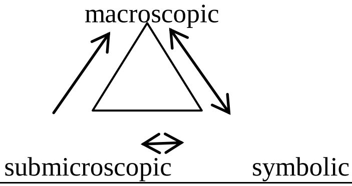
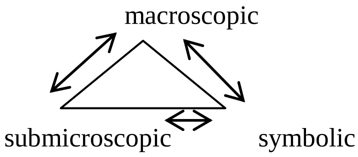
In terms of teacher's talk at multiple levels of representation (macroscopic, submicroscopic, symbolic), percentage of teacher's statement (13.4%) is higher than percentage of teacher's question, which was only 7.7%.

How Do Chemistry Teachers Link Between These Multiple Representation Levels in Teaching Redox Reactions?

Based on the transcribed classroom observations, line by line coding was made under three major themes. Three major themes are macroscopic, submicroscopic and symbolic. There are two types of arrows presented in this table. The single headed arrow, ⟶ represents shift from one representation level to another. The double headed arrow, which is represented by ⟷ means there is continuous link between the two representational levels. As shown in Table 2, there are three patterns of integration of multiple representation levels in teaching redox reactions.

Table 2: *Patterns of Application of Multiple Representation Levels*

Type of Pattern	Respondent	Pattern	Explanation
1	R01, R02, R03, R04, R05, R06, R07, R08, R09, R10	       	Incomplete integration of multiple levels of representation as it involves two levels of representation only. Furthermore, there is no continuous discussion on these three levels as represented by single headed arrow (↔).

		symbolic	
2	R05, R07	 	Incomplete integration of multiple levels of representation. Although the three levels of representation were applied in discussing a concept, however, there is no continuous discussion on these three levels as represented by single headed arrow (→).
3	R06, R10		Complete integration of multiple levels of representation. The three levels of representation were applied in discussing a concept, and there is continuous discussion on these three levels as represented by double headed arrow (↔).

Type of pattern 1 showed the emphasis and integration occurred between two representation levels only. All respondents showed this type of pattern during the observed chemistry lessons. This type of pattern showed incomplete integration of multiple levels of representation as it involves two levels of representation only. Example of an episode of chemistry lesson that illustrates pattern 1:

[Context of lesson: Electrolysis of lead (II) bromide]

Teacher: See here... There is little bit of grey solid formed at this electrode. This electrode, is it anode or cathode? → macroscopic

Student 1: So, at cathode, were the electrons accepted or released? → submicroscopic

Accepted.

[Respondent R01]

Nevertheless, it was found that there were two other types of patterns. Besides type of pattern 1, two respondents (R05 and R07) showed pattern 2. This type of pattern showed emphasis occurred on three levels, however the integration is incomplete.

Example of episode of lesson that showed pattern 2 as shown below:

[Context of lesson: Reaction between magnesium and copper, copper and copper metals]

Teacher : Which metal is more electropositive?
Ok…the position is higher in the electrochemical series?
Student 1 : Copper.
Student 2 : Magnesium.
Teacher : Ok. Magnesium metal.
Ok, why is magnesium more electropositive than copper?

→ macroscopic

Student 3 : Tendency to release electron higher. → submicroscopic

Teacher : Because the position higher in?
Student 4 : Electrochemical series.
→ macroscopic

Teacher : Which metal will donate the electrons?
Student 2 : Magnesium.
→ submicroscopic

Teacher : Ok, so, magnesium will donate the electrons.
Ok, how many electrons?
(Teacher writing half equation at white board)
Student 1 : Three.
Student 2 : Two.
Teacher : Ok. Two.
→ symbolic

[Respondent R02]

In type 1 and type 2 patterns displayed, these respondents do not ask probing questions to enhance discussion on redox reactions. Questions asked were merely based on questions in the chemistry textbooks or modules. Consequently, there was lacking of integration between these three levels of representations.

Meanwhile, respondents R06 and R10 also displayed type of pattern 3, besides than type of pattern 1. This type of pattern 3 showed complete linkage between these three representation levels. The best practice of teaching chemistry is showed by type of pattern 3.

However, only two teachers (20%) of the participants showed this pattern.

Example of an episode of the lesson which showed this pattern is as shown below:
[Context of lesson: Displacement reaction]

Teacher : Do you observe what happened?
Student : Yes.
Teacher : Really? If yes, Danisa, what happened to the magnesium ribbon?
Danisa : Corrode…
Teacher : Other than that?
Student 1 : Thinner.
Teacher : Other than thinner?
Student 2 : Dissolve.
Teacher : Yes. Magnesium dissolves or becomes thinner. How about copper plate, Ailia?
Ailia : Gas bubbles are released at copper plate.
→ macroscopic

Teacher : Is it the copper that releases the hydrogen?
Student 3 : No.
Teacher : From the…?
Student : Solution.
Teacher : Ok, magnesium atom will form? Magnesium?
Student 3 : Ion.
→ submicroscopic

Teacher	:	Yes, it will forms magnesium ion, Mg two plus. Where do we add these electrons? (Teacher writing equation on the white board)	→ symbolic
Student	:	On the right.	
Teacher	:	Ok, and then put the two in front. (Teacher balancing half ionic equation).	
Teacher	:	Initially, magnesium is in the form of metal. Then, it dissolves.	→ macroscopic
Teacher	:	Why it dissolves? As it becomes? Ion. Where do the electrons go? (showing the equation)	→ symbolic
		Electrons will flow to copper plate. What are the ions present in the electrolyte?	→ submicroscopic
		Na plus, H plus… (Teacher writing the chemical formula on the white board)	→ symbolic
Student 2	:	OH minus.	
Teacher	:	And?	
Student 2	:	H plus.	
Teacher	:	The voltmeter reading shows the flow of electron.	→ submicroscopic
		That is the reason the voltmeter shows a reading.	→ macroscopic

[Respondent R06]

[Note: Danisa and Alia – pseudonym]

The example above showed that respondent R06 emphasises on these multiple levels of representation and at the same time showed complete integration between these levels. Based on observations made by students during practical work (macroscopic level), the teacher linked those observations made (magnesium ribbon dissolves and gas bubbles released at copper plate) to the theory to explain the phenomena (magnesium atom will forms magnesium ion - submicroscopic level). Not only that, half equations of the reaction were discussed (symbolic level). Hence, teachers should assist students in understanding chemical concepts at multiple levels of representation to enhance their conceptual understanding as suggested by Valanides, Nicolaidou and Eilks (2003); Tan *et al*. (2009); Nieves, Barreto and Medina (2012). This is because these three levels of representations complement each other (Johnstone, 2000). Furthermore, students' reasoning and problem solving skills could be improved when they learn scientific concepts at multiple representation levels as stated by Nieves, Barreto and Medina (2012).

In order to investigate why teachers lacked practice of integration between these multiple levels of representation, semi-structured interviews were carried out. The finding from the semi-structured interviews revealed that all these teachers could not define the terms "macroscopic, submicroscopic and symbolic" as they were seemed not to be aware of these terms. Example of the transcribed interview:

Researcher : Are you aware of macroscopic, submicroscopic and symbolic terminology?

Respondent 03: Ah? What is that?

After the researcher explained about these three terminologies, further question was asked.

Researcher : You tend to focus on macroscopic compared to submicroscopic and symbolic. Could you explain why?

Respondent R03: Based on my experience, as these students I am teaching are weak students, hence, I focused more on macroscopic level which were mostly asked in the examination.

Lacking in full integration at these multiple representation levels also may be due to teachers were not exposed to these terminologies and depends on ability of the students in the class. Treagust and Chandrasegaran (2009) emphasized that teachers should be aware of these terminologies and need to apply these multiple representation levels in explaining chemical phenomena during classroom instruction. Teachers' implications of integrating these multiple representation levels could lead to their students' understanding of chemistry concepts.

CONCLUSION and IMPLICATION

The aims of this research were to explore the differences in attitudes towards science among the Malay and Aboriginal Year 4, 5 and 6 primary students, specifically by gender, grade level, and ethnicity. Since there was no two-way interactional effect between gender and grade level, the main effects for gender as well as grade level could therefore be interpreted in a straightforward manner without any concern of moderating effect. The findings indicated that, while there was no significant difference in attitudes towards science between the boys and the girls, there was a statistical significant difference by grade level in which Year 5 students had more positive attitudes towards science than Year 4 students, and that Year 6 students had more positive attitudes towards science than Year 4 students. However, there was no significant difference in attitudes towards science between Year 5 and Year 6 students. In terms of ethnicity, the Malay students have more favourable attitudes towards science as compared to the Aboriginal students.

This study shed some light in bridging the gap between theory and practice of multiple representation levels in chemistry lessons. Although many researchers suggest the usage of integration on multiple representation levels, how chemistry teachers make link between these three representation levels is still unknown. Finding of this study showed that majority of the chemistry teachers emphasised on macroscopic aspect, followed by symbolic and the least was submicroscopic aspect. Perhaps teachers could use model as suggested by De Jong and Taber (2007) or video animation to illustrate particles involved during a chemical reaction in redox reactions. Besides that, hands-on activity that incorporates these three levels of representation as suggested by Nieves, Barreto and Medina (2012); González-Sánchez, Ortiz-Nieves and Medina (2014) are needed to enhance the application of these three levels during classroom instruction.

Percentage of student's talk is higher than teacher's talk, which showed a positive sign towards student-centred classroom. In terms of the manner teacher integrates these multiple representation levels in classroom, there is lacking of the integration between these three levels, as it involves only two levels of representation (pattern 1) (see Table II). Teachers should try to link observations made at the macroscopic level to explain the observations made at submicroscopic level as mentioned by Tsaparlis (2009). Based on the finding from the interviews, chemistry teachers should be aware of these terminologies of multiple representation levels. Although, most of these teachers specialised in chemistry education, they have not heard of these terms and therefore could not define when asked by the researchers.

Application of these three levels of representation is the key model for chemical education (Gilbert and Treagust, 2009). Therefore, lecturers of higher institution should look into this matter seriously in preparing well-versed pre-service teachers in these aspects. Furthermore, in-house training should be organised for in-service teachers to expose these teachers with these multiple representation levels and the application of it in chemistry lesson. This is necessary as teachers are the key person in producing chemically literate students.

As this study focused on redox reaction, in future, an extensive in-depth study on other chemistry topics which involves verbal and non-verbal aspects of interactions is necessary to provide a broader view of application of multiple representation levels.

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APPENDIX 1: *Observation Instrument in Inquiry Teaching through Verbal Interaction (OIITVI)*

Category			Reference	Representation level
Teachers' question (Flanders, 1970; Mohamed Najib, 1997; Egglestone, Galton and Jones, 1975; Brandon *et al.*, 2008; Tay, 2010)	Content	1a. to relate students' prior knowledge and lesson	Eggleston, Galton and Jones,1975; Tay, 2010	macroscopic
				submicroscopic
				symbolic
		1b. to arouse students' thinking of a concept	Tay, 2010	macroscopic
				submicroscopic
				symbolic
		1c. to obtain meaning of a definition/principle/concept	Mohamed Najib, 1997; Brandon *et al.*, 2008	macroscopic
				submicroscopic
				symbolic
	Science process skills	1d. Observing	Eggleston, Galton and Jones,1975	macroscopic
				submicroscopic
				symbolic
		1e. Classifying		macroscopic
				submicroscopic
				symbolic
		1f. Measuring and Using Numbers		macroscopic
				submicroscopic
				symbolic
		1g. Making Inferences	Egglestone, Galton and Jones, 1975, Mohamed Najib, 1997	macroscopic
				submicroscopic
				symbolic
		1h. Predicting		macroscopic
				submicroscopic
				symbolic
		1i. Communicating		macroscopic
				submicroscopic
				symbolic
		1j. Using Space-Time Relationship		macroscopic
				submicroscopic
				symbolic
		1k. Interpreting data	Egglestone, Galton and Jones, 1975	macroscopic
				submicroscopic
				symbolic
		1l. Defining operationally		macroscopic
				submicroscopic
				symbolic
		1m. Controlling variables		macroscopic
				submicroscopic
				symbolic
		1n. Making hypothesis	Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997	macroscopic
				submicroscopic
				symbolic
		1o. Experimenting	Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997	macroscopic
				submicroscopic
				symbolic
	Not related to content/science process skills	1p. Class management	Tay, 2010	
Teachers' statement (Egglestone, Galton and Jones, 1975; Mohd Najib, 1997; Brandon *et al.*, 2008; Tay, 2010)	Content	2a. to relate prior knowledge and lesson		macroscopic
				submicroscopic
				symbolic
		2b. state the objective of the lesson		macroscopic
				submicroscopic
				symbolic
		2c.accept or use students' ideas	Flanders, 1970; Tay, 2010	macroscopic
				submicroscopic
				symbolic
		2d. explanation	Flanders, 1970; Tay, 2010	macroscopic
				submicroscopic
				symbolic
		2e. application of the concept		macroscopic
				submicroscopic
				symbolic
	Science process skills	2f. Observing		macroscopic
				submicroscopic
				symbolic

		2g. Classifying		macroscopic submicroscopic symbolic
		2h. Measuring and Using Numbers		macroscopic submicroscopic symbolic
		2i. Making Inferences		macroscopic submicroscopic symbolic
		2j. Predicting	Egglestone, Galton and Jones, 1975	macroscopic submicroscopic symbolic
		2k. Communicating		macroscopic submicroscopic symbolic
		2l. Using Space-Time Relationship		macroscopic submicroscopic symbolic
		2m. Interpreting data		macroscopic submicroscopic symbolic
		2n. Defining operationally		macroscopic submicroscopic symbolic
		2o. Controlling variables		macroscopic submicroscopic symbolic
		2p. Making hypothesis	Egglestone, Galton and Jones, 1975	macroscopic submicroscopic symbolic
		2q. Experimenting	Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997	macroscopic submicroscopic symbolic
	Related to students' statements	2r. Praise/encourage/guide	Flanders, 1970; Brandon *et al.*, 2008; Tay, 2010	
		2s.criticize/ authority justification	Flanders, 1970; Tay, 2010	
	Related to students' questions	2t. With answer	Mohamed Najib, 1997; Tay, 2010	macroscopic submicroscopic symbolic
		2u. No answer	Brandon *et al.*, 2008; Tay, 2010	
		2v.revert the questions to class		macroscopic submicroscopic symbolic
	Not related to student's statement or question	2w. Give instruction	Flanders, 1970; Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997	
Students' question (Flanders, 1970; Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997; Brandon *et al.*, 2008; Tay, 2010)	Related to content/science process skills	3a. to obtain/verify facts/principles/ concepts	Mohamed Najib, 1997; Egglestone, Galton and Jones, 1975; Tay, 2010	macroscopic submicroscopic symbolic
		3b. to obtain explanation of a process	Mohamed Najib, 1997; Egglestone, Galton and Jones, 1975; Tay, 2010	macroscopic submicroscopic symbolic
	Not related to content/science process skills	3c. Class management	Tay, 2010	
Students' statement (Flanders, 1970; Mohd Najib, 1997; Brandon *et al.*, 2008)	Related to teachers' questions or statement	4a. with answer	Flanders, 1970; Mohamed Najib, 1997; Tay, 2010	macroscopic submicroscopic symbolic
		4b. no answer	Brandon *et al.*, 2008; Tay, 2010	
	Chemistry content	4c. To give further explanation		macroscopic submicroscopic symbolic

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Students' Conceptions of Learning in Genetics: A Phenomenographic Research

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ABSTRACT

The purpose of this study is to identify university students' conceptions of learning in genetics. In this study, 108 students were asked to answer to open-ended questions to identify how they conceive learning genetics. The data were analyzed using phenomenographic method. According to the results, sampled university students' conceptions of learning genetics can be divided into five different categories as follows; memorization, testing, research, application and seeing in a new way. The educational system and learning environment, to which these university students enrolled, played a role in their conceptions of learning genetics. This study proposed a framework to describe the variations of the conceptions of learning and how to consist of the desired conceptions.

Keywords: Conceptions of Learning; Genetics; Phenomenographic Method; Higher Education.

INTRODUCTION

One of the primary goals of the studies carried out in the field of education is to find new ways to increase student achievement. In that respect, variety of research studies have been conducted with numerous variables as different teaching methods and techniques, identification of students' cognitive and affective qualities, increasing both teachers and students' motivation and conceptions of scientific knowledge. Another issue that has recently attracted the attention of researchers is to clarify how students are conceptualizing learning especially in different countries. It is claimed that students' approaches and conceptualization of learning have close relationship and accordingly student achievement might be affected (Entwistle & Peterson, 2004; Tsai, 2004; Chiou, Liang & Tsai, 2012; Alamdarloo, Moradi & Dehshiri, 2013). In general, conception of learning refers to ways of learning and beliefs regarding the learning period (Benson & Lor, 1999; Liang & Tsai, 2010; Chiou, Liang &Tsai, 2012). Therefore, it includes many variables such as individual's aims and strategies in learning, and efforts in the learning period (Vermunt & Vermetten, 2004; Alamdarloo, Moradi & Dehshiri, 2013). The oldest study in this field was conducted by Saljo (1979) with 90 university students. In this study, one-to-one interviews were administered to identify the students' conceptions of learning and five categories were determined based on the data analysis. These five qualitatively different conceptions of learning were a) increase of

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knowledge, b) memorization, c) acquisition of facts and procedures, d) abstraction of meaning, e) an interpretative process aimed at the understanding of reality. Marshall et.al. (1999) conducted a similar qualitative study and mentioned five categories of learning conceptions. These categories were classified as a) memorizing definitions, formulas and procedures, b) applying formulas and procedures, c) learning the rationale behind the concepts and procedures in physics, d) creating a new perspective and e) causing a change in behavior. Another phenomenographic study was conducted by Tsai (2004) with 120 university students and seven subcategories were identified for students' conceptions of science learning (memorization, exam preparation, calculation of problems and application, increase of knowledge, application, understanding and creating a different perspective). Similar to previous studies (Vermunt & Vermetten, 2004), Tsai (2004) claimed that there was a hierarchical relationship among seven categories and first three categories are "lower-level conceptions of learning" and the last four ones are "higher-level conceptions of learning." In lower-level conceptions of learning, students aimed only at acquiring knowledge, getting high scores in the exams or learning in order to solve problems. However, in higher-level conceptions of learning, there was a more sophisticated conception of learning. This includes the application of new knowledge and creation of new perspectives. Liang and Tsai (2010) conducted a quantitative study with 407 Taiwanese university students and they identified these students' opinions regarding scientific knowledge and their conceptions of learning. It was found that there was a crosslink between these two important variables. It was concluded in this study that student with sophisticated epistemological beliefs has higher-level conceptions of learning. Recently Li et. al. (2013) conducted a study with 369 university students to investigate students' conceptions of learning chemistry and the link between these conceptions and learning approaches. Learning approaches questionnaire and conceptions of learning chemistry questionnaire were administered and therefore conceptions of learning chemistry have been categorized under four categories as follows; memorization, exam preparation, calculation and application, and creating a change in the individual (a change in behavior for meaningful learning). It was also stated that students adopted in-depth learning approach have higher-level conceptions of learning (a change in behavior for meaningful learning), while students preferring superficial learning approach have lower-level conceptions of learning (memorization, test preparation, calculation and application).

Additionally, researches has also revealed that students who conceptualized learning as a qualitative view of learning (such as understanding) prefer to use deep approaches of learning; on the other hand, students who conceptualized learning as a quantitative view of learning (such as memorizing) tended to use surface approaches to learning (Dart et al., 2000). Many educators agree that deep or more meaningful learning approaches as trying to integrate the acquired knowledge were associated with better learning outcomes (Liang et al., 2010; Chin & Brown 2000, Trigwell & Prosser 1991). Since some researchers have suggested students' conceptions of learning are related to students' learning strategies, and thus their outcomes (Lederman, 1992; Tsai, 2000), this study was intended to identify university students' conceptions of learning genetics in Turkey.

In addition to abovementioned studies, there have been just a few studies to identify students' conceptions of learning and to reveal their conceptualization in Turkey. Dikmenli and Çardak (2010) conducted a qualitative study with 86 students at Biology Education department to investigate their conceptions of learning biology. Through content analysis, they divided students' conceptions of learning biology under six categories (increase of knowledge, memorization, acquisition of facts and procedures, abstraction of meaning, interpretation, causing a change in the individual (a change in behavior for meaningful learning)). These researchers claimed that students can be especially categorized under lower-level conceptions of learning (increase of knowledge, memorization, acquisition of facts and procedures).

Analyzing the related literature, it is clear that studies usually focused on university students' conceptions of learning science or more specifically school subjects such as biology and chemistry. These studies emphasized that students' conceptions could change depending on each subject and could be categorized different categories. Therefore future research should move forward to explore conceptions of learning in more specific domains to gain a deeper understanding of how students learn in various scientific domains (Chiou et al., 2012). In particular, since university education involves different disciplines (i.e. genetics); a better understanding regarding the students in higher education by different discipline is necessary. Therefore, in this study, it is aimed to identify and then categorize the conceptions of learning genetics of the students who took genetics course before or who are still taking the course through a phenomenographic analysis. Among the research studies conducted in Turkey, any study which specifically aims to find out the conceptualization of university students' conceptions of learning genetics using the phenomenographic method was present. Therefore, this study is expected to make an important contribution to the related literature. In addition it was also suggested that there were some cultural differences in students' conceptions of learning and categorization of these conceptions (Purdie et al., 1996; Tsai, 2004; Tsai, 2006; Tsai, 2008; Tsai & Kuo, 2008). For example; it is revealed that the conceptions of learning Australian and Japanese students differ dramatically and these conceptions are differently categorized (Purdie et al., 1996; Tsai, 2004; Tsai, 2006; Tsai, 2008; Tsai & Kuo, 2008). By using qualitative research methods as phenomenography, researchers have tried to identify the effect of the cultural beliefs about learning (Boulton-Lewis et al., 2004; Richardson, 1999; Tsai, 2004).They generally stated that students' conceptions of learning could be affected by culture. Therefore, in Turkey which is a meeting point for many cultures because of its geographical position, it is aimed to carry out a qualitative study to identify how students' conception of learning genetics is categorized.

The aim of this study is to reveal how students conceptualized learning in genetics. In this way, it will be possible to understand whether these students have higher-level conceptions or lower-level conceptions and various solutions will be discussed for the students who have lower-level conceptions.

METHODOLOGY

The phenomenographic method, which is one of the qualitative data analysis methods, was utilized in this study. Aiming to reveal how events/phenomena in the environment are perceived by individuals; phenomenographic method is a widely accepted method in educational research studies (Entvistle 1997; Prosser & Trigwell 1999; Wihlborg 2004). In phenomenographic studies, researchers aim to categorize the topic, based on the data which they obtain from different individuals and they form qualitatively different categories (Tsai, 2004). However, each individual category should have a close link to the research topic. Therefore, each and every category has an informative role in identifying individuals' different conceptions (Marton & Booth, 1997). In this study, the answers that the students provided to the open-ended questions were gradually analyzed according to the phenomenographic method.

Like other qualitative studies, phenomenographic researcher provided an open account of a study's method to illustrate verification of the study. For that reason, in the present study convenient samples were selected and used to prevent biased sample and to provide a background for any attempt at applying the results in other contexts (Cope, 2004). Also, data analysis method was clearly identified. Categories of description were tried to be fully described and adequately illustrated with quotes.

a) Research Group

This study was conducted in the fall term of 2012-2013 academic years with 108 (62 female and 46 male) students from department of Biology and department of Nursing. They all taking genetics course as part of their undergraduate education. The convenience samples were used to conduct this phenomenographic study. Ages of the students were varied between 20 and 22. The major characteristics of the students were similar with respect to socio-economic status, the proportion of boys and girls in both departments. Such characteristics are taken into consideration for this study since socio-economic status and gender may affect learners' conceptions of learning (Kapucu & Bahcivan, 2014). The students who took part in the study were taken Genetics course as a must course for one semester because it was one of the departmental requirements. The same instructor gave the course by using the same teaching strategies. The course covered the definitions of several terms such as genetics, variation, and modification in addition to chromosomes, chemistry and primary functions of genes, replication, transcription, protein synthesis, gene manipulations and genetically inherited diseases.

b) Data Collection Tool

The students were asked several questions to help them to express their conceptions of learning genetics. These questions were prepared based on previous studies (Tsai, 2004). Answers to questions of "what is learning?", "how do you learn topics related to genetics?" "how would you define your learning in genetics course?" "how do you realize that you have acquired a new piece of information related to genetics?" were analyzed.

c) Data Analysis

In the present study, the students' answers to open-ended questions were analyzed in line with the aim of the phenomenographic method and the categories were formed. Firstly, the answer sheets of the students were quickly read three times. After the third reading, important sentences and some key words in each answer sheet that were relevant to students' conceptions of learning genetics were underlined. In the next step, preliminary categories were formed according to the similarities and differences in the underlined sentences and keywords (Tsai, 2004). These preliminary categories were re-examined in detail in the next stages and students' answers were located in the appropriate categories. As a result, how students conceptualize learning genetics was identified with the help of qualitatively different categories.

To exemplify how these categories were formed, it can be said that words such as "memorizing," "remembering," and "revising" were thought to be in the same conception class and thus, were located in the first category of "memorization" (Tsai, 2004). For example, the student answer below can be examined:

"There are a lot of terms in genetics. In order to remember those terms, I do a lot of revisions."

In this answer, the researcher tried to identify the student's conceptions of learning genetics by underlining the words "remember" and "revision". Another student's paper was examined below:

"When learning genetics, I generally try to memorize. Before taking the exam, I continuously read my notes and do some revision. In this way, it becomes easier for me to remember in the exam."

In this answer, the researcher underlined the words "memorize," "revision" and "remember" again and put the answers of these two students in the same category. As a result, categories of students' conceptions of learning genetics were created by taking into consideration similar and different answers. In short, the researcher took into consideration the similarities and differences in the answers among the students rather than the similarities and differences in students individual papers and formed the categories (Marton et al. 1997, cited in Tsai, 2004).

Additionally, to check reliability in this phenomenographic study, interjudge reliability (interjudge communicability) has been used (Cope, Horan & Garner, 1997; Trigwell, Prosser & Taylor, 1994). The quotes and entire answers were given to researcher external to the study to ensure interjudge communicability. Then, the researcher outside the study independently classified the students' answers against the categories of description. Both researchers had the same idea in the creation of the categories.

FINDINGS

Through a phenomenographic analysis of students' answers to open-ended questions, five different conceptions of learning genetics were identified. If the name given to each category and the conceptions of learning in the literature overlapped, the same category name was preferred. For example, if key words in student answer sheets such as "remembering" and "revising" are widely categorized into the category of memorizing in the literature. Same key words were located into same category with the same category name in this study.

In order to explain and exemplify each category, the student answers were given in detail below. However, when choosing the answer, a number and a letter were given to each student (Tsai, 2004). Letter B was used for "Biology" students and Letter N was used for "Nursing" students. Numbers were given to each student respectively.

Memorizing: In the first category, students characterize learning genetics as "memorizing" definitions, formulas and terms. For them the purpose of learning genetics is storing all information in mind and remembering it when necessary. Students' answers are given below:

B12: "When learning genetics, I memorize the topics and their definitions that I find important. If I revise them for several times, I remember them more easily. When studying, I always underline the terms and definitions and re-read them to remember easily."

B27: "When learning genetics, I continuously try to write down what my teacher tells us. The notes that I take during the lesson are very important for me because I revise my notes for several times and try to memorize them. If I don't memorize them, I can't remember the terms and definitions."

N3: "When learning genetics, I listen to my teacher very carefully and take notes of the points that I find important. Later, I memorize my notes by reading them for many times. Then, it becomes easier for me to remember in exams."

N24: "In genetics course, there are a lot of terms and most of these terms are not familiar to me and learning them is very difficult. In order to keep the terms in mind, first of all, I read them several times, and then, I revise them by myself. I try to memorize until I don't need to look at the book."

The students in this category prefer to use memorization technique in order to learn genetics. Therefore, it can be concluded that the most important indicator of their conceptions of learning genetics is memorizing topics in genetics.

Testing: In the second category, students' primary goal in learning genetics is to pass the exams. They categorize conceptions of learning genetics as preparing for the exam and passing the course. The answers in this category are given below:

B8: "To me, learning genetics means passing the exam successfully. When learning the topics, I learn the related topics by focusing on the possible exam questions."

B10: "When learning genetics, my primary aim is to pass the course by getting a high grade in the exams. If there weren't any exams, I don't feel any need to learn genetics."

B18: "Learning genetics doesn't mean much to me, but I have to pass the exams since we take them as a must course. Therefore, I am learning genetics."

N22: "I am learning genetics just because it is a course. I have to answer the questions in the exams."

N36: "I cannot learn genetics well. I learn it in an exam-oriented manner. Getting a high grade in the exams is very important to me."

N48: "When learning genetics, I identify the topic that might be asked in the exam and I try to keep them in mind even if I don't understand because these topics usually appear in the exam."

Among the students who participated in this study, the ones who were categorized in this group define learning genetics as preparing for the exam and getting high grades. Moreover, they decide whether they have learned genetics or not by considering their exam results.

Researching: The third category refers to students' conceptions of learning genetics which they define as researching. The university students in this study stated that it is effective in learning genetics to do research especially on the Internet. Student answers are given below as follows;

B5: "I like learning while doing research on topics related to genetics on the Internet. I search every topic on the Internet when I find it interesting. I learn genetics by finding out about the topics that I wonder about genetics."

B22: "Learning genetics means being curious about a topic and obtaining information on that topic by doing a research."

N8: "I learn genetics through books or by doing research on the Internet. When there is a topic that I don't know, I prefer to get help from somebody or to do research on it."

N14: "I don't follow the teacher in genetics course; therefore, I can say that I learn it through the Internet. I learn by doing research with the help of books and the computer."

These university students characterized learning genetics as doing research. In order to get information about a topic related to genetics, they usually preferred doing research on the Internet.

Applying: The university students characterize conceptions of learning genetics as "application". They define the goal of learning genetics as the application of the topics related to genetics to daily life. For example:

B33: "My purpose in learning genetics is to have some information that I can apply on genetically inherited diseases that I may come across all my life."

B39: "Learning genetics is not to learn the concepts and terms, but it is to solve the problems that we may come across in daily life by using these pieces of information. Therefore, I try to apply each and every piece of information."

N66: "Especially for my subject area, learning genetics is to apply the pieces of information that I have acquired because I know that in my professional life, I will need all the information that I have learned in genetics course."

In the application category, the participants of the study believe that it is necessary to apply the acquired information and to transfer it to the daily life.

Seeing in a new way: In the last category, university students regard the conceptions of learning genetics as self-improvement by creating a new perspective. Learning genetics is seen as interpreting what is happening around them and in the nature in a different way and suggesting solutions to the problems. The students' answers are given below:

B2: "Learning genetics enable me to make different comments and provide a new perspective in some events that take place around me, especially in medical cases. As a result, I believe that I improve myself with every piece of information that I learn."

N67: "Genetics is an area which covers a lot of topics and has a link with different subject areas such as physics and chemistry. Learning genetics means improving myself in other areas at the same time and suggesting different solutions."

Although some students stated that learning genetics is important to improve themselves and creating different perspectives, it is necessary to emphasize that they are in low frequency.

Distribution of Students' Conceptions of Learning Genetics

Based on the answers provided by participating university students giving answers to the open-ended questions, five different categories were identified and each category students' conceptions of learning genetics is expressed. While naming the categories, previous studies were taken into consideration based on the related literature. Another independent researcher was also asked to contribute in stages where the similarities and differences in student papers were identified. The given answers were categorized and the frequencies of each subcategory were given in table 1.

Table 1: *Students' Conceptions of Learning Genetics (N=108) and Their Frequencies.*

Conceptions	n	f (%)
Memorizing	30	27.8
Testing	35	32.4
Researching	20	18.5
Applying	15	13.9
Seeing in a new way	8	7.4

It is clear from Table 1 that, students' conceptions of learning genetics were heavily distributed in the category of "testing" (32.4 %). The next frequent one was "memorizing" for 30 students (27.8 %). Some of the students (18.5 %) stated that they learn by "researching". However, 13.9 % of the students viewed learning genetics as "applying" and few students perceived learning genetics as 'seeing in a new way' (7.4 %).

DISCUSSION and CONCLUSION

This study was conducted to explore university students' conceptions of learning, particularly toward the subject of genetics by using phenomenographic method. Many students who participated in the study conceive learning genetics in the categories of "testing", "memorizing" and "researching", but fewer students has "applying" and "seeing in a new way" as their conceptions of learning genetics. In fact, this result shows that the deep-rooted structure in the education system which has been expected to overcome for many years but has not been changed yet. The reason is that the conceptions of learning by "memorizing" and "testing" has not changed. However, although they are few in number, there are still some students who prefer to learn by applying the information they have acquired and by improving themselves.

According to the results, 18.5 % of the students learn genetics by "researching" (Table 1). In fact, this category has not been mentioned in the previous studies in the literature. The lecturing style of the lecturers at universities might have an effect on the emergence of this new category because it is known that educational environments have an effect on students' conceptions of learning (Cano, 2005; Chin & Brown, 2000; Trigwell, Prosser & Waterhouse, 1999). If the lecturers ask students to do some research on the topic and then make a presentation in class, students might also prefer learning by "researching." This new category might have emerged as the direct result of the educational environment. This study reveals that especially the participants of this study prefer to do research through the Internet. They prefer doing research using a computer rather than using written sources. In future studies, this issue might be chosen as the research topic to discuss its reasons and results. Another striking finding of the study is that the conception of “testing” is the category with the highest frequency among the all categories. Nearly 32% of the students expressed their conception of learning genetics as “testing.” This result is not so surprising for Turkey because this country is described as “a country of exams” (Yıldırım, 2010), where students take a lot of exams during their education life. They also have to take another exam to start working at public institutions after they graduate from high school/university. For example, in Turkey, in the new system regarding the transfer to secondary education (for students to be able to make a preference list for high school), from 2013-2014 academic year on, one of the exams given by the teacher for 6 basic subjects in 8th grade during a semester will a centralized examination. In other words, every student has to take 2 examinations prepared by the Ministry of National Education (MoNE) per year. As a result, they will be able to make their preferences for the following year’s high school (Anatolian, science, vocational and religious high schools) depending on their yearly grade average. In the last year of their high school education, they have to take Higher Education Examination (HEE) and Undergraduate Placement Examination (UPE) in order to enroll a university. Every year, about two million people apply for these exams and these students are expected to get high grades and gain the right to get education at the desired university and desired department. After they complete their undergraduate education, if they want to work at public institutions as a civil servant, they also have to get high grades in Civil Servant Selection Examination (CSSE) and to gain the right to apply for the related vocational positions. Therefore, in a country where there is such an exam load mentioned above, it is not surprising that students have a conception of learning in the category of “testing” In addition, since getting high grades in the exams is something that pleases the teachers and the parents, it is natural for these students to have the conception of “testing.” However, Tsai (2004) in his study highlighted that the conception of “testing” is a quantitative view of learning. Quantitative learning refers to the action of keeping or saving up new and correct pieces of information in mind. In other words, the students in this study perceive genetics as a separate learning area and memorize the concepts, terms and definitions without forming a lot of links because they aim to get a high grade in the exam. On the other hand, 27.8 % of the students participated in the study has “memorizing” as their conception of learning genetics. In order to change this familiar learning style (memorizing), which has a long tradition in the education system, there are revised curricula which have been implemented gradually since 2004 in primary and secondary education. Unfortunately, these curricula which are based on the constructivist philosophy have not yet implemented at the desired level. This might be the reason why the conception of “memorizing” still has a high frequency. In order for a conception of learning to change from “lower level conceptions of learning” to “higher level conceptions of learning” (Dart et al., 2000; Tsai, 2004; Ferla, Valcke, & Schuyten, 2008; Lee et al., 2008; Edmunds & Richardson, 2009), it is necessary for teachers to completely change their teaching style from traditional teaching to constructivist teaching and to educate their students accordingly. According to Trigwell, Prosser and Waterhouse (1999), if teachers adopt the content-oriented view of teaching and use traditional methods, students perceive learning as only acquiring information and keeping that information in memory. However, at this point it is necessary to mention that if this study was conducted in secondary or high school level, the number of the conception of “memorizing” in learning genetics might not be so high. Depending on the change in the learning environment, different results might be obtained. Since this kind of a study is necessary for Turkey, this might be an important research topic for future studies.

Another conclusion that can be drawn from the results of the study is that 18.5% of the students have “applying” as the conception of learning, while 7.4% have the conception of “seeing in a new way.” As it was stated in the previous studies, these two conceptions of learning are called “qualitative view of learning” (Marton et al. 1993, 1997 cited in Tsai, 2004). The students achieve meaningful learning by forming a link between the new information they have acquired and the existing information. Learning is not only keeping the information in mind, but it is also using it in different situations. According to Dart et. al. (2000), if students adopt a qualitative conception of learning (such as seeing in a new way and applying), they tend to have deep approaches to learning. Tsai (2004) claimed that there is a link between the qualitative view of learning and constructivist view. From this perspective, for example, the constructivist view of dealing with the curriculum and the lessons thoroughly instead of dealing with them in a superficial manner (Brooks & Brooks 1993, cited in Tsai, 2004) and of the application of the acquired information (Tsai, 2001) are included in scope of the qualitative view of learning (Tsai, 2004). Therefore, educators, guidance teachers and teachers should internalize and implement the constructivist approach in educational settings very well in order to create qualitative view of learning instead of quantitative view of learning. Both the educators and the students have a lot of important responsibilities in all grade levels in Turkey. Administrators, teachers, experts and curriculum developers should spend more efforts to change the students' lower-level conceptions of learning such as "memorizing" and "preparing for the exam." Fully implementing the constructivist approach in class might be the most important stage of this change.

In this study, as mentioned above, a new category named "researching" was formed. Depending on the students' answers, this category was defined as accessing information only by researching. The category of "researching" was not regarded as a higher-level conception of learning which requires the discovery of new information. Therefore, it was defined as merely obtaining information and was regarded as quantitative view of learning together with "memorizing" and "testing."

In short, in this study, five categories of conceptions of learning genetics (memorizing, testing, researching, applying and seeing in a new way) for sampled university students were identified. The subject of genetics which has a close link with other subjects (biochemistry, chemistry, general biology and health) was chosen and the study was conducted on this subject. Since conception of learning is domain dependent (Buehl & Alexander, 2001; Hofer, 2000; Tsai, 2004; Lee et al, 2008; Chiou et al. , 2012, cited in Li, Liang & Tsai, 2013), it does not mean that the same categories will be identified in conceptions of learning in other subjects. As a result, it is necessary to identify the students' conceptions of learning in other subjects such as biochemistry, chemistry, physics and mathematics to form the categories. Also, the effect of departments on the conceptions of learning should be researched in future studies. In addition, there might be differences in the identification of conceptions of learning at high school. New studies would be conducted for different grade levels. Moreover, this study was conducted using phenomenographic method. After the analysis of the answers to open-ended questions, the categories were formed. The study might be repeated by making interviews. Students' conceptions of learning might be identified by using quantitative research methods as well as qualitative research methods.

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Brain Based Biology Teaching: Effects on Cognitive and Affective Features and Opinions of Science Teacher Trainees

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ABSTRACT

This study investigates the effectiveness of a brain based teaching approach on biology achievement, attitude, critical thinking disposition and self-efficacy scores of science teacher trainees. Also, science teacher trainees' opinions about brain based teaching were investigated. A mixed method approach was used in the current research and it was composed of two parts: Part A and Part B. Part A was comprised of a sample of 65 science teacher trainees and Part B was composed of nine science teacher trainees. The results of Part A revealed no significant effect of the teaching method on achievement, attitude, critical thinking disposition and self-efficacy scores. On the other hand, the results of Part B showed brain based teaching to some extent affects cognitive, affective and metacognitive features. This is similar to the results of some other studies. This study also indicated that various factors may affect students' cognitive and affective features besides the teaching method.

Keywords: Brain Based Learning; Pre-Service Science Teachers; Achievement; Attitude; Critical Thinking Disposition; Self-Efficacy.

INTRODUCTION

In the last 25 years, with the growth of neuroscientific knowledge, some scientists and educators are becoming increasingly aware of the benefits neuroscience is making in terms of the brain and its function when students learn (Howard-Jones, 2008). However contemporary opinions exist regarding the relationship between neuroscience and education - on the one hand, neuroscience is believed to have potential for solving many important challenges educators face and on the other hand, it is thought that neuroscientific knowledge is irrelevant to educators' understanding of learning. This debate continues to be discussed (Bruer, 1998; Geake & Cooper, 2003; Davis, 2004; Goswami, 2004; Howard-Jones, 2008; Bawaneh et al., 2012; Clement & Lovat, 2012). However it is clear that neuroscience provides additional data related to human learning and learning deficits. Therefore, educators can benefit from those data. However they should avoid direct applications of neuroscience findings to education since learning is related to several factors such as social, cultural and contextual (Mason, 2009).

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Leslie A. Hart synthesized the findings of many disciplines including neuroscience and proposed a theory known as the “Proster Theory” which is a brain based theory of human learning (Hart, 1981). Various researchers have taken her work as well as data of current neuroscience in order to develop methods and strategies that will complement the brain's natural development (Caine & Caine, 1990; Caine & Caine, 1995; Jensen, 2000; Prigge, 2002; Roberts, 2002; Willis, 2007; Nuangchalerm & Charnsirirattana, 2010; Hardiman, 2012). These researchers assisted educators in implementing brain based teaching strategies in the classroom. Caine and Caine (2002) define brain-based learning as “recognition of the brain’s codes for a meaningful learning and adjusting the teaching process in relation to those codes.” Therefore, instruction should be planned and organized so that it is respectful of the brain’s natural learning system and educators should know how the brain receives, processes, interprets, connects, stores and retrieves information (Greenleaf, 2002).

The aim in constructing a brain based classroom is to help students optimize the usage of their brain potential and learning during each lesson. This needs students to feel safe and also to be cognitively, physically and emotionally prepared to learn a given topic in the classroom, since research findings presented that environment, diet, teaching time, chronotype, amount/quality of sleep, music, colour, oxygen, temperature, humidity, movement, exercise, and water intake all affect the way our brain responds and learns (Taylor, 2007; Azevedo et al., 2008; Valdez, Reilly & Waterhouse, 2008; Wilmes et al., 2008; Kotsopoulou & Hallam, 2010). Therefore, teachers’ decisions on what, where and how much should be done in order to improve learning outcomes and achieve meaningful learning are important. The main goal in these decisions should be to create an enriched environment where all students can learn and develop. Therefore, brain based learning is closely related with the constructivist theory of learning which indicates learning is individual and unique (Cercone, 2006). However, teaching in higher institutions is still conducted without considering individual differences (e.g. learning styles and learning approaches) and is generally teacher-centred. This implies that current practices and instruction may in fact diminish or prohibit learning and its quality.

The quality of learning is closely related to students’ beliefs about their abilities, attitudes towards courses and how they accept the learning content (Enochs et al., 1995; Beşoluk & Önder, 2010; Brígido et al., 2012). In higher education students are expected to be good critical thinkers who can interpret, analyse, evaluate and criticise the content taught. Meanwhile, their judgments regarding their capabilities to execute a given type of performance should be positive since those judgments affect their effort, goals and commitment to learn (Bandura, 2006). In fact, brain based teaching can meet expectations of higher education since, in brain based teaching, students are encouraged not to limit their learning with the content provided, have creative thinking skills, criticise the information obtained, be aware of what they have learned and construct relations between the concepts so as to learn meaningfully (Bulut, 2014).

Several studies investigating the effectiveness of brain based learning indicated that teaching designed on brain based learning affects positively students’ cognitive and affective features, such as; conceptual understanding and learning motivation (Saleh, 2012), knowledge and practice of healthy behaviour (Banchonhattakit et al., 2012), academic achievement (Cengelci, 2007; Özden & Gültekin, 2008; Duman, 2010; Odabaşı & Celkan, 2010; Çelebi & Afyon, 2011; İnci & Erten, 2011; Aziz-Ur-Rehman et al., 2012; Oktay & Çakır, 2013) and attitude (McFadden, 2001; İnci & Erten, 2011; Şeyihoğlu & Yarar Kaptan, 2012; Yavuz & Yağlı, 2013). However, contrary to the aforementioned experimental studies McFadden (2001) and Yavuz and Yağlı (2013) indicated no significant differences in achievement scores when brain based methods were compared to traditional methods. Similarly, no significant reduction in anxiety was obtained when methods were compared in McFadden’s study.

Studies that explore the effectiveness of brain based learning on some cognitive and affective variables are generally conducted on primary and secondary school students. Few of these studies questioned the effect of brain based learning on university students and even less is longitudinal. Therefore the objectives of this long term study were 1) to investigate the effectiveness of brain based teaching on biology achievement, attitude, critical thinking disposition and self-efficacy scores of science teacher trainees, and 2) to find out their opinions about brain based teaching.

METHODOLOGY

A mixed method approach was used in the current research and it was composed of two parts: Part A and Part B. The research design of Part A was quasi-experimental with a non-equivalent control group pre-test-post-test design. The experimental group received instruction based on brain based learning while the control group was taught with conventional teaching. Part A lasted 14 weeks (one semester). Part B was conducted at the end of the Part A. In Part B a phenomenological approach was followed. Nine students from the experimental group of Part A were interviewed in order to capture their thoughts, feelings, and perceptions regarding the application of the experimental treatment and its effects. Semi-structured interviews were conducted and each interview lasted 25 to 30 minutes.

a) Sample

The participants in Part A were 65 sophomore elementary science teacher trainees enrolled in Elementary Science Teacher Education Programme at Sakarya University, Turkey. There were 30 students in the experimental group and 35 in the control group, all of whom were from a General Biology class. In the experimental group, 66.4% of the subjects were female and 33.4% male while in the control group, 71.4% of the subjects were female and 28.6% male. The mean age of the sample was 20.2 years (ranging between 19 and 21). The participants in Part B were nine sophomore elementary science teacher trainees. They were selected randomly from the experimental group of Part A. Five of the participants were female and four were male.

b) Procedure

Procedure of part A: Once the experimental and control group were defined, students in the experimental group received a four hour workshop about how the brain learns, what brain based learning is, what they were going to do in the biology course throughout the semester, their learning styles and learning approaches. Meanwhile, the importance of learning styles and approaches in teaching and learning were discussed. The biology course is a six hour compulsory course. Since the course was given by the same instructor, the course for the control and experimental group started at different times of the day. In the control group the course started at 10:00 a.m. and ended at 11:45 a.m. while in the experimental group the course started at 3 p.m. and ended at 4.45 p.m. in a three day of a week. One of the researchers thought out the course for both the experimental and the control groups. At the beginning of the research, researchers developed the materials, power point presentations, animations, models, laboratory activities and concept maps that were going to be used while teaching the course. Meanwhile photographs and music were chosen. Classical music without lyrics was chosen in order not to disturb the students' attention and to make the process more enjoyable and interesting (Brewer, 1995; Dosseville et al., 2012) since listening to music engages the entire brain (Jensen, 1998). Kolb Learning Style Inventory III and Revised Two Factor Study Process Questionnaire were administered before the study in order to determine students' learning styles and approaches and for arranging instruction and informing students (see Table 1).

Table 1. *Students Learning Styles and Learning Approaches*

Group		N	Learning Styles (f)				Learning Approaches (f)	
			Converger	Diverger	Assimilator	Accommodator	DA	SA
EG		30	4	12	3	11	23	7
	Female	20	3	7	2	8	16	4
	Male	10	1	5	1	3	7	3
CG		35	3	18	8	6	26	9
	Female	25	2	13	6	4	19	6
	Male	10	1	5	2	2	7	3

Note: EG: experimental group, CG: control group, DA: deep learning approach, SA: surface learning approach, N: number, f: frequency

Biology Achievement Test, Attitude Scale towards Biology, California Critical Thinking Disposition Inventory and Biology Self Efficacy Scale were administered as pre and post-tests to both groups before and at the end of the research. Below the teaching processes in both groups were summarised.

The students in the experimental group received instruction based on brain based learning. The instruction was designed mainly considering twelve principles and three elements mentioned by Caine and Caine (1990; 1995) for brain based learning. Meanwhile, instruction was conducted considering individual differences between students such as learning styles and learning approaches. Therefore, several activities, models, visuals and animations were included and students were free to study alone or in a group. In addition, students developed posters and PowerPoint presentations and they worked individually or as a group on a project they had selected. Also they performed open ended laboratory experiments. The lecturer was responsible for helping students concentrate on a subject and to help them when they needed support. Moreover, students were allowed to drink water and eat something while courses were occurring and were reminded of the importance of healthy feeding for learning from time to time.

In one of the lectures, for example, the lecturer started with an event he had experienced about plants and posed a question regarding photosynthesis (How the anatomy of leaves affects the performance of photosynthesis in various environmental conditions?). While students were working as a group the lecturer presented some visuals that would help them realise the problem and find some clues. Students searched on the internet, looked at the PowerPoint presentations prepared, watched videos explaining the photosynthesis and read their books in order to provide an answer to the question. While students were working, a lecturer supported each group and joined groups as one of the group members in order to observe the process and help groups. Then answers from each group were gathered and discussed. After the discussion the lecturer asked them to design and then conduct an experiment that would help students to understand better the answer to the question they had just discussed.

The students in the control group received conventional teaching in which the course was mainly taught by lecturing. Major concepts (photosynthesis, immunity, reproduction, blood circulation, respiration, excretion etc.), equations, and definitions were presented by the lecturer and students were asked to take notes while listening to the lectures. The laboratory activities were designed as closed-end experiments.

Procedure of part B: Each of the nine science teacher trainees (STT) was interviewed separately and all interviews were video-recorded. The duration of the interviews varied from 25 to 30 minutes. Then, the interviews were transcribed and these transcripts were checked by comparison with the video-recordings. The data were analysed by following a qualitative content analysis approach. The researchers individually decided on categories and themes based on careful reading of the nine records. The classification of the data among the researchers was reviewed and the reasons for the classification were discussed during a one hour meeting. In the case of inconsistencies in classification among the researchers, agreements and disagreements were discussed until consensus was achieved.

c) Instruments

Data collecting tools that were used for informing students and arranging instruction before the study are presented below.

Revised two factor study process questionnaire: The Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) which was developed by Biggs, Kember and Leung (2001) and was adapted into Turkish by Önder and Beşoluk (2010) was used to measure the students' approaches to learning. It is a 20-item Likert-type instrument with deep and surface approach scales. The total score in each scale ranges from 10 to 50. The test retest validity was reported as 0.60.

Learning style inventory: Learning style preferences were determined using the Kolb Learning Style Inventory III (KLSI-III) which was developed by Kolb (1999). This scale was adapted into Turkish by Evin Gencel (2006). The scale contains 12 items. The total score in the scale can range between 12 and 48. The internal consistency coefficients reported for the sub-scales in the adapted version were changing between 0.71 to 0.84.

Data collecting tools that were used in Part A and B of the study are presented below.

Biology achievement test: The Biology Achievement Test was developed by the researchers of the study. This test was administered to both experimental and control group students as a pre and post-test. The test was composed of 61 multiple choice questions related to the biology concepts they will study throughout the semester. The test contains items related to Embryonic Development, Nervous System, Hormone System, Reproductive System, Circulatory System, Respiratory System, Excretory System, Immune System and Digestive System. In order to establish whether the content universe addressed by the test is appropriate, the test was judged by two experts in biology teaching. They have indicated that the test adequately samples the intended universe which is an evidence of content validity. The internal consistency of the test was 0.73 and a Split-half reliability coefficient was 0.75.

Attitude scale towards biology: This scale was developed by Geban et al. (1994) and was adapted to the Biology course by Özatlı (2006). It was used to measure students' attitudes towards Biology as a school subject. The scale contains 15 items in 5 point Likert-type scale. The internal consistency coefficient of the scale was reported as 0.92. The Cronbach's α for the scale of the current study was 0.89 and .86 in pre and post administrations respectively.

California critical thinking disposition ınventory: Critical thinking dispositions were measured by the California Critical Thinking Disposition Inventory (CCTDI) developed by Facione, Facione and Giancarlo (1998). This scale was adapted into Turkish by Kökdemir (2003). The original scale contains 75 items, however the adapted scale contains 51 Likert-type items. The adapted scale consisted of six sub-scales which are; analyticity, open-mindedness, inquisitiveness, self-confidence, truth-seeking and systematicity. In CCTDI a score with marks above 300 indicates a positive overall disposition towards critical thinking. Kökdemir (2003) found an overall alpha coefficient of 0.88, with 0.61 to 0.78 on the sub-scales. In the present study, the Cronbach's alpha of the CCTDI was 0.83, and for the sub-scales was 0.55 to 0.81.

Biology Self Efficacy Scale: Self-efficacy scores of the students were determined by the "Biology Self Efficacy Scale" which was developed by Woo (1999) and was adapted into Turkish by Ekici (2009). The scale was composed of 40 Likert-type items and three sub-scales. The total score of the scale can range between 40 and 200. The reliability constant reported for the scale was 0.94. In the present study, the Cronbach's alpha of the scale was 0.89.

Semi Structured Interviews: Semi-structured interview questions developed by researchers were used to collect data on elementary science teacher trainees' thoughts, feelings, and perceptions regarding the application of the experimental treatment and its effects. A semi-structured interview method was chosen since it allows for the obtaining of rich and varied data. The following are the main interview questions used:

1. Which factors do you think were remarkable in the teaching and learning process of this course? Please explain.
2. How were you affected by this teaching and learning process? Please explain.

FINDINGS

Part A

One way ANCOVAs were performed on whether differences existed between the two groups on achievement, attitude, critical thinking disposition and self-efficacy scores. Pre-tests were treated as a covariate in order to partial out their effects on each analysis. Adjusted means and standard deviations of post test scores for experimental and control groups are given in Table 2.

Table 2. *Descriptive Statistics of the Achievement, Attitude, Critical Thinking Disposition and Self-Efficacy Scores*

Group	N	Achievement	Attitude	Critical Thinking Disposition	Self-Efficacy
		Adjusted M ± SD	Adjusted M ± SD	Adjusted M± SD	Adjusted M ± SD
EG	30	56.60±11.75	56.37±8.79	194.53±16.54	102.56±13.57
CG	35	58.36±9.44	56.34±8.31	191.00±15.88	102.57±15.40

Note: M: Mean, SD: Standard deviations

The results of ANCOVAs that were utilised to analyse whether there is a significant difference or not are given in Table 3.

Table 3. *ANCOVA Results of Achievement, Attitude, Critical Thinking Disposition and Self-Efficacy Scores*

Factors	Source	SS	df	MS	F	p
Achievement	Covariate (pretest)	2235.93	1	2235.93	28.90	.00
	Group	45.21	1	45.212	0.58	.45
	Error	4795.82	62	77.35		
	Total	222849.00	65			
Attitude	Covariate (pretest)	1571.43	1	1571.43	32.26	.00
	Group	54.14	1	54.14	1.11	.29
	Error	3019.41	62	48.70		
	Total	211015.00	65			
Critical Thinking Disposition	Covariate (pretest)	2909.77	1	2909.77	13.26	.00
	Group	33.17	1	33.17	0.51	.69
	Error	13601.68	62	219.38		
	Total	2428643.00	65			
Self-Efficacy	Covariate (pretest)	1836.46	1	1836.46	9.83	.00
	Group	52.04	1	52.04	0.27	.59
	Error	11573.46	62	186.66		
	Total	697239.00	65			

Note: SS: Sum of Squares, df: Degrees of freedom, MS: Mean Square

Results of ANCOVAs performed indicated a non-significant group difference in achievement ($F_{1,62}$= 0.585, p > .05) and attitude ($F_{1,62}$ = 1.112, p > .05). Similarly, there were no significant differences between groups on critical thinking disposition ($F_{1,62}$ = 0.151, p > .05) and self-efficacy scores ($F_{1,62}$ = 0.279, p > .05).

PART B

During qualitative data analysis three main themes were developed: “Teaching Materials”, “Outstanding Factors”, and “Attention to Physiological Needs” regarding the teaching and learning process. Meanwhile four main themes were developed: “Affective Domain”, “Metacognitive Awareness”, “Cognitive Skills”, and “Habits” regarding the effect of the experimental treatment. Tables 2 and 3 show the frequency and percentages of science teacher trainees for each category of beliefs, based on their responses. Below each table narrations and quotations were provided to explain the meaning of each theme in relation to the study aim.

Table 4. *Science Teacher Trainees’ Opinions about Remarkable Things in Teaching and Learning Process*

Codes	Themes	f	%
PowerPoint presentations	Teaching Materials	7	33.4
Videos		5	23.8
Posters		4	19.0
Animations		3	14.3
Pictures		2	9.5
Total		*21*	*100*
Music	Outstanding Factors	7	28.0
Enjoyable activities		6	24.0
Open-ended experiments		5	20.0
Friendly atmosphere		2	8.0
Increased workload		2	8.0
Learning by discovery		1	4.0
Mutual interaction		1	4.0
Boring course		1	4.0
Total		*25*	*100*
Water	Attention to Physiological Needs	3	33.4
Feeding		2	22.2
Oxygen		2	22.2
Sleep		1	11.1
Lighting		1	11.1
Total		*9*	*100*

As it can be seen in Table 4, science teacher trainees mostly mentioned some experiences they had in the teaching and learning process (outstanding factors) and teaching materials as remarkable factors of the course. Meanwhile, some of them also stated the importance of paying attention to physiological needs. In considering teaching materials, science teacher trainees generally indicated visual elements such as PowerPoint presentations, videos and posters. For example, two of them gave the following explanations in the interviews:

“STT2: ...especially presentations, I mean PowerPoint presentations were remarkable. We saw how the things were in reality in the presentations and videos”

“STT7: The posters were attractive and fairly interesting for me and the videos were useful in visualisation of things.”

Music, enjoyable activities and open-ended experiments emerged as the main outstanding factors from the interviews. Regarding music some of the participants presented positive feelings, however negative and neutral feelings were also stated. Some quotations from interviews were presented below:

“STT5: Music helped me to gather my attention and concentration and motivated me.”

“STT4: Music actually everybody says is positive but in fact it was not positive for me, rather I was distracted. I think I cannot do two things at the same time. Frankly, both listening to music and the lesson was not favourable for me.”

"STT8: To be honest, music did not affect me either positively or negatively..."

"STT6: It was more effective to do open ended laboratory experiments since we were discovering. Seeing things was more impressive…"

Also, water, feeding and oxygen were generally mentioned as physiological needs that are considered in the teaching and learning process. They gave the following explanations in the interviews:

"STT7: ...the instructor reminded us every time and said that if you're hungry, eat something because when you feel fear or you are hungry or you are nervous you and your learning will be affected. For example, low oxygen also affects you therefore these all helped me to pay attention to them…"

"STT2: In addition, the relaxation of the brain requires a certain level of oxygen to be in the environment. Therefore, during our courses we opened the windows in the classroom and paid attention to our environment so as to have enough oxygen…"

Table 5. *Science Teacher Trainees' Opinions about How They were affected by the Teaching and Learning Process*

Codes	Themes	f	%
Increase in motivation	Affective Domain	5	35.7
Increase in interest		5	35.7
Increase in attention		2	14.4
Increase in attitude		1	7.1
Distracted attention		1	7.1
Total		*14*	*100*
Recognising how the brain works	Metacognitive Awareness	5	55.5
Recognising his/her own learning style		3	33.4
Recognising his/her own deficiencies		1	11.1
Total		*9*	*100*
Ability to relate their knowledge to daily life	Cognitive Skills	6	66.7
Increasing problem solving skills		1	11.1
Increasing critical thinking skills		1	11.1
Increasing research skills		1	11.1
Total		*9*	*100*
Difficulty in note taking	Habits	2	33.3
Sustain his/her own study habits		2	33.3
Sustain his/her own learning habits		1	16.7
Not preparing for the course		1	16.7
Total		*6*	*100*

According to Table 5, science teacher trainees' opinions mainly focused on Affective Domain, Metacognitive Awareness and Cognitive Skills. Meanwhile, in some views, effects on habits were indicated. In affective domain, science teacher trainees generally mentioned an increase in motivation, interest and attention. For example, some of them said that:

"STT7: So, what we did in the course helped me to give my attention to the lessons, and so I was more interested in the course."

"STT8: I always loved biology and loved it even more this semester…"

"STT6: ...different activities in the course helped me to be more motivated."

With respect to Metacognitive Awareness, interview results indicated that some trainees recognised and presented their positive feelings on understanding how the brain works. Two of them said that:

"STT2: ...in some activities I have realised that the things that we were doing were in parallel with how the brain works and I also understand better how the brain works..."

"STT3: For example, I have realised that I am learning better with visual representations and therefore, I started to give more weight to visuals. For example, I started watching videos about biology; in order to understand the subject better. Also, I bought magazines related to living things."

For Cognitive Skills, science teacher trainees' opinions were mainly concentrated on the ability to relate their knowledge to daily life; on the other hand, few opinions were centred on an increase in problem solving skills, critical thinking skills and research skills. Some quotations were presented below:

"STT5: For example, I can now relate biology to problems I have faced, so I can say that this is the case or as follows now."

"STT4: ...for example when someone has a headache or an event occurs, I can provide some suggestions and relate it to daily life.

Finally it is interesting that science teacher trainees resist changing their habits. They still indicated that they have difficulty in note taking, sustaining their study and learning habits and preparing for the course. For example one of them gave the following explanations in the interview:

"STT4: I sometimes felt as if I had lost the connection with the lesson while trying to take notes…"

"STT5: It was nice to know how the brain works, but I did not change my way of working"

"STT3: … learning how one learns was good, but I continued in the same way, so I did not change my learning style."

DISCUSSION and CONCLUSION

In the current study the effectiveness of brain based teaching on achievement, attitude, self-efficacy and critical thinking dispositions was investigated and no significant effect of the teaching method on achievement, attitude, critical thinking disposition and self-efficacy scores was found. It is an unexpected result to obtain no difference between groups with respect to self-efficacy and attitude scores since brain based education was more student centred. In fact, some studies presented positive effects of brain based education to attitude scores (McFadden, 2001; Yavuz & Yağlı, 2013). On the other hand obtaining no difference in critical thinking disposition scores can be explained to some extent. Although one of the goals of university education is to improve students' critical thinking dispositions, recent studies indicated that university students' critical thinking scores are generally low (Guest, 2000; Van Gelder, 2005; Beşoluk & Önder, 2010) and resistance to using critical thinking is prevalent among higher education faculties (Paul 1990). In the faculty where the research was conducted, courses are generally taught by the lecturing method and the content presents little chance for students to discuss topics so as to enhance their critical thinking dispositions. On the other hand, qualitative results showed that brain based teaching has an effect on affective, cognitive and metacognitive variables of some science teacher trainees. Changes indicated in the affective domain were high compared to other themes. This is contrary to the quantitative results of this study. However, in quantitative analysis group means are used which may in turn hinder to observe the variation in scores individually. Therefore, if we consider both quantitative and qualitative results, we can say that brain based teaching may have an effect on the affective, cognitive and metacognitive domain, and this effect may be different with each individual.

Similar to the results of this study, McFadden (2001) found no significant difference in achievement and reduction in maths anxiety when traditional and brain based teaching methods were compared. Yavuz and Yağlı (2013) also found no significant difference in achievement scores of students who received brain based teaching and conventional teaching. However, qualitative results of the current study and several other studies have found brain based teaching to affect cognitive and affective features (Özden & Gültekin, 2008; Duman, 2010; İnci & Erten, 2011; Aziz-Ur-Rehman et al., 2012; Banchonhattakit et al., 2012; Saleh, 2012). Those studies indicating the effectiveness of brain based teaching on students' achievements are generally conducted in primary or secondary schools. As the age of students increases, it becomes harder to change students' learning and studying habits. Qualitative results of the study support this argument. Therefore, adaptation of university students to new teaching methods becomes difficult. Moreover, Ioakimidis and Myloni (2010) indicated that culture plays an important role and unintended results can occur if instructors employ teaching methods which violate the cultural expectations of students. In countries like Turkey where generally the masculine culture is dominant, students feel most comfortable in structured learning situations where clear objectives, detailed assignments, and strict timetables exist and they expect expert teachers who can answer all the questions. Therefore, it is difficult to develop learner autonomy and the students' ability to learn on their own since it requires them to change their ideas about the teachers' and students' roles in the education process and examine their learning and study habits. One of the reasons for obtaining no effect from the teaching method may result from this fact.

The students in the experimental group took five courses as well as Biology while the study was conducted. They received brain based teaching just in the Biology course, however, in other courses mainly conventional teaching was used by instructors. This could make it difficult for students to change their learning and studying habits and therefore, they probably have had difficulty in adapting to this new environment and teaching. Therefore, the effect of brain based education might be masked by the teaching methods used in other courses. To get more reliable results, brain based education should be conducted in most of the courses. Moreover, in order for students to achieve the maximum benefit from brain based education, they should arrange their life styles, feeding habits, water intake, sleep schedule, study habits etc. Therefore, to help students in arranging these habits, the structure and policy of educational institutions should be designed or arranged in a way that supports brain based education.

The students in both the experimental and the control group received instruction from the same academician and the course schedule was different. In the control group the biology course started at 10:00 a.m. and ended at 11:45 a.m., while, in the experimental group, the course started at 3 p.m. and ended at 4.45 p.m. on three days of the week. Therefore, the results may also have been affected from teaching time because the classes met at different times of the day. The experimental group started the course at a time considered to be a "low" time of the day for the brain to be working (Jensen, 1996). Moreover, students learning and achievement depends on many factors (Fraser et al., 1987; Beşoluk, 2011; Teodorović, 2012) including; methods of instruction, teaching materials, motivation, learning approach, learning styles (Beşoluk & Önder, 2010), anxiety, sleep (Drake et al., 2003), the quality of teaching/teachers, teaching time (Beşoluk & Önder, 2011), achievement goals (Gherasim et al., 2013), chronotype (Beşoluk, Önder & Deveci, 2011), feeding habits (Rampersaud et al., 2005), self-discipline (Duckworth & Seligman, 2005), intelligence, thinking styles (Fabbri et al., 2007), lifestyle regularity (Randler & Frech, 2006), physical condition of learning environments, cultural and social factors (Teodorović, 2012).

As a conclusion, we did not find any statistically significant difference in dependent variables of the study although qualitative results presented some positive aspects. However, knowing that many factors such as culture, school structure, course schedules, age and gender may affect research variables and these effects change individually which may mask the effect of the teaching method, considering both quantitative and qualitative results, we can conclude that brain based teaching may affect some of the teacher trainees' cognitive and affective features.

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Preservice Science Teachers' Belief Systems about Teaching a Socioscientific Issue

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ABSTRACT

We investigated the belief system of Turkish preservice science teachers (PSTs) about teaching a socioscientific issue (GM Foods) using a belief system model. This model includes three belief pools: content beliefs (CBs), core pedagogical beliefs (CPBs) and pedagogy of content beliefs (PCBs). Based on this model, we developed a questionnaire in order to see interrelationships among three belief pools about teaching GM Foods. For content beliefs, we selected content knowledge, risk perceptions, moral beliefs and religious beliefs. For pedagogy of content beliefs, we selected teaching efficacy, preferred teaching methods and preferred teacher's roles. We administered the questionnaire to 423 PSTs. Using correlation analysis, multinomical logistic regression and structural equation modelling we tried to understand the relationships between CBs and PCBs and to make interpertations about possible CPBs working as a filter between CBs and PCBs. The results show that PSTs are relatively knowledgeable, hold high risk perceptions and certain moral and religious beliefs about GM Foods. They possess high teaching efficacy beliefs, choose the teaching role of Neutral Impartiality and prefer large class discussion and computer-assisted teaching. As core pedagogical beliefs (CPBs), they may have traditional epistemologies, moral and religiously-based teaching goals.

Keywords: Belief System; Teaching Socioscientific Issues; Preservice Science Teachers; Turkey.

INTRODUCTION

Genetically Modified (GM) foods, nuclear plants, cloning and global warming occupy international agendas more than ever before. These issues are controversial and lack clear-cut answers and decision alternatives. Therefore, all stakeholders (i.e., scientists, government bodies, representatives of industry and, in particular, the public) have different points of view,

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ideologies and beliefs. These contemporary societal and scientific topics are referred to as socioscientific issues (Driver et al., 1996). Many countries are attempting to engage with these issues through policy development, *perhaps because of their economic significance*. For instance, the European Union has addressed socioscientific issues (SSI) through the development of responsible research and innovation as a fundamental policy (European Union [EU], 2012). Turkey, in three vivid examples of SSI, has established two new nuclear plants and invested in space and military technologies and in genetically modified (GM) foods.

On the other hand, in addition to the economic significance of SSI, governments realised that public understanding of these issues is crucial after many of the policies that did not account for public opinion failed (EU, 2012). The banning of DDT and closure of nuclear plants in different countries are only two results of such ill-structured policies. Therefore, *many countries began to prioritise raising public awareness about these issues*. They have incorporated SSI into national curricula so that school students, future citizens, can make informed decisions about them (Dawson, 2001).

There is sufficient evidence to argue that SSI-learning yields positive learning outcomes that are favourable to government goals. In SSI-based courses, school students learn how to collect and analyse data, build and defend strong arguments, develop decision-making skills, address moral dilemmas and develop their moral sensitivity (Sadler, 2011a). However, these learning environments have been designed either by researchers or by science teachers with the guidance of scholars (Sadler, 2011a). Consistent with this idea, *many science teachers in countries that underwent SSI curriculum reform argue that teaching SSI is challenging and requires a new set of teaching skills,* such as giving authority to students, dealing with uncertainties and discussing moral and emotional perspectives (Oulton, Dillon & Grace, 2004).

Turkey revised its science curriculum using SSI-based education in February 2013, when the Turkish Ministry of Education (TME) updated its science teaching programme. The development of scientific habits of mind using SSI is now one of the 12 basic goals of Turkey's science teaching programme (TME, 2013). However, most of these new developments are not yet reflected in teaching materials, textbooks or in preservice and in-service teacher education programmes. Currently, Turkish science teachers present SSI topics in unplanned learning environments because they do not know how to address these issues (Author, 2012a). In the present study, we focused on PSTs who must apply SSI perspectives in their classrooms under recent curriculum reform. *Taking a closer look at PSTs, we aimed to measure the possible success of SSI educational reform in Turkey.*

Furthermore, studies on SSI-based science teaching and teachers' perspectives are, to date, limited, and the literature focuses on knowledge types (subject matter or pedagogical content) (vanderZande et al., 2012) and individual beliefs such as goals for teaching SSI (Jones & Carter, 2007), teaching efficacy beliefs (Lee, Abd-El-Khalick& Choi, 2006) and the intention to use SSI (Sadler et al., 2006). At this point, *a theoretically sound approach - such as one using the model of 'belief system' - will provide stronger results about the nature of teachers' approaches and beliefs* (Pajares, 1992). Thus, in the present study, we focused on preservice science teachers' belief system about a socioscientific issue.

Teaching SSI

Scholars agree that science teachers usually have positive attitudes towards incorporating SSI into their teaching programmes (Lumpe, Haney &Czerniak, 1998). Teachers believe that addressing SSI in classrooms gives them the opportunity to promote democratic participation and social justice and to raise scientifically literate citizens (Jones & Carter, 2007). They also stress that teaching SSI helps students understand scientific concepts, apply science to everyday life and develop decision-making skills (Ekborg et al., 2013).

However, despite this positive affect, many teachers do not enact their beliefs in practice and do not address SSI in a systematic manner (Author et al., 2012a). Students usually raise topics in their classrooms, and their teachers respond quickly (Sadler et al., 2006) with informal discussions of poor quality (Day & Bryce, 2010). In addition, teachers spend little time on these discussions (Lee et al, 2006).

The existing literature shows that low level of efficacy beliefs among teachers (Lee et al., 2006), incorrect roles during SSI teaching (Simmonneaux, 2007) and inappropriate teaching methods (Author 1 et al., 2012a) are responsible for these negative results. Below, we discuss each component in detail.

Teaching Efficacy Beliefs about SSI Education

Bandura (1997) defines self-efficacy as 'beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments' (p.3). A teacher's self-efficacy implies 'a teacher's belief that he or she can reach even difficult students and help them learn' (Woolfolk, 2001, p.389). Teachers with a high sense of efficacy work harder and persist even when students are difficult to teach; they are also strong motivated in helping their students learn (Bandura, 1997).

There are a few studies about self-efficacy beliefs associated with teaching SSI. Lee, Abd-EI-Khalick and Choi (2006), for example, stressed that Korean science teachers do not have a strong sense of efficacy about teaching SSI. They found SSI different from other topics in the science curriculum because there are no clear-cut answers to the queries they posed for students. Similarly, Reiss (1999) reported that science teachers feel under-equipped to teach ethical and moral questions. In addition, Bryce (2004) noted that teachers do not feel they are experts on these issues and said that a 'messy' science curriculum was a time-consuming obstacle to teaching.

Teachers' Roles in SSI Education

Kelly (1986) identified four teachers' roles in teaching controversial topics: Exclusive Neutrality, Exclusive Partiality, Neutral Impartiality and Committed Impartiality. In Exclusive Neutrality, teachers do not introduce controversial issues into the broader community or share opinions on such topics. These teachers see scientific knowledge as the key and avoid potential problems in teaching SSI by sticking to facts (Oulton et al., 2004).

In Exclusive Partiality, teachers aim to convince students to adopt a correct position on controversial issues and share their views to persuade students to accept their own perspectives. In SSI teaching, Lemke (1990) considers that power relations in science classrooms may contribute to this effect. Ratcliffe and Grace (2003) note that teachers in this group use strategies to show their bias, such as presenting their opinions as facts and highlighting a particular set of facts that support their opinions.

In Neutral Impartiality, the teacher promotes classroom discussion and does not reveal his/her position on SSI. Rather than impose an opinion, the teacher aims to present different opinions that can assist in making decisions about SSI. Most in-service and PSTs prefer this role (Oulton et al., 2004). They suggest that they aim to provide a balanced experience and a range of opinions so that students can make up their own minds and develop their own value systems. Certain teachers in this group believe that they should provide equal information about all perspectives on an SSI (Sadler et al., 2006), in terms of both quality and quantity (Cross & Price, 1996).

In Committed Impartiality, the teacher promotes classroom discussion, discloses his/her opinions on controversial topics and encourages students to do the same. The goal is to model a thinking process, not to advocate an outcome. Certain science teachers would like to present different perspectives neutrally but believe it is impossible to avoid revealing their views and values. Therefore, they prefer to explain their positions without imposing them on students; thus, they aim to be a role model for adult decision-making and argumentation (Simmoneaux, 2007). Certain scholars (Kelly, 1986; Oulton et al., 2004) suggest that Committed Impartiality is the best role in SSI teaching.

Teaching Methods in SSI Education

Scholars (e.g., Sadler, 2011b) believe that teaching SSI requires collaborative and interactive classroom environments, where students and teachers feel safe and demonstrate mutual respect. Although most current science teachers' practices do not create these classroom environments (Lee et al., 2006; Sadler et al., 2006), empirical research (e.g., Sadler, 2011a) that assisted teachers in designing SSI-based classroom environments showed that certain existing teaching methods fit with SSI teaching.

The following teaching methods yield positive learning outcomes in SSI teaching: online modules based on student discussion, field trips (Tal et al., 2011), role playing, small group discussions and debates (Sadler, 2011b), drama (Aikenhead, 2006), case studies based on real contexts (Driver et al., 1996), problem based learning (Keefer, 2003), ethical and moral dilemmas (Zeidler& Lewis, 2003) and preparation of media reports (Ratcliffe& Grace, 2003). In addition, classrooms benefit from didactic teaching (i.e., lecturing), lab exercises and, to some extent, guided inquiry (Sadler, 2011b).

Teachers' Belief Systems about SSI Teaching

Empirical and theoretical work has shown that teachers' beliefs exist as a system (Fives &Buehl, 2012). Because they are insiders of education (Pajares, 1992), they develop many beliefs about learning and teaching even in precollege education (Borko& Putnam, 1996). These beliefs are incorporated into a complex network that includes core and peripheral beliefs. Core beliefs are usually more resistant to change relative to the peripheral ones (Fives &Buehl, 2012).

Author and colleagues (2013) argued that teachers possess a belief system that incorporates the three types of beliefs: content beliefs (CBs), core pedagogical beliefs (CPBs) and pedagogy of content beliefs (PCBs). They used the theoretical assumptions of Abelson (1979) and Rokeach (1968) to support this belief system model. The unbounded nature of beliefs suggested by Abelson (1979) helped them to understand the relationships between different beliefs in the same system. Accordingly, they argued that teachers' CBs, CPBs and PCBs are strongly interrelated because the boundaries among these beliefs are uncertain. For instance, a teacher with strong pessimistic beliefs about building nuclear plants (CBs) may try to impose his or her point of view when teaching nuclear energy (PCBs). Similarly, a teacher with naive epistemologies about the nature of knowledge (CPBs) may choose didactic methods when teaching cloning (PCBs).

Using Rokeach's (1968) opinions about belief segmentation (Types of Beliefs), Author and collaborators (2013) also determined two levels of belief in a system. CBs and PCBs were peripheral, whereas CPBs were the core beliefs underlying peripheral ones. Core beliefs can be epistemologies, beliefs about the Nature of Science (NOS) and teaching goals. Author and colleagues (2013) argued that CPBs work as a filter between CBs and PCBs eventhough they believed that there may also be direct relationships between peripheral beliefs.

To test the concept of belief systems, Author and colleagues (2013) designed a mixed study focused on a socioscientific issue: GM foods. Their model included two pools of beliefs, which were CBs and PCBs. As CBs, they identified content knowledge, risk perceptions, moral beliefs and religious beliefs about GM foods. For PCBs, they used teaching efficacy beliefs. They first prepared specific questionnaires targeting the belief types in their model and administered them to 445 PSTs. The quantitative results showed that content knowledge and risk perceptions were positive and significant predictors of teaching efficacy. Follow-up interviews with eight participants identified that traditional epistemologies, such as knowledge transfer, explained the relationships between knowledge and teaching efficacy. In addition, the task values (or goals) of teaching science, such as a desire to shape future generations, were responsible for the relationships between risk perceptions and teaching efficacy. Therefore, they incorporated these CPBs into their belief system model (for further information, please see Author, 2013).

An Extended Belief System Model for Understanding Beliefs about Teaching a Socioscientific Issue

The proposed belief system model in the present study is shown in Figure 1. We extended the set of PCBs by adding two new dimensions: beliefs about teacher's roles in SSI teaching and beliefs about methods in teaching GM foods. We used the same CBs that we used in our previous research (Author, 2013). Our goal was to retest the belief system model for SSI teaching by extending it. This test will also provide us stronger information about the nature of teachers' belief systems in SSI teaching. Such information can be used in preparing more efficient curricula for preservice teacher education and professional development oppurtunities for current teachers.

Our criteria for selecting CBs were a high frequency for each parameter in the literature and the potential impact of these parameters on the PCBs. For beliefs related to GM foods, we selected content knowledge, religious beliefs, moral beliefs and risk perceptions, which we identified as important content-specific beliefs in understanding SSI and decision-making (EuroBarometer, 2010). For the PCBs, we identified teaching efficacy beliefs, beliefs about teachers' role in SSI teaching and beliefs about teaching methods in SSI teaching that were problematic and that became important bariers before successful SSI teaching. In addition, as scholars (Lee et al., 2008; Oulton et al., 2004; Sadler, 2011) suggest, we consider these three dimensions to be crucial in decisions about SSI teaching, teaching material preparation, the management of student learning and the achievement of learning outcomes such as higher order thinking skills and ethical reasoning.

We believe that PCBs are, of all belief types, the closest to real classroom practices. These professional beliefs are usually formed when teachers enter teacher training, and we hold that personal CBs and CPBs shape these beliefs. In the present study, we firstly investigate the relationships between CBs and PCBs. These relationships help us to elicit CPBs as Author (2013) suggested that these beliefs work as a filter between peripheral beliefs. We believe that identifying three types of beliefs in the same belief system will allow us to find significant educational implications for SSI reform in Turkey and in similar contexts.

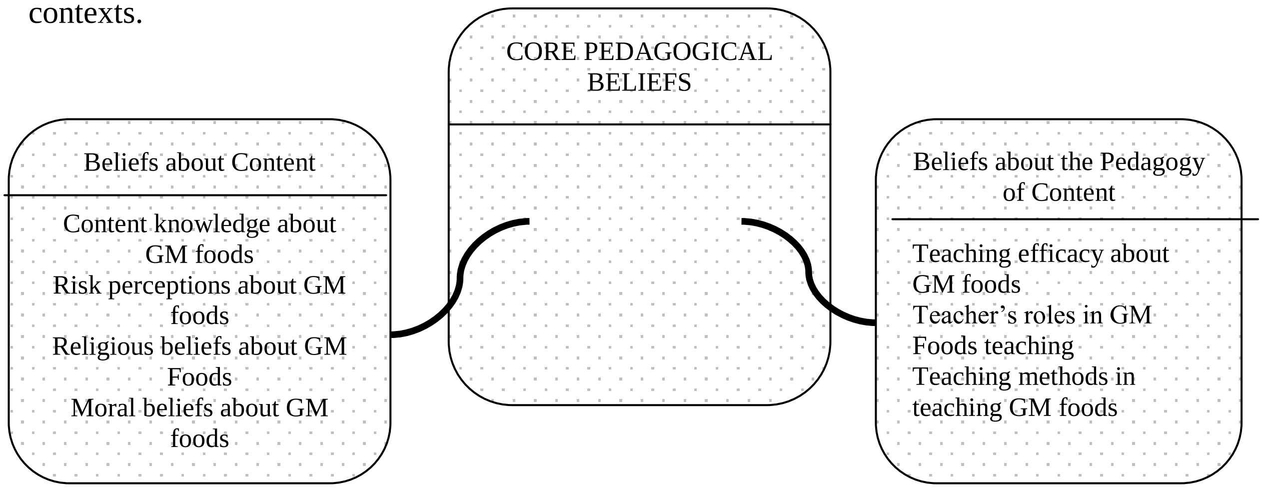

Figure 1. *Theoretical Belief System for Teaching about GM Foods*

The purpose of this research is to investigate Turkish preservice science teachers' belief systems about teaching GM foods. We attempted to answer the following research questions:

1. What types of relationships exist in preservice science teachers' belief systems about teaching GM foods?
2. To what degree does the belief system model (Figure 1) reveal the contributions of factors related to belief systems in the teaching of GM foods?

METHODOLOGY

We organized a quantitative research based on correlation and regression models in the present study.

a) Sample

We selected PSTs from ten universities with Teaching Science departments in different regions of Turkey as our sample using convenience sampling procedures. These universities offer same science teacher education curricula with slight changes permitted by Higher Education Council. The science teacher education in Turkey takes four year. The PSTs take a range of content (e.g., Physics), pedagogy (e.g., Educatinal Pscyhology) and pedagogy of content courses (e.g., Specific Teaching Methods). Our sample included 423 (127 [30 %] male and 296 [70 %] female) PSTs with a mean age of 21.5 (SD=1.39, range=18-27). In addition, we selected participants in their third and fourth years of study because they had taken many pedagogical and science courses. Of the sample, 262 (62 %) participants were in Year 3 and 161 participants (46.3 %) in Year 4.

b) Development of Belief System Questionnaire

We developed a Teacher Belief System Questionnaire (TBSQ) using the belief system model in Figure 1. The TBSQ included eight sub-questionnaires: Content Knowledge about GM Foods (CKGF), Moral Beliefs about GM foods (MBGF), Religious Beliefs about GM Foods (RBGF), Risk Perceptions about GM foods (RPGF), Teaching Efficacy Beliefs about GM Foods (TEBGF), Teachers' Roles in Teaching GM Foods (TRTGF), Efficacy Beliefs about Teaching Methods (EBTM) and Effectiveness Beliefs about Teaching Methods in Teaching GM Foods (EBTMTGF). The questionnaire was preceded by a cover sheet requesting personal information, such as gender, age, university and year group. The items in the TBSQ are shown in Appendix.

We selected items based on questionnaires that are frequently used in the literature (see Table 1). In the development of TEBGF, we also conducted semi-structured interviews with six experienced science teachers regarding their teaching efficacy beliefs about SSI. These interviews targeted teachers' understandings of SSI, actual teaching experiences, confidence in teaching these topics and the sources of their teaching efficacy (Author, 2013).

In the section of the questionnaire dealing with teachers' role in SSI teaching, we used Kelly's (1986) teacher's roles (Exclusive Neutrality, Exclusive Partiality, Neutral Impartiality, Committed Impartiality) in teaching controversial topics. We prepared a scenario to represent each role and asked the PSTs to choose one of them (Author, in submission).

We investigated the potential use of a teaching method in teaching GM foods in two final parts of the questionnaire. The first part (EBTM) included 25 teaching methods (e.g., didactic teaching), and we asked PSTs how well they could use these methods. In the second part (EBTMTGF), we relisted the same teaching methods and asked the PSTs to evaluate how effective these teaching methods would be in teaching SSI.

After the selection of items, we held a meeting with sixteen participants. This group included four science education professors, a professor who worked in genetics and biotechnology, a professor who was an expert in statistics and questionnaire development, a reading education professor, a lecturer from the Turkish Language and Literature department, three doctoral students and six Master's students. This group scrutinised the items and the layout of the sub-questionnaires in terms of content and language. Minor changes were made to some items.

After pilot tests with large samples, we reached the final versions of the sub-questionnaires in Table 1. The alpha reliability scores of the sub-questionnaires ranged from 0.61 to 0.91.

Table 1. *Information about the Sub-Questionnaires in TBSQ*

Sub-questionnaire	Abbreviation	Number of items	Available responses	Item sources
Content Knowledge about GM Foods	CKGF	5	True, False, Don't Know	Eurobarometer (2010) Sjöberg (2008)
Risk Perceptions about GM Foods	RPGF	13	Absolutely not, Very little, Rather little, To some extent, To a rather high degree, To a high degree, To a very high degree	Fischhoff et al. (1978) Sjöberg (2008)
Moral Beliefs about GM Foods	MBGF	4	I completely disagree, I disagree, I neither agree nor disagree, I agree, I completely agree	Eurobarometer (2010)
Religious Beliefs about GM Foods	RBGF	5	I completely disagree, I disagree, I neither agree nor disagree, I agree, I completely agree	Eurobarometer (2010)
Teaching Efficacy Beliefs about GM Foods	TEBGF	10	Nothing (1).... A great deal (9)	Riggs &Enochs (1990) Semi-structured interviews
Teachers' Roles in Teaching GM Foods	TRTGF	4	Role 1, Role 2, Role 3, Role 4	Kelly (1986)
Efficacy Beliefs about Teaching Methods	EBTM	25	Never (1)… Very (5)	Yilmaz-Tuzun (2008)
Effectiveness Beliefs about Teaching Methods in Teaching GM Foods	BTMTGF	25	Never (1)… Very (5)	Yılmaz-Tuzun (2008)

c) Administration of the Teacher Belief System Questionnaire (TBSQ)

We identified a lecturer contact in each programme, and, before administering the questionnaire, the authors initiated phone conversations with the contacts to inform them about the aims of the study, to identify possible questions from the participants and to explain the administration procedure. Almost all of the lecturers distributed the questionnaires in their regular classrooms and allowed time for the clarification of participants' queries. The participants completed the questionnaires in approximately 25 minutes.

d) Data Analysis

We used various descriptive and inferential analyses in the present study. Descriptive statistics were used to understand the psychometric factors of GM foods and the teaching of this topic. We used structural equation modelling (SEM) as an inferential analysis to test the relationships between CBs and teaching efficacy beliefs. We controlled the assumptions of SEM such as normality, random missing data and model specification. To find the predictors of beliefs about teachers' roles in teaching SSI, we used Multinomial Logistic Regression (MLR). In addition, we tried to understand the potential use of a teaching method in SSI education with a scatter gram, which was plotted using the mean scores of the responses to questionnaire items in the first part (efficacy beliefs) against the mean scores of the responses to the items in the second part (effectiveness beliefs). To measure the relations between CBs and beliefs about teaching methods, we used Pearson Moments Correlations and correlated the CBs with the effectiveness beliefs about teaching methods in SSI education.

FINDINGS

Beliefs about Gm Foods (CBS)

Content Knowledge about GM Foods: We found that the participants were relatively well informed about GM foods. 58 % of the participants answered all of the items correctly. Many participants were aware of focus areas for genetic modification, such as development of resistant species, and the basic techniques of GM food production.

Risk Perceptions about GM Foods: The participants considered GM foods risky, most commonly reporting this idea with the responses 'To some extent (4)' and 'To a high degree (5)'. They agreed that GM foods are the result of humans' negative impact on nature (M=4.82, SD=1.15). They also believed that these foods present a serious risk to human health, and the risks with high mean scores were illnesses in future generations (M = 4.86, SD=1.08) and cancer (M = 4.88, SD=1.13). Other items also had relatively low mean scores: items related to the severity of GM foods (M = 4.43, SD=1.14) and the harmful effects of GM foods on plants (M = 4.41, SD=1.21).

Moral Beliefs about GM Foods: The participants held certain moral beliefs about GM foods, which varied according to different items. In terms of emotional aspects, a small proportion (31%) of the participants reported that they would feel guilty if they preferred GM foods to other foods, whereas about a half (44 %) said that they would feel embarrassed. Only a quarter (26%) believedthat buying GM foods would conflict with their principles. However, approximately half (44 %) said that they would not eat GM foods for moral reasons.

Religious Beliefs about GM Foods: The participants in this study had moderate religious beliefs. More than half (58 %), for example, thought that eating GM foods was a sin. Similarly, 45 % believed that genetic modification was a sin. In addition, 45 % agreed that the genetic modification of organisms interfered with God's work. A similar proportion of the participants believed that the people who performed genetic modifications would be punished by God during their lifetime (51 %) or after their death (45 %).

Beliefs about Pedagogy of GM Foods (PCBs)

Teaching Efficacy Beliefs: Based on the descriptive results in Table 2, we can argue that the participants had moderately high efficacy beliefs about teaching GM foods. All of the items had mean scores over 6 and in the range of 1-9. On one hand, the participants strongly believed that they could hold their students' attention during discussions and develop their thinking skills. On the other hand, preparing materials and scenarios, using different teaching methods and teaching ethical reasoning had lower mean scores.

Table 2. *Descriptive Results for Teaching Efficacy Items*

Items	Mean	Std Deviation	Range
How well can you prepare scenarios and materials for discussions?	6,02	1,64	1-9
How well can you use different teaching methods in teaching controversial issues, such as GM foods?	6,22	1,48	1-9
How well can you teach your students to reason ethically about genetic modification?	6,23	1,64	1-9
How well can you respond to student questions about GM foods?	6,31	1,61	1-9
How well can you implement the necessary steps to teach ideas about GM foods?	6,32	1,52	1-9
How well can you determine the learning goals for this course?	6,33	1,46	1-9
To what extent can you provide an alternative explanation or example when students are confused?	6,38	1,51	1-9
How well can you help your students to be aware of different opinions and beliefs about GM foods?	6,39	1,67	1-9
To what extent can you develop students' higher order thinking skills during discussions about GM foods?	6,41	1,31	1-9
How well can you hold students' attention during discussions?	6,57	1,43	1-9

Based on the belief system model in Figure 1, we assumed that CBs (content knowledge, moral beliefs, religious beliefs and risk perceptions) would affect teaching efficacy beliefs about GM foods. Our theoretical structural model based on this belief system is displayed in Figure 2.

Because the proposed structural relationships between the parameters can be conducted with a SEM analysis, we analysed all the participant responses using AMOS 18. The theoretical model was evaluated and compared with the various fit measures. Confirmatory testing of the theoretical model revealed that the model is acceptable from an empirical point of view. Considering the fit indices (chi-square = 1624.573, chi-square per degree of freedom = 2.626, RMSEA = .062, NFI = .80, TLI = .85, CFI = .87), we can say that the theoretical structure has a strong model fit (Tabachnick& Fidel, 1996).

Figure 2 also shows the summary of the maximum likelihood parameter estimates (standard coefficients) and the significance of the t-values, indicated by asterisks. Knowledge (content knowledge about GM foods) and risk (risk perceptions about GM foods) were significant predictors of the variation in SEB (Self Efficacy Beliefs about teaching GM foods). Religious beliefs (beta= .07) and moral beliefs (beta=.01) had small and nonsignificant relations with teaching efficacy beliefs. In addition, the independent variables were significantly correlated between -.33 and .37.

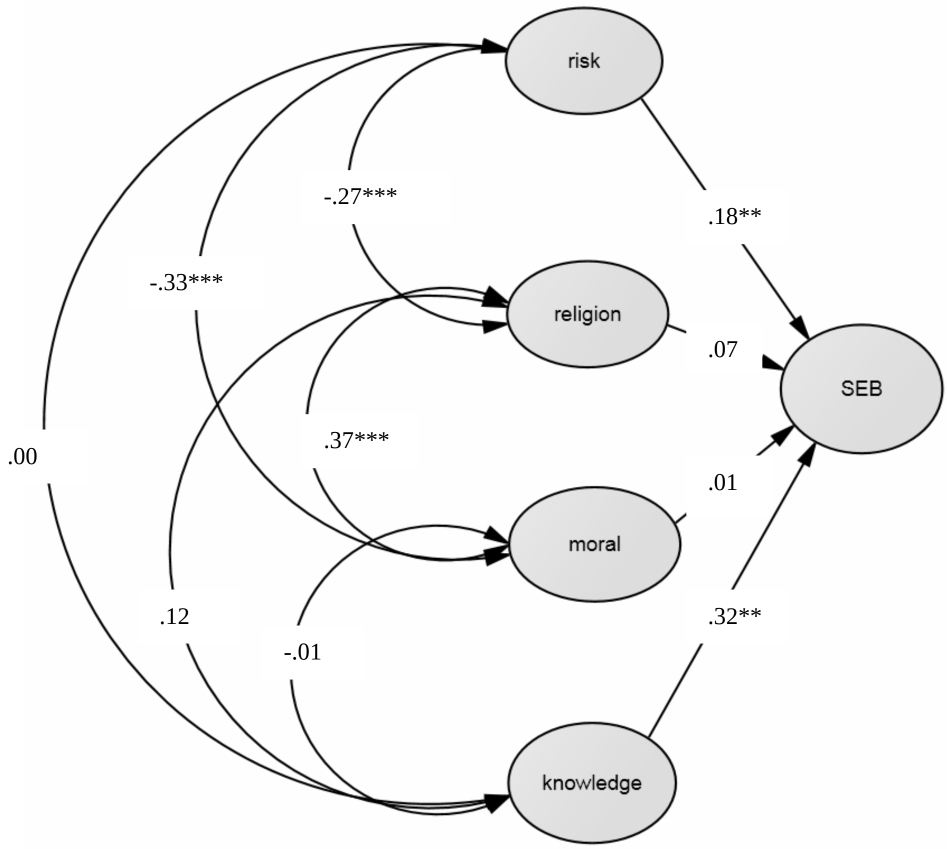

Figure 2. *Theoretical Structural Model Based on the Belief System in Figure 2 and Maximum Likelihood Parameter Estimates* (**: p <0.01, ***: p<0.001, risk: risk perceptions about GM foods; religion: religious beliefs about GM foods; moral: moral beliefs about GM foods; knowledge: content knowledge about GM foods; SEB: Self-efficacy beliefs about teaching GM foods).

Teachers' Roles in SSI Education: The results showed that 34 (9.3 %) participants selected Exclusive Neutrality, 34 participants (9.3 %) Exclusive Partiality, 204 (55.9 %) participants Neutral Impartiality and 93 (25.5 %) participants Committed Impartiality.

To test the model in Figure 1, we used Multinomial Logistic Regression (MLR). This type of regression enables the prediction of categorical dependent variables with either nominal or ordinal independent variables. The categorical dependent variable in our model was the selection of one of four roles for teachers in SSI education. The nominal independent variables were mean scores of content knowledge, religious beliefs, moral beliefs and risk perceptions. In MLR, the parameters are interpreted using odds ratios, whichrepresent the odds that an outcome will occur with a particular exposure compared to the odds of the same outcome occurring in its absence (Szumilas, 2010). Odds ratios over 1.0 indicate an increased likelihood, whereas ratios between 0 and 1 indicate a decreased likelihood. We set Committed Impartiality as the reference category because it is the role that many scholars (Oulton et al., 2004; Simmonneaux, 2007) suggested during SSI discussions. The results ofthe MLR are displayed in Table 3. We also provide descriptive results about each role in Table 4 to clarify the results of the MLR.

Table 3. *MLR Results*

	Likelihood ratio tests			P value			Odds ratios		
	Chi-square	df	sig.	EN	EP	NI	EN	EP	NI
Knowledge	6.899	3	.075	.113	.052	.943	.25	.21*	1.04
Religion	38.373	3	.000	.000	.011	.948	**.23*** **	**.50***	.99
Moral	23.939	3	.000	.006	.001	.629	**2.13****	**2.55*****	.92
Risk	4.822	3	.185	.049	.115	.209	**.54***	.65	.79

The reference category: Committed Impartiality (CI)
Model fit criteria: -2 log likelihood = 775.794, chi-Square =62.856, df = 12, p < 0.01, Nagelkerke R = .19, *p <0.05, **p<0.01, *** p<0.001

Table 4. *Descriptive Results about Each Role*

	Knowledge		Moral Beliefs		Religious Beliefs		Risk Perceptions	
	M	SD	M	SD	M	SD	M	SD
Exclusive Neutrality	.69	.28	**3.19**	.94	**2.78**	.83	**4.65**	.58
Exclusive Partiality	.66	.31	**3.50**	1.00	**3.36**	.87	4.70	1.28
Neutral Impartiality	.77	.26	2.88	.82	3.52	.92	4.67	.72
Committed Impartiality	.77	.26	**2.98**	.86	**3.59**	.91	**4.80**	.74

Our results show that religious beliefs, moral beliefs and risk perceptions were significant predictors in the selection of teachers' roles. The participants who held strong religious beliefs were 0.23 times less likely to select Exclusive Neutrality and 0.50 times less likely to choose Exclusive Partiality, compared to the Committed Impartiality reference group. In other words, the participants who had a lower level of religious beliefs than the ones who chose Committed Partiality selected Exclusive Partiality and Exclusive Neutrality.

Furthermore, the participants who reported strong moral beliefs were 2.13 times more likely to select Exclusive Neutrality and 2.55 times more likely to choose Exclusive Partiality, compared to Committed Impartiality. Thus, the participants who had stronger moral beliefs than the ones who selected Committed Impartiality selected Exclusive Partiality and Exclusive Neutrality. In addition, the participants with high risk perceptions were 0.54 times less likely to select Exclusive Neutrality than the Committed Impartiality group.

Overall, the characteristics of the participants who selected Neutral Impartiality and Committed Impartiality were similar for all the independent variables (i.e., knowledge, moral beliefs, religious beliefs and risk perceptions). The participants with less religious beliefs tended to select Exclusive Neutrality and Exclusive Partiality. In addition, the ones who selected Exclusive Neutrality and Exclusive Partiality held stronger moral beliefs than the other groups. Finally, the participants who selected Exclusive Neutrality had the lowest risk perceptions of all the groups.

Teaching Methods in SSI Education: In the scatter gram in Figure 3, the teaching methods located in the upper part of the (those with a higher mean score) are considered effective in GM food teaching by many students, whereas the methods in the lower part are considered less effective. Similarly, the teaching methods to the left of the plot were identified by the participants as inefficient, and those to the right were identified as efficient.

Looking at the positions of the various teaching methods on the plot, it can be seen that didactic teaching was not viewed as suitable for GM Foods teaching. Although the participants considered that inviting experts to classroom would be useful in teaching GM Foods, the efficacy of this method was limited.

Because the scales of efficacy and effectiveness included five response alternatives (from low (1) to high (5)), we believe that the responses over 4 for both scales can be used to find teaching methods with the highest use potential. We used the lines to show these teaching methods. Accordingly, it seems that the participants would use large class discussions and computer assisted teaching in their future careers because they identified these methods as efficient and effective in teaching GM foods. Collaborative and inquiry-based teaching methods (i.e., project based learning, inquiry, problem based learning, cooperative learning and case method) follow these methods in the list of PSTs. In addition, the PSTs showed high efficacy beliefs for lab-based activities and question-answer sessions even though they reported relatively limited effectiveness beliefs. In addition, PSTs believed that the methods about teaching conceptions such as analogy, 5E learning cycle, conceptual change texts and concept maps would not be useful as much as other methods would be in teaching SSI. Regarding role-play and drama, which are suggested methods for SSI-education, they considered these methods to be useful in teaching GM Foods to some extent but reported a limited efficacy in using them.

To measure the relations between CBs and beliefs about teaching methods, we used Pearson Moments Correlations. We investigated the relationships between CBs and beliefs about the effectiveness of each teaching method in teaching GM foods. Table 5 shows that risk perceptions were positively correlated with beliefs about the effectiveness of certain teaching methods. However, the correlation scores did not exceed .200, meaning that risk perceptions had weak relationships with the effectiveness of teaching methods. Apart from a few exceptions, the other content beliefs did not correlate with effectiveness beliefs.

DISCUSSION

In the case of CBs, we found that the PSTs were relatively knowledgeable and held certain moral beliefs, moderate religious beliefs and high risk perceptions. Apart from religious beliefs, the results about the CBs were consistent with our previous research (Author 1, 2013). It is possible that undergraduate courses, such as Specific Issues in Biology and Genetics, as well as media coverage are responsible for the sample's relatively strong conceptual background in GM Foods. In addition, the PSTs in this sample had stronger religious beliefs than did those in previous research (Author 1, 2013). It is hard to explain this result because the PSTs are from different regions and backgrounds across the universities. It is possible that genetic modification is a new topic for the religious authorities, and there is not yet any confirmation for its use, which causes it to be of interest to people with moderate religious beliefs. In addition, the new and unknown nature of these foods (Sjöberg, 2008) may be the reason for high risk perceptions in Turkey.

In terms of PCBs, the PSTs reported relatively high teaching efficacy beliefs. They commonly chose the role of Neutral Impartiality and preferred large class discussions and computer assisted teaching as teaching methods. Although this picture seems optimistic for the future of SSI reform in Turkey, we believe that further investigations are essential.

In the case of teaching efficacy beliefs, we noted that PSTs' efficacy beliefs were high for general instructional practices, such as holding student attention, but that efficacy decreased in the cases of preparing discussion scenarios and teaching ethical reasoning, which are specific components of SSI-based education. Similarly, Author (2013) found that PSTs were not confident in teaching the nature of science or in incorporating families into learning, which are specific elements of SSI teaching. It is possible that PSTs use general science teaching efficacy to interpret the items about teaching SSI and that this efficacy does not represent the beliefs about SSI teaching (Author, 2013). In addition, content knowledge and risk perceptions were positive significant predictors of teaching efficacy. Although certain studies show similar relationships (Cakiroglu& Boone, 2002), Author's (2013) comments are crucial for understanding these relations. Consistent with their arguments, we believe that certain CPBs influence these relations. In the case of content knowledge, traditional epistemologies based on knowledge transfer might come into play because most Turkish PSTs have naïve beliefs about learning and teaching knowledge (YılmazTuzun & Topcu, 2008). The PSTs with a strong knowledge background and naïve epistemologies based on knowledge transfer might believe that they can teach SSI efficiently. Regarding risk perceptions, a teaching goal such as the desire to raise a healthy generation might be influential because Turkish PSTs are sensitive about the social utility of teaching (Author, 2012b). Author (2013) found that PSTs believed that their risk perceptions led them to teach these topics effectively due to potential for health problems in the near future. Similarly, the PSTs in the present study with high risk perceptions and a desire to foster a healthy society might develop high teaching efficacy beliefs so that their students can better learn about the negative sides of GM Foods.

Regarding teachers' roles in SSI education, it was encouraging to find that only a small percentage of the PSTs chose Exclusive Neutrality (Role 1) and Exclusive Partiality (Role 2). This finding implies that most of the PSTs will incorporate SSI into their teaching without imposing their personal opinions. Although a large portion of PSTs selected Neutral Impartiality, the existing literature and we suggest this result might be an illusion. Many scholars (Kelly, 1986; Oulton et al., 2004; Simmonneaux, 2007) argue that most teachers and PSTs prefer this role before real teaching experience but soon change their role due to the impossibility of not disclosing personal values and opinions in the classroom. In addition, Author (in submission) noted that one of the reasons for choosing Neutral Impartiality was the desire to reach absolute truths by discussing different perspectives, which is an immature belief. They associated this result with the naive epistemologies of Turkish PSTs about certainty of knowledge. In addition, about a quarter of the sample selected the teaching role of Committed Impartiality. This proportion is similar to the results found in a previous study (Author, in submission). We believe that certain PSTs may have concerns about this role, such as the risk of influencing school students with their personal opinions and/or the possibility for difficult and unplanned debates (Author, in submission).

We believe that the predictors for the set of CBs strengthen our comments about beliefs in teachers' roles because, using them, we may identify CPBs. For example, the PSTs with higher religious beliefs preferred Neutral Impartiality or Committed Impartiality. They reported that they would incorporate SSI into their democratic learning environments without imposing their points of view on their students, though they may make their opinions explicit. Religiously based CPBs may come into play in this finding. Regarding creating a democratic environment highlighted in both Neutral Impartiality and Commited Impartiality, Islam, the Koran and the practices of Prophet Muhammad emphasise that there should be no pressure on people while they make their decisions. An individual should tell his/her opinion about a controversial issue but leave the decision to others (Esposito & Voll, 1996). Regarding being a model in Committed Impartiality, we can argue that modelling is crucial in Islam, especially while raising children, who learn what to do and not to do from observing models around them (Esposito & Voll, 1996). In addition, the PSTs with stronger moral beliefs particularly selected Exclusive Neutrality and Exclusive Partiality. This finding may imply that if a PST is convinced that GM foods are good or bad, he/she will not create a democratic environment that permits the discussion of possible alternatives, as in the roles of Neutral Impartiality and Committed Impartiality. These teachers will either avoid incorporating SSI into their teaching or impose their points of view. For the former, we believe that PSTs with higher moral beliefs may not be willing to teach these issues in their classrooms because they do not want students to learn different perspectives about them. For the latter, a moral teaching goal, such as protecting children from the harmful effects of GM foods, might be responsible (Lee &Witz, 2009). In addition, the PSTs who chose Exclusive Neutrality had a lower level of risk perceptions than did those who chose Committed Impartiality. It is possible that a higher risk perception will lead PSTs to incorporate these issues into their teaching. This finding may also be related to a moral teaching goal, such as desire to educate a healthy generation of students (Cross & Price, 1996). However, we do not know whether PSTs with higher risk perceptions will impose their ideas, create a democratic environment or be a model for children.

Table 5. *Pearson Moments Correlations between Effectiveness Beliefs about Teaching Methods and Content Beliefs*

	Knowledge	Moral	Religion	Risk
Conceptual Change text	.112*			.144**
Drama				
Large class discussion				.143**
Role play				.111*
Multiple intelligence				.103*
Inquiry				
Concept Cartoons				.153**
Small group discussion			.111*	
Concept maps				
Computer assisted teaching	.107*			
Using newspapers				.133**
Project based learning	.111*			
Didactic teaching				
Lab activities				.108*
Question-answer sessions	.117*			
Play				
Inviting experts				.135*
Discovery				
Internet research	.109*			
Cooperative learning				
Analogy				
Problem-based learning				
Case				.135*
5E learning cycle				
Outdoor education				.184**

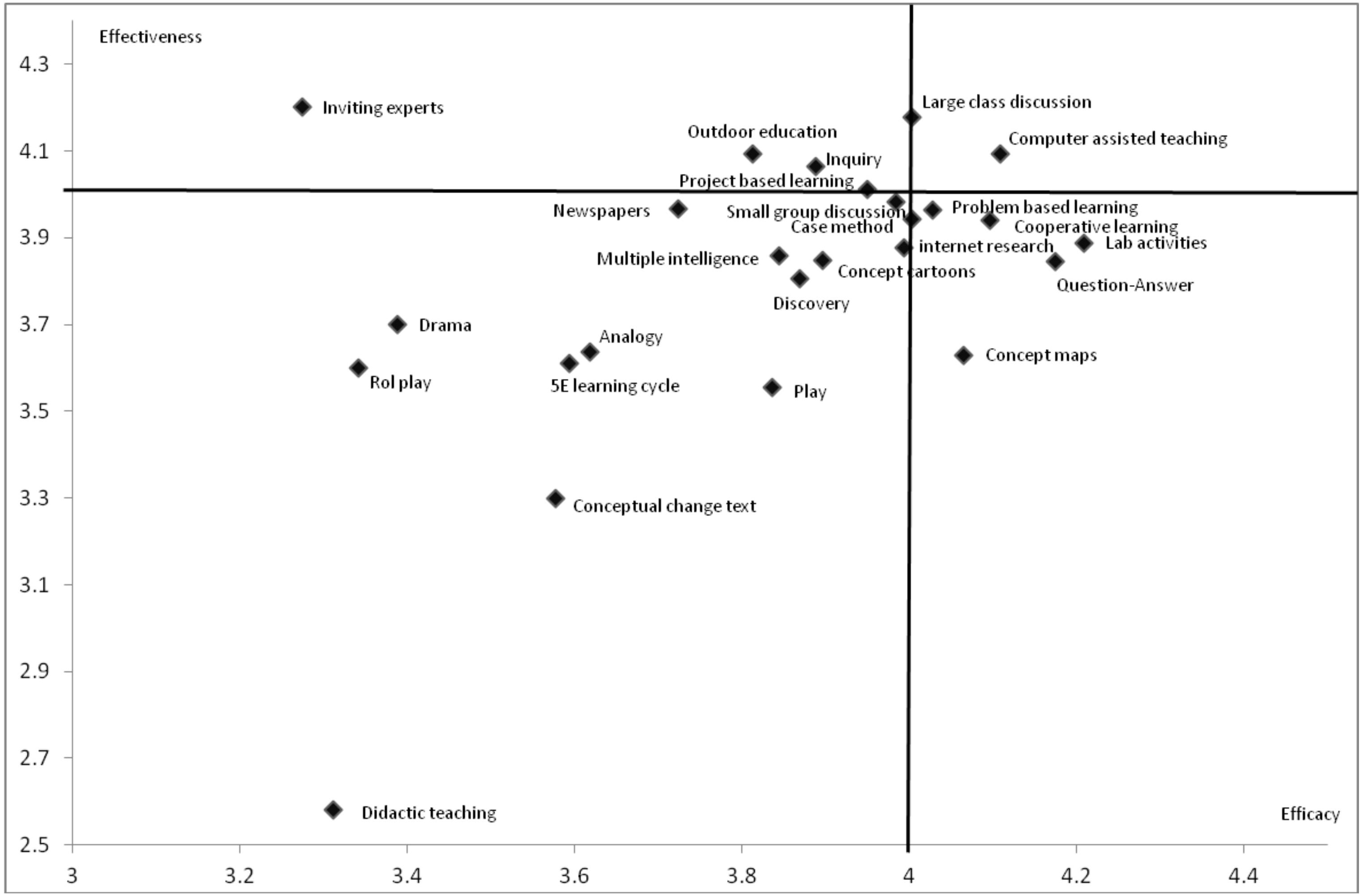

Figure 3. *The Scatter Gram Showing the Potential Use of Teaching Methods in SSI Education*

In terms of teaching methods, PSTs would potentially use computer assisted teaching and large class discussions in SSI-based education in the future. Collaborative and inquiry-based learning environments such as project based learning, cooperative learning, small group discussion, inquiry and problem based learning follow these methods. In addition, they most commonly considered that conceptual change methods would not be very effective in teaching SSI. These results show that PSTs can feel that SSI-based education requires collaborative and interactive classroom environments, where students collaboratively produce knowledge, collect data and make inquires. In addition, they can separate these methods from more classical ones based on teaching conceptions. These positive results are consistent with expectations and suggestions of scholars (e.g., Sadler, 2011a). However, we still believe that these results should be interpreted carefully considering certain opposite results in Turkish literature. For example, computer assisted teaching and large class discussion are frequently used by science teachers and lecturers in Turkey. It seems that the PSTs selected these methods to provide a conceptual background about GM foods for their students because computer assisted teaching in Turkey is a preferred method for particularly conveying new concepts (Yesilyurt, 2011). In addition, large class discussions are a form of recitation, including question-answer-evaluation sessions, in Turkish classrooms (Author, in submission). These findings show that the methods with high potential of use may turn into the environments where students deal with conceptions and try to memorize them.

Another intriguing result was the reluctance of certain PSTs to use role-play and drama in teaching about GM Foods, even though these methods include roles that represent different positions and ideas about SSI cases. Consistent with their responses, we can argue that PSTs lack experience in using these methods in SSI-based education. Lack of expertise is also observed in inviting experts even though this method is considered very effective. This situation may stem from PST's previous schooling and teacher training. Perhaps they had limited mastery and vicarious experiences about these methods. In addition, we found weak correlations between CBs and beliefs about the effectiveness of teaching methods. Considering the correlation coefficients are less than .200, it is not appropriate to make any causal comment. However, we can speculate that PSTs with high risk perceptions tend to use a range of teaching methods or a combination of different teaching methods to convey pessimistic messages to school children.

Finally, based on the above interpretations, we completed our theoretical model in Figure 1 by adding CPBs in Figure 4.

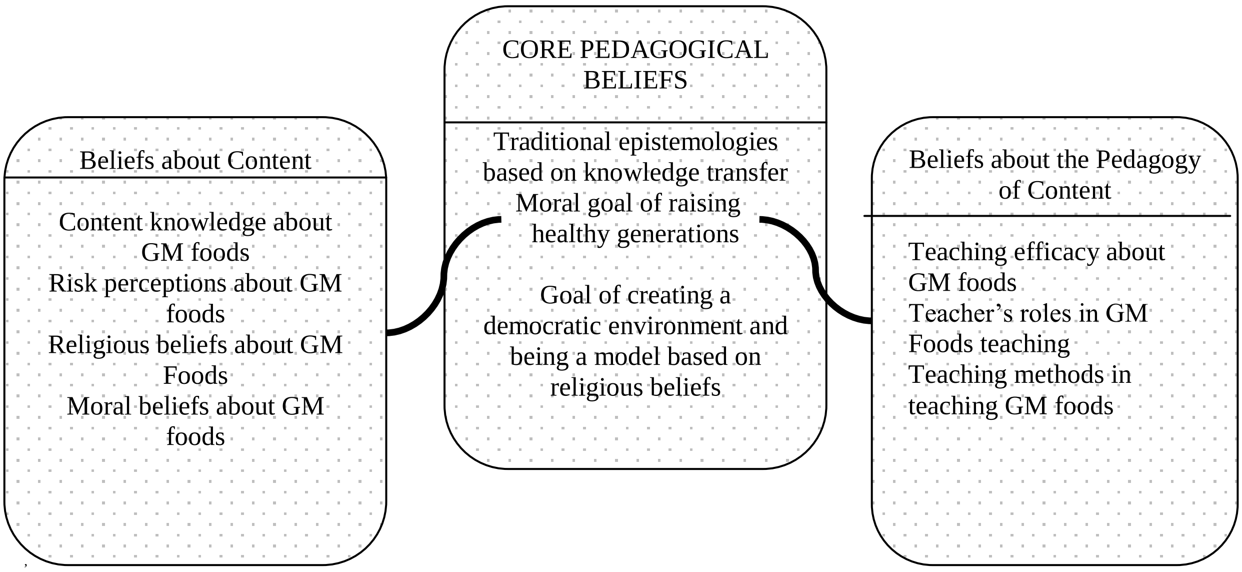

Figure 4. *Final Version of the Belief System for Teaching about GM Foods*

CONCLUSION and IMPLICATIONS

We argue that a belief system about teaching SSI exists and suggest that it includes a nested belief framework including professional beliefs (CPBs and PCBs) and personal beliefs (CBs). PSTs may bring their personal values and beliefs into classrooms and use their core educational beliefs as a filter, and it is possible personal CBs about SSI, reshaped by CPBs, influence PCBs about SSI. For instance, a teacher who is unwilling to cook with GM foods for her children may believe that she should bring her pessimism from home into the classroom. She may have a core educational belief such as raising a healthy future generation, which will lead her to impose her personal beliefs on school children without discussing positive views of GM foods. She may consider that she can teach negative perspectives more efficiently because of her personal beliefs and core educational beliefs. She may not permit exchanges in the classroom and prefer recitation and question-answer sessions that guide students towards her personal truths. Therefore, any suggestions about the implications of this study should not take only individual beliefs into account, but the whole belief system.

Two fundamental implications emerge from our results: Change and New Focus

A) Change

We could easily argue that PSTs are not ready for curricular reform in Turkey. In particular, their PCBs do not generally fit with the expectations of SSI reform. In terms of teaching efficacy beliefs, rather than general science instruction and knowledge transfer, we believe that it is essential to prioritise NOS instruction, the development of moral and ethical reasoning and sophisticated epistemologies. We suggest more (mastery) practices for SSI instruction in Science Teaching Methods courses and teaching practicums in real classrooms so that PSTs can experience inconsistencies between their existing beliefs and intended ones (Posner et al., 1982). In these practices, explicit NOS learning and teaching (Akerson, Abd-El-Khalick, 2000) and the tenets of ethical and moral reasoning (Zeidler& Lewis, 2003) can be emphasised. In addition, incorporating advanced science courses such as 'Specific Issues in Biology' into science teacher education will enhance PSTs' teaching efficacy about SSI because content knowledge is an important predictor of efficacy. Similarly, rather than selecting positions of Exclusive Neutrality and Exclusive Partiality due to moral teaching goals, teachers can select more dialogical roles such as Neutral Impartiality or Commited Impartiality based on mature epistemologies and promising teaching goals such as character development. At this point, the four teacher roles identified by Kelly (1986) can be introduced to PSTs, who should then reflect on these roles. In addition, rather than selecting teaching methods based on traditional goals, such as teaching concepts and transmitting knowledge, teachers should choose methods based on the interplay of different ideas and dialogues between student and teacher and student and student (small group discussion, role-play, drama, etc.). Science teacher educators can highlight that conceptual understanding is only one goal of SSI teaching among a set of cognitive, affective and behavioural outcomes. Methods such as role play and drama can be incorporated into Science Teaching Methods courses by contextualising them within SSI education. In addition, successful examples of inquiry based technology integration in SSI education (see the COREFLECT project: www.coreflect.org) and efficient discussion environments such as deliberative discourse (Michaels, O'Connor &Resnick, 2008) can be introduced to those PSTs who already believe that both these environments are suitable for SSI education.

Apart from content knowledge, we believe that we should not try to change personal (content) beliefs because they are unique to individuals and are shaped by a range of factors, on which pedagogical environments have a limited influence. In addition, certain personal beliefs can make the belief shift easy, as in the case of the effect of religious beliefs on the selection of Committed Impartiality. We suggest that science teacher educators should diagnose these content beliefs before giving instructions about teaching SSI. This diagnostic awareness will provide educators with certain predictions (e.g., PSTs with strong moral beliefs may not want their students to learn different perspectives) and allow them to organise their teaching programmes, modules and materials to these specific groups.

We believe that if educators aim to create a complete shift in PSTs' minds, then change-based strategies should target CPBs (filters) even though these beliefs are the most resistant group to change in the belief system (Ertmer, 2005). However, this change is likely to automatically cause the expected changes in PCBs. Although most core educational beliefs are shaped before entering university, teacher training institutions still have a chance to reshape their student-teachers' beliefs (Pajares, 1992). As scholars (e.g., Pajares, 1992) argue, three steps may be useful: eliciting beliefs, creating inconsistencies and encouraging a willingness to use suggested beliefs. Using questionnaires and/or interviews, science teacher educators can understand PSTs' existing core educational beliefs in first stages of university education. After that, they can plan a purposeful teaching programme in both science and science education courses that takes into account existing core frameworks. As a second step, we believe that PSTs should encounter inconsistencies within their core system and the system we ask them to enact. In our teaching SSI context, PSTs should master mature epistemologies: for example, 'knowledge is uncertain in some cases', and 'truths are true to some extent and according to context'. In addition, the current goals of science teaching should be made explicit in different courses (e.g.,educating scientifically literate people who can make informed decisions, handle uncertainties and build arguments). Lecturers in science and science education courses can continuously use inquiry based, collaborative teaching approaches, support PSTs directly and/or vicariously and adopt dialogical roles in controversial issues. In addition, it should be emphasised that teaching SSI is different from teaching other regular science topics and that, in addition to conceptual learning, it includes collecting and analysing the data, evaluating evidence, coping with uncertainties, defending arguments and increasing moral and ethical sensitivity. If these goals and inconsistencies based on experience and professional support are incorporated into science teacher training, we believe that certain PSTs may be willing to change their core beliefs and produce better ones that fit with suggested SSI teaching.

B) New Focus

One another contribution of this research is its theoretical approach. The study of belief systems, rather than individual beliefs, provides more reliable information about teachers' beliefs (Fives &Buehl, 2012). We suggest that beliefs are complex and interrelated. When we discard a few beliefs from existing belief systems, we may lose sight of important relationships and core factors. For instance, if we had focused on teaching efficacy beliefs without investigating content beliefs, we may have concluded that PSTs have moderately high efficacy beliefs and that this is good news for curricular reforms. However, our finding that risk perception is a predictor of teaching efficacy recalibrated our focus and led us to suggest that (science) teacher education researchers need to do the same. Instead of observing the content of a small cell in a leaf, studying part of the tissue provides additional information about the relationships between the cells and their effects on one another. The present study reconfirmed the importance of the belief system model in SSI teaching, which was suggested in previous works. We consider this model to be useful in understanding teachers' beliefs and reactions to topics in science and other areas.

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APPENDIX

Teacher Belief System Questionnaire

Content Knowledge about GM Foods

Genetically modified tomatoes include genes, whereas normal tomatoes do not.
One of the areas in which gene transfer is used in plants is producing disease resistance.
Genetically modified foods cannot be digested.
In order to modify the genes of a plant, its cells should be killed.
A plant's need for fertilizers and pesticides is decreased by changing its genetical structure.

Moral Beliefs about GM Foods

Buying GM foods instead of normal ones is against my personal principles.
I feel guilty if I buy foods produced by genetically modified organisms instead of other foods.
I do not find any problem with GM foods in terms of moral aspects.
Buying foods produced by genetically modified organisms instead of other foods makes me embarrassed.
I do not eat GM foods due to moral reasons.

Religious Beliefs about GM Foods

I think genetic modification of organisms is interfering with God's work.
Modification of the genetic structure of an organism is a sin.
I believe that people who change the genetic structure of organisms will be punished by God after they die.
I believe that people who change the genetic structure of organisms will be punished by God in this world.
Eating GM foods is a sin.

Risk Perceptions about GM Foods

To what extent will genetic modification lead to illnesses in future generations?
To what extent will genetic modification cause cancer?
To what extent will genetic modification have severe consequences?
To what extent is genetic modification a result of humans who destroyed the balance of nature?
How much will GM foods harm humans?
To what extent will the other people expose this risk?
How much will genetic modification lead to negative effects unknown today?
How much will genetic modification lead to negative irreversible effects?
How much will genetically modified organisms harm animals in nature?
How much will GM foods harm the environment?
How much will genetically modified organisms harm plants in nature?
To what extent do GM foods have risks that are not easily avoided?
How much is GM technology dreaded?

Teaching Efficacy Beliefs about GM Foods

There are different perspectives regarding the production of foods from genetically modified organisms. Some scientists say that there may be significant harm from these foods in the future in terms of health and the environment, whereas others say that this technology is risk-free and may be important to healthily and cheaply meet the food needs of a rapidly increasing population. Suppose that the Ministry of Turkish National Education asks students to make informed decisions about the production, consumption, encouragement or restriction of GM foods. You plan a 3-h science course in which you attempt to teach the concepts and skills needed to make informed decisions and to discuss different perspectives. The following statements are possible competences we prepared for this course. Please choose one of the options that best represent your opinion of how much you can realize these competences and practices.

How well can you prepare scenarios and materials for discussions?
How well can you use different teaching methods in teaching controversial issues, such as GM foods?
How well can you teach your students to reason ethically about genetic modification?
How well can you respond to student questions about GM foods?
How well can you implement the necessary steps to teach ideas about GM foods?
How well can you determine the learning goals for this course?
To what extent can you provide an alternative explanation or example when students are confused?
How well can you help your students to be aware of different opinions and beliefs about GM foods?
To what extent can you develop students' higher order thinking skills during discussions about GM foods?
How well can you hold students' attention during discussions?

Teacher's Roles about GM Foods Education
The roles that science teachers take in teaching GM Foods are given below. Please tick one of these roles that best represents your choice when you become a science teacher.

ROLE 1: The teacher does not introduce controversial issues in the broader community, nor does the teacher share opinions on such topics. Teachers should stick to the value-free teaching of that knowledge and set of skills which have been conclusively demonstrated to be true or important through rigorous scientific investigation or through broad consensus within the community.

ROLE 2: The teacher strives to convince students to adopt a correct and preferable position on controversial issues such as GM foods. Teachers disclose for the purpose of convincing students to accept the teacher's own perspective.

ROLE 3: The teacher promotes classroom discussion and is committed to not explicating his/her position on GM foods, but encourages students to do so. The aim here is not to impose other ideas, rather to show that different ideas, previously overlooked or under-considered in the discussion, would be relevant in making informed decisions about GM foods.

ROLE 4: The teacher promotes classroom discussion and is committed to disclosing his/her opinions on GM Foods and encourages students to do the same. The goal is to model a thinking process not to advocate for an outcome.

Teaching Methods (Efficacy) in SSI Education
Pleaseshow how muchyou can use following each method efficiently when you become a teacher, by choosing one of the numbers in response alternatives.

Teaching Methods (Effectiveness) in GM Foods Education

How much will following teaching methods be effective in a course where concepts, different points of views and decision making skills about GM foods are taught?

Role play
Drama
Large class discussion
Small group discussion
5E learning cycle
Problem based learning
Concept Cartoons
Conceptual Change text
Conceptmaps
Computer assisted teaching
Using news papers
Project based learning
Didactic teaching
Lab activities
Outdoor education
Cooperative learning
Question-answer sessions
Play
Case
Discovery
Internet research
Analogy
Inquiry
Inviting experts
Multiple intelligence

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Kimya Öğrencilerinin Nanobilim ve Nanoteknoloji Konularındaki Bilgi Düzeyleri

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ÖZET

Önümüzdeki yirmi yıl içerisinde nanoteknolojiye dayalı iş ve yaşam tarzının hayatımızda köklü değişikliklere yol açacağı ön görülmektedir. Buna bağlı olarak eğitim sistemimizde de nanobilim ve nanoteknolojinin daha fazla yer alacağı tahmin edilmektedir. Eğitim sisteminde yer alan öğrencilerin nanobilim ve nanoteknoloji hakkında bilgilerinin ortaya çıkarılması, bahsedilen konuların eğitim sistemimize dâhil edileceği süreçte önemli ve öncelikli adımlardan birini teşkil etmektedir. Bu sürece yönelik olarak, Eğitim Fakültesi Kimya Öğretmenliği programı ve Fen Fakültesi Kimya bölümü öğrencilerinin nanobilim ve nanoteknoloji hakkında bilgi seviyelerinin belirlenmesi amaçlanmıştır. Bu çalışma 2011–2012 akademik yılında Doğu Karadeniz'de yer alan köklü bir üniversitenin Fen Fakültesi Kimya Bölümünde ve Eğitim Fakültesi Kimya Öğretmenliği programında öğrenim gören toplam 53 öğrenci ile yürütülmüştür. Katılımcılara, 11 açık-uçlu sorudan oluşan bir anket uygulanarak nanobilim ve nanoteknoloji konusu ile ilgili anlamaları ve kimya bilgilerini nanoteknoloji konularına transfer etme düzeyleri araştırılmıştır. Anketten elde edilen ham veriler anlama seviyelerini ortaya çıkaracak şekilde kategorilere ayrılarak analiz edilmiştir. Elde edilen bulgulara dayalı olarak, Fen Fakültesi Kimya Bölümüne devam eden öğrenciler biraz daha iyi olmakla birlikte, her iki programdaki öğrencilerin nanobilim ve nanoteknoloji ve ilgili kavramları anlama seviyelerinin oldukça düşük olduğu ve sahip oldukları kimya bilgilerini nanoteknoloji konularına yeterince transfer edemedikleri belirlenmiştir. Dolayısıyla hızla gelişen bir alan olan nanoteknoloji hakkında, nano seviyedeki parçacıklar arası ilişkileri irdeleyen bir alan olan kimyada öğrenim gören lisans öğrencilerin dahi çok fazla bilgisinin olmadığı ve eğitim sistemimizin gelişmekte olan bu alana göre kendisini yeterince güncelleyemediği görülmüştür. Nanobilim ve nanoteknolojiye yönelik derslerin programlara zorunlu olarak girmesi zor olacağı için, bu alanla ilgili kavramlara temel kimya konuları ve ilgili dersler çerçevesinde atıflarda bulunulmalıdır.

Anahtar Kelimeler: Kimya; Kimya Öğretmenliği; Nanobilim; Nanoteknoloji; Kimya Bilgisi.

GİRİŞ

Bilimsel buluşlar ve icatlar çağında fen bilimlerinde ve mühendisliklerde ortaya konan buluşların, icatların ve/veya tasarımların kimler tarafından gerçekleştirildiği apaçık ortadadır. Fakat son yüzyılda birçok disiplinin ortak çalışması sonucu ortaya konan bilim ve mühendisliğe dayalı eserlerde, buluşlarda ya da icatlarda kimin neyi bulduğunu veya kimin neyi keşfettiğini söylemek oldukça güçtür. Bu teknolojilerden bir tanesi de Nanoteknoloji'dir

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(Sandhu, 2006). Nanoteknoloji terimi ilk kez nerede kullanıldığı hususunda itilaflar olsa da 1960'li yıllardan sonra kullanılmaya başlandığı bilinmektedir (URL-1, 2013). Günümüzde *nanobilim* 1 ile 100 nanometre arasındaki büyüklüklerdeki atom ve moleküler yapılar ve bunlar arası etkileşimler ile ilgilenmektedir (Katz, Shipway & Willner, 2004; Laherto, 2010; Liz-Marzan & Kamat, 2004; Whitesides, 2005). *Nanoteknoloji* ise atomik ve/veya moleküler seviyedeki etkileşimlerden yararlanarak elektronik, ilaç, tekstil, kozmetik vb. endüstri alanlarında ürünleri tasarlamayı, üretmeyi ve kullanmayı içermektedir (Bowman & Hodge, 2007; Foley & Hersam, 2006). Bu bağlamda nanoteknoloji disiplinler arası bir alan olarak karşımıza çıkmaktadır (Ratner & Ratner, 2003; Tessman, 2009). Nanoteknoloji sayesinde maddeyi nanometre düzeyinde işleyerek ve ortaya çıkan değişik özellikleri kullanarak, yeni teknolojik nano ölçekte aygıtlar ve malzemeler yapmak mümkün olmuştur. Tarihsel bir perspektiften bakıldığında, 21. Yüzyılın sanayi devrimi denebilecek bir bilimsel ve teknolojik devrime tanıklık ettiğimiz söylenebilir (Özdoğan, Demir & Seventekin, 2006; Wansom, Mason, Hersam, Drane, Light, Cormia, Stevens & Bodner, 2009). Bowman & Hodge (2007), 2015 yılına kadar dünya genelinde doğrudan iki milyon, dolaylı ise 5 milyon yeni iş imkânının oluşacağını tahmin etmektedirler. Benzer şekilde Foley ve Hersam (2006), 2014 yılına kadar dünya ekonomisinde nanoteknolojiye dayalı üretimlerin 2,6 trilyon dolar düzeyinde yer alacağını tahmin etmektedirler.

Nanoteknolojinin hızlı bir şekilde gelişmesi ve ekonomiye olan etkisi, nanoteknoloji eğitimi üzerine odaklanılmasına neden olmuştur. Zira bahsedilen büyüklükteki nitelikli insan gücünün kolayca ve kısa sürede yetiştirilmesi zordur (Laherto, 2010). Nanoteknoloji ve ona dayalı endüstrilerden pay almak isteyen toplumlar nanoteknoloji eğitimi için büyük miktarda maddi kaynak ve insan gücü yatırımı yapmaktadırlar (Roco & Bainbridge, 2003; Wanson ve diğ., 2009). Bu nedenle ilk, orta ve yüksek-öğretim seviyesinde araştırmalar ve bunlara bağlı olarak gerekli düzenlemeler yapılmaktadır. Bu bağlamda 2001 yılında Amerika Birleşik Devletleri başkanı Clinton'ın öncülüğünde "Ulusal Nanoteknoloji Girişimi" (National Nanotechnology Initiative) başlatılmış ve akabinde Amerika Birleşik Devletleri Ulusal Bilim Kurumu (NSF; National Science Foundation) destekli Öğrenme ve Öğretim için Nanoteknoloji Merkezi (NCLT; Nanotechnology Center for Learning and Teaching) kurulmuş ve eğitim alanındaki girişimler desteklenmiştir (Wansom ve diğ., 2009). Benzer çalışmalar Avrupa Birliği çerçevesinde yürütülmektedir (Laherto, 2010).

Bu süreçteki öncelikli çözülmesi gereken sorun nanobilim ve nanoteknoloji eğitimindeki içeriğin belirlenmesi olarak görülmektedir. Nitekim bu amaçla "Büyük Fikirler" (Big Ideas) olarak geçen nanobilim ve nanoteknoloji öğretiminde ve değerlendirilmesinde temel olacak konu ve kavramlar ve bu kavramlar hakkında öğrencilerin anlama seviyeleri belirlenmeye çalışılmıştır (Daly, Hutchinson & Bryan, 2007; Hutchinson, 2007; Hutchinson, Bodner & Bryan, 2011; Light ve diğ., 2007; Stevens, Sutherland, Schank & Krajcik, 2007; Tessman, 2009; Wansom ve diğ., 2009). Nanobilim ve nanoteknoloji eğitimcilerinin büyük bir bölümünün fikir birliğine vardığı konu ve kavramlar şu şekilde sıralanmaktadır (Hingant & Albe, 2010; Stevens, Sutherland & Krajcik, 2009):

- Boyut ve ölçek
- Maddenin yapısı
- Kuvvetler ve etkileşimler
- Kuantum etkileri
- Boyuta bağlı özellikler
- Kendiliğinden oluşum
- Araçlar
- Modeller ve benzetimler
- Bilim, teknoloji ve toplum

Amerika ve Avrupa'da nanobilim ve nanoteknoloji eğitiminde ilköğretimden seviyesinden başlayarak devam eden yoğun eğitim planlama ve araştırmalarına karşın ülkemizde gerçekleşen eğitim araştırmalarında ve planlamalarında nanobilim ve nanoteknolojiye yeterince yer verilmediği görülmektedir. Yeni güncellenen İlköğretim Fen Bilimleri ve Ortaöğretim Biyoloji Dersi öğretim programlarında nanoteknolojiye hiç değinilmediği tespit edilmiştir. Ortaöğretim Kimya Dersi için sadece 12. sınıf programında "Karbon Kimyasına Giriş" ünitesi içerisinde "nanotüpler" bir örnek olarak yer almaktadır. Ortaöğretim Fizik Dersi programında ise 12. sınıf "Modern Fiziğin Teknolojideki Uygulamaları" ünitesi çerçevesinde bir konu başlığı olarak nanoteknoloji ve nano madde kavramlarına kısaca değinilmektedir (URL-2, 2013). Başka bir ifadeyle, 12 yıllık zorunlu örgün eğitimde fen ve matematik alanlarını seçen öğrencilerin, mezun olana kadar tahmini olarak iki veya üç ders saatlerinin nanoteknolojiye ayrıldığı görülmektedir. Üniversitelerimizdeki ders içeriklerinde de benzer durum sözkonusu olmaktadır. Yapılan katalog incelemelerine dayanarak, bazı üniversitelerimizin mühendislik ve fen fakültelerinde nanobilim ve nanoteknoloji ile ilgili lisans düzeyinde sunulan seçmeli dersler olmakla birlikte bunlar sınırlı düzeyde kalmaktadır. Lisansüstü seviyede ülkemizde en bilinen ve özellikle nanoteknoloji üzerine araştırmalar yapan Ulusal Nanoteknoloji Araştırma Merkezi (UNAM) önemli bir adım olmakla birlikte benzeri şekilde kamusal ve özel olan enstitü ya da merkezlere ihtiyaç vardır. Ancak daha da önemlisi, bu merkezlerin kurulabilmesi ve iyi beyinlerin buralara yönlenmesi için genel bir nanobilim ve nanoteknoloji farkındalığına varılması gerekmektedir. Bu bağlamda nanobilim ve nanoteknoloji farkındalığını arttırmak amacıyla ilköğretimden üniversite seviyesine kadar eğitimin-öğretim faaliyetlerinin bilinçli ve programlı bir şekilde düzenlenmesi gerekmektedir. Bu süreçteki en önemli ve ilk adım mevcut durumu analiz etmek olarak görülmektedir. Mevcut durumu analiz sürecine kimya bölümü ve kimya öğretmenliği programlarında, eğitimlerine devam eden öğrencilerin nanobilim ve nanoteknoloji hakkındaki bilgi seviyelerinin belirlenmesiyle başlamanın önemli ve yerinde olacağı düşünülmektedir. Çünkü Liz-Marzan ve Kamat'ın (2004) ifade ettiği gibi kimya nanoteknoloji ile doğrudan ilişkili olup, nano-yapıların ve materyallerin oluşturulmasında iyi kimya bilgisine sahip olunması gerekmektedir. Benzer şekilde Whitesides'ın (2005) ifade ettiği gibi her ne kadar nanoteknoloji denince akla elektronik cihazlar gelse de, kimya nanobilim ve nanoteknolojinin kalbinde yer almaktadır. Dolayısıyla, nanobilim ve nanoteknoloji ile yakın bağı olan bir program olan kimya ve kimya öğretmenliğinde öğrenim görmekte olan öğrencilerin sahip oldukları bilgi ve anlama düzeylerinin belirlenmesinin, ülkemizdeki nanobilim ve nanoteknoloji konusundaki farkındalık ve bilgi düzeyi hakkında önemli bulgular sağlayabileceği düşünülmektedir.

Bu çalışmanın temel amacı, Fen Fakültesi Kimya Bölümünde ve Eğitim Fakültesi Kimya Öğretmenliği Anabilim Dalında eğitimlerine devam eden öğrencilerin büyük fikirler başlığı altında toplanan temel nanobilim ve nanoteknoloji kavramları hakkındaki anlama düzeylerini belirlemektir.

YÖNTEM

Çalışmanın amacı doğrultusunda, 2011-2012 akademik yılı güz döneminde Doğu Karadeniz Bölgesinde yer alan köklü bir üniversitenin Fen Fakültesi Kimya Bölümü dördüncü sınıfta (N=30) ve Eğitim Fakültesi Kimya Öğretmenliği Programı üçüncü ve dördüncü sınıflarda (N=23) öğrenim gören ve çalışmaya gönüllü olarak katılan toplam 53 öğrenciyle çalışma yürütülmüştür. Kimya bölümü öğrencilerinin seçilmesinin nedenlerinden biri kimya bölüm mezunlarının da kimya öğretmenliği yapabilme ihtimallerinin olmasıdır. Kimya bölümü öğrencilerin çalışmaya dahil edilmesindeki bir diğer gerekçe ise profesyonel iş hayatlarında nanobilim ve nanoteknoloji ile daha çok karşılaşabileceklerinden dolayıdır. Yukarıda betimlenen örneklem grubuna açık-uçlu sorulardan oluşan bir anket uygulanmıştır.

Veri toplama aracı olarak kullanılan anket, Hutchinson (2007) tarafından "büyük fikirler" tartışmalarını dikkate alarak geliştirilmiştir. Açık uçlu 11 sorudan oluşan ve son hali Tablo 1'de verilen bu anketin Türkçeye uyarlanması araştırmacılar tarafından gerçekleştirilmiştir. Öncelikle anketin orijinali yukarıda verilen "büyük fikirleri" kapsayacak şekilde hazırlanmış olduğu için kapsam geçerliği sağlanmış olduğu varsayılmaktadır. Soruların her biri günlük hayatta yer edinmiş olan nanoteknoloji ürünlerini bağlama alarak bu örnekler üzerinden açıklamaların yapılması sağlanmıştır. Bu anket doktora eğitimini yurt dışında tamamlamış olan bir araştırmacı tarafından Türkçeye çevrilmiş daha sonra ise alan eğitiminde lisansüstü çalışma yapan başka bir araştırmacı tarafından çevirisi kontrol edilmiştir. Çeviri işleminin ardından anket bir dil bilgisi uzmanı tarafından incelenerek yeniden düzenlenmiş ve altı kişiden oluşan küçük bir grup kimya öğretmen adayı üzerinde pilot çalışması yapılarak anlaşılmayan noktaları, eksiklikleri ve aksaklıkları giderilmiştir. Sorular açık uçlu olduğu için, katılımcılara yönlendirme olmaması için nanobilim ve nanoteknoloji kavramlarına sorularda yer verilmemiştir. Katılımcıların geniş bir açıyla soruları değerlendirmeleri ve kendilerinin nanobilim ve nanoteknolojiyi temele alarak soruları cevaplamaları beklenmiştir.

Tablo 1. *Öğrencilere Yöneltilen Anket Soruları*

No	Sorular
1	Metal bir lira küçük parçacıklardan oluşmasına rağmen neden kum gibi parçalarına ayrılmıyor? Açıklayınız.
2	Kurşun kalem, elmas yüzük, araba lastiği ve kömürün ortak noktası sizce ne olabilir? Açıklayınız.
3	Sizce bir kertenkele tavanda baş aşağı şekilde nasıl yürüyebiliyor? Açıklayınız.
4	Sizce aspirin baş ağrısını nasıl keser ve ateşi nasıl düşürür? Açıklayınız.
5	Hangi tür makinelerin canlı bir hücre içine sığabilecek kadar küçük olabileceğini düşünüyorsunuz? Açıklayınız.
6	Sizce DNA gibi hareket eden bir robotu nasıl yapabiliriz? Açıklayınız.
7	Sizce strafor, sis, süt, jöle, lâteks boya ve çeliğin ortak noktaları neler olabilir? Açıklayınız.
8	Neden CD'nin arka yüzeyi rengârenk bir yansıma gösterir? Sizce bu renklerin CD'ye depolanan müzik ile ilgisi var mıdır? Açıklayınız.
9	Kir ve suyun yapışıp kalmadığından emin olunarak bir camı temiz tutmak için sizce ne yapılabilir? Açıklayınız.
10	Sizce ne zaman altın artık sarı renkli olur/görünür? Açıklayınız.
11	Sizce atomların varlığını nasıl anlayabiliriz? Açıklayınız.

Kimya bölümü ve kimya öğretmenliği öğrencilerinin nanobilim ve nanoteknoloji konularındaki bilgi seviyelerini tespit etmek amacı ile uygulanan anketteki her bir soru için elde edilen veriler, tümden gelimsel bir yaklaşımla (Patton, 2002), Abraham ve meslektaşlarının (1994) öğrenci kavramalarını analiz etmede kullandıkları kategorilere benzer olarak Tablo 2'de verilen kategorilere uygun şekilde iki kimya eğitimcisi tarafından ayrı ayrı analiz edilmiş ve analizler üzerinde fikir birliği oluşturulmuştur. Burada "doğru cevap" sorunun cevaplanmasında geçerli kavramları doğru kullanmayı ve anlamayı ifade etmektedir. Diğer kategoriler de benzer şekilde hiyerarşik olarak anlamayı ifade etmektedir. Bu bağlamda anlama ise nanobilim ve nanoteknoloji farkındalığının bir göstergesi olarak görülmektedir. Kimya bölümü ve kimya öğretmenliği öğrencilerinin ankette yer alan sorulara vermiş oldukları cevapların analizleri ayrı ayrı tablo halinde organize edilmiştir.

Tablo 2. *Soruların Analizinde Kullanılan Kategoriler, Kategori Tanımı ve Örnekler*

Kategori	Kategori Tanımı	Soru 1'e Uygun Örnekler
Doğru Cevap	Geçerliliği olan cevabın, ilgili kavramları doğru kullanarak, tam olarak ifadesi	*Bozuk parayı oluşturan atomları bir arada tutan metalik bağlardır. Metal atomlarının dış yörüngelerindeki elektronlar serbestçe hareket ederek bir elektron denizi oluştururlar. Bundan dolayı atomlar biribirine sıkı şekilde bağlanır ve parçalanmazlar.*
Kısmen Doğru Cevap	Geçerli olan cevabın bir yönünü içeren ve kavramların doğru olarak kullanıldığı ancak, eksik ve yarım ifadeler	*Metaldeki bağlar daha kuvvetli olduğundan dolayı.*
Yanlış Cevap	Kavram yanılgıları içeren, tamamen yanlış cevaplar	*Çok yüksek sıcaklıkta eridiği için; Metal daha kararlı yapıdadır.*
Boş	Boş bırakma ve bilmiyorum şeklindeki cevaplar	*Fikrim yok; Bilmiyorum.*

BULGULAR ve YORUMLAR

Katılımcıların 11 maddeli açık-uçlu sorulara verdikleri cevaplar Tablo 2'de belirtilen kategorilere uygun olarak analiz edilerek Tablo 3 elde edilmiştir. Tablo 3'de görüldüğü gibi veriler dört ana kategoride her bir bölüm için ayrı olacak şekilde frekansları ve yüzde dağılımlarına göre soru soru verilmiştir.

Tablo 3'de görüldüğü gibi metal bir paranın küçük parçacıklardan oluşmasına rağmen neden kum gibi dağılmadığıyla ilgili ilk soruyu Kimya Bölümü öğrencilerinin %3'ü ve Kimya Öğretmenliği öğrencilerinin %9'u boş bırakmıştır. Soruya Kimya Bölümü öğrencilerinin %30'u doğru cevap verirken Kimya Öğretmenliği öğrencilerinden bu soruya doğru cevap veren çıkmamıştır. Doğru cevap veren 3 öğrenci soruyu kimyasal bağlar konusu ile ilişkilendirebilmişlerdir. Öğrencilerin yaklaşık üçte biri bu soruya kısmen doğru cevap kategorisine giren cevaplar vermişlerdir. Bu cevaplar genellikle "*Bağ yapısından dolayı", "Metaldeki bağlar daha kuvvetli olduğundan dolayı"* ve benzeri ifadeleri içermektedir.

Tablo 3. *Anket Sorularına Katılımcıların Vermiş Oldukları Cevapların Frekans ve Yüzde Dağılımları*

Soru No	Doğru Cevap				Kısmen Doğru Cevap				Yanlış Cevap				Boş			
	K		KÖ		K		KÖ		K		KÖ		K		KÖ	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
1	9	30	-	-	9	30	10	43	11	37	11	48	1	3	2	9
2	4	13	2	9	24	80	18	78	1	3	3	13	1	3	-	-
3	-	-	-	-	15	50	4	17	11	37	8	35	4	13	11	48
4	-	-	-	-	4	13	1	4	19	63	18	78	7	23	4	17
5	-	-	1	4	8	27	4	17	15	50	6	26	7	23	12	52
6	-	-	-	-	-	-	-	-	10	33	10	43	20	67	13	57
7	1	3	-	-	6	20	10	43	6	20	6	26	17	57	7	30
8	-	-	-	-	5	17	2	9	17	57	14	61	8	27	7	30
9	1	3	-	-	3	10	-	-	20	67	15	65	6	20	8	35
10	-	-	-	-	-	-	-	-	22	73	13	57	8	27	10	43
11	1	3	-	-	3	10	-	-	11	37	14	61	15	50	9	39

K: Fen Fakültesi Kimya Bölümü *KÖ: Eğitim Fakültesi Kimya Öğretmenliği Anabilim Dalı*

Kısmen doğru cevaplar kategorisine giren cevaplarda öğrenciler kum ve metal arasındaki bağ farkının fiziksel özelliklerde farka neden olduğunu ifade etmelerine rağmen, bağların nasıl etki ettiğine dair bir fikir beyan etmemişlerdir. Öğrencilerin büyük çoğunluğu ise bu soruya yanlış cevap vermişlerdir. Öğrencilerin soruya vermiş oldukları yanlış cevaplar arasında en çok aşağıdakilere benzer ifadeler yer almaktadır:

"Çok yüksek sıcaklıkta eridiği için", "Metal daha kararlı yapıdadır", "Metal içindeki alaşımlardan dolayı", "İçinde parçaları bir arada tutan bir madde(dir) (vardır)."

Temel kimya bilgileriyle cevaplanabilecek diğer bir soruda ise kurşun kalem, elmas yüzük, araba lastiği ve kömürün ortak noktasının ne olduğu açıklamaları istenmiştir. Tablo 3'de görüldüğü gibi öğrencilerin büyük bir kısmı soruyu cevaplamışlardır. Soruya Kimya Bölümü öğrencilerinin %13'ü doğru cevap verirken, Kimya Öğretmenliği öğrencilerinin %9'u doğru cevap verebilmişlerdir. Genel olarak bakıldığında katılımcıların cevaplarının büyük kısmı kısmen doğru cevap kategorisine girmektedir. Bu cevaplar, iki öğrencinin "*Karbon içerdikleri için,"* ve *"Karbon atomlarından oluşmuştur"* ifadelerine benzer cevaplar içermektedir.

Öğrenciler verilen örneklerin hepsinin karbon atomlarından oluştuğunu bilmelerine rağmen, atomların dizilimi hakkında bir fikir beyan etmemişlerdir. Kimya Bölümü öğrencilerinin %3'ü, Kimya Öğretmenliği Bölümü öğrencilerinin ise %13 ü soruya yanlış cevaplar vermişlerdir. Öğrencilerin vermiş oldukları yanlış cevaplar aşağıdaki alıntılara benzer ifadeler içermektedir:

"Hepsi karbonun izotopudur," "Kalemde kömürden yapılmış bir maddedir," "Araba lastiği kömürden imal edilir."

Nanoteknolojiye ilişkin doğal ve canlı bir örnek olan kertenkelenin tavanda baş aşağı şekilde nasıl yürüyebildiğinin sebebinin açıklanması istenen soruyu Kimya Bölümü öğrencilerinin %13'ü Kimya Öğretmenliği öğrencilerinin ise %48'i boş bırakmışlardır. Soruya her iki gruptan da tam doğru cevap veren öğrenci çıkmamıştır. Kimya Bölümü öğrencilerinin %50'si ve Kimya Öğretmenliği Bölümü öğrencilerinin %17'si bu soruya *"Kertenkelenin ayağında kılcal yapılı tüyler bulunur"* şeklinde kısmen doğru ifadeler içeren cevaplar vermişlerdir. Öğrenciler kertenkelenin ayağında kılcal yapılar bulunduğu hakkında fikir yürütmelerine rağmen bu kılcal yapıların boyutu, miktarı hakkında yorum yapamamış ve asıl önemlisi tavana tutunmayı nasıl sağladığı hakkında fikirlerini belirtmemişlerdir. Kimya Bölümü öğrencilerinin %37'si ve Kimya Öğretmenliği Bölümü öğrencilerinin ise %35'i soruya yanlış cevaplar vermişlerdir. Bu cevaplar şu şekilde ifadeler içermektedir:

"Kertenkelenin ayaklarında vakum etkisi vardır" ve "Kertenkelenin ayaklarında modifikasyon sağlayan yapılar vardır."

Özellikle organik kimya derslerinde sentezi ve özellikleri verilen Aspirinin, baş ağrısını nasıl kestiği ve ateşi nasıl düşürdüğüne ilişkin soruyu Kimya Bölümü öğrencilerinin %23'ü Kimya Öğretmenliği öğrencilerinin %17'si boş bırakmışlardır. Tablo 3'e bakıldığında görülebileceği gibi, bu soruya doğru cevap veren öğrenci çıkmazken, Kimya Bölümü öğrencilerinin %13'ü Kimya Öğretmenliği öğrencilerinin %4'ü soruya kısmen doğru kategorisine giren *"Ağrıya neden olan enzimi inhibe eder"* ifadesine benzer cevaplar vermişlerdir.

Öğrenciler aspirinin ağrıya neden olan reaksiyonun enziminin inhibe olduğunu belirtmişler fakat soruya tam olarak yorum getirememişlerdir. Katılımcıların üçte ikiden fazlası soruya yanlış cevaplar vermişlerdir. Bu cevaplar arasında *"Savunma mekanizmasında etkisi vardır," "Uyuşturucu etki yapar,"* ve *"Psikolojik olarak bağımlılık yapar"* gibi ifadeler yer almıştır.

Nanoteknoloji ile doğrudan ilişkili olan hangi tür makinelerin canlı içine sığabilecek kadar küçük olabileceğine ilişkin soruyu Kimya Bölümü öğrencilerinin %23'ü, Kimya Öğretmenliği öğrencilerinin ise %52'si boş bırakırken soruya Kimya Öğretmenliğinden bir öğrenci doğru cevap verirken, Kimya Bölümü öğrencilerinden soruya doğru cevap veren olmamıştır. Kimya Bölümü öğrencilerinin %27'si ve Kimya Öğretmenliği öğrencilerinin %17'si soruya *"Biyoçipler olabilir" gibi* kısmen doğru ifadeler içeren cevaplar vermişlerdir. Öğrenciler biyoçiplerle bu işlemin gerçekleştirilebileceğini düşünmüşlerdir fakat yapılabilecek işlemler hakkında tam olarak doğru ifadeler içeren cevaplar verememişlerdir. Aynı soruya Kimya Bölümü öğrencilerinin %50'si, Kimya Öğretmenliği öğrencilerinin ise %26'sı *"Mikro makinelerle"* ve *"mikroçiplerle"* gibi yanlış cevaplar vermişlerdir.

Tablo 3'de görüldüğü gibi DNA benzeri kendi başına hareket eden bir robotun nasıl yapılabilineceğiyle ilgili olarak öğrencilerin neredeyse üçte ikisi herhangi bir yorumda bulunamamıştır. Soruya doğru ve kısmen doğru cevap veren de olmamıştır. Başka bir ifadeyle bu soruya verilen cevapların tamamı *"DNA'daki zayıf etkileşimlerden yararlanarak"* veya *"Yapay beyin takviyesiyle"* gibi ifadeler içeren yanlış cevap kategorisinde yer almıştır.

Strafor, sis, jöle, lateks boya ve çeliğin ortak noktasının ne olduğuna ilişkin soruyu Kimya Bölümü öğrencilerinin %57'si, Kimya Öğretmenliği öğrencilerinin ise %30'u boş bırakmışlardır. Verilen cevaplardan yalnız biri doğru cevap olarak sınıflandırılırken, Kimya Bölümü öğrencilerinin %20'si ve Kimya Öğretmenliği öğrencilerinin %43'ü soruya *"Hepsi karışımdır"* şeklinde kısmen doğru ifadeler içeren cevaplar vermişlerdir. Bu cevaplardaki ifadeler şu şekildedir:

Öğrenciler strafor, sis, jöle, lateks boya ve çeliğin karışım olduğunu ifade etmelerine rağmen nasıl karışımlar oldukları hakkında yorum yapmamışlardır. Aynı soruya Kimya Bölümü öğrencilerinin %20'si ve Kimya Öğretmenliği Bölümü öğrencilerinin %26'sı beklenen cevaplardan farklı olarak *"Deneysel olarak sentezlenebilir"* ve benzeri yanlış ifadeler içeren cevaplar vermişlerdir.

Neden CD'nin arka yüzeyinde rengârenk bir yansıma gözlendiği ve bu renklerin CD'ye depolanan müzikle alakası olup olmadığına ilişkin soruyu öğrencilerin dörtte birinden fazlası boş bırakmışlardır. Soruya her iki gruptan da doğru cevap veren öğrenci çıkmazken, Kimya Bölümü öğrencilerinin %17'si ve Kimya Öğretmenliği Bölümü öğrencilerinin %9'u kısmen doğru cevaplar vermişlerdir. Öğrencilerin bu kategoride vermiş oldukları cevaplara örnek olarak "*Depolanan müzikle renklerin ilgisi vardır"* ifadesi verilebilir. Öğrenci cevaplarında depolanan müzikle renklerin alakası olduğu ve bunun renklerin absorplanmaları ile alakalı olabileceği ifade edilmekle birlikte tam olarak doğru cevap verilememiştir. *"Depolanan müzikle alakası yoktur"* ya da *"sadece ışığı yansıtır"* şeklinde ifadeler kullanan katılımcıların yarıdan fazlasının cevapları yanlış cevap olarak sınıflandırılmıştır.

Havadaki kir ve yağmur suyunun yapışıp kalmadığından emin olunarak bir camın nasıl temiz tutulabileceğine ilişkin soruyu Kimya Bölümü öğrencilerinin %20'si, Kimya Öğretmenliği öğrencilerinin ise %35'i boş bırakmışlardır. Soruya yalnızca bir Kimya Bölümü öğrencisi doğru cevap verebilmiştir. Soruya Kimya Bölümü öğrencilerinin %10'u kısmen doğru ifadeler içeren cevaplar verirken, Kimya Öğretmenliği öğrencileri arasından soruya kısmen doğru cevap veren de çıkmamıştır. Aynı soruya katılımcıların yaklaşık üçte ikisi yanlış cevaplar vermişlerdir. Öğrencilerin cevapları *"Cam apolar madde ile kaplanabilir" veya "çözeltiler kullanılabilir"* şeklinde ifadeler içermektedir.

Tablo 3'e bakıldığında altının ne zaman sarı renkli olduğu/göründüğüne ilişkin soruya hiçbir katılımcının doğru veya kısmen doğru cevap veremediği görülmektedir. Kimya Bölümü öğrencilerinin %27'si, Kimya Öğretmenliği öğrencilerinin ise %43'ü ilgili soruyu boş bırakırken geri kalan cevaplarlar *"Altına beyaz ışın düştüğünde"* ya da *"altın atomları o rengi aldığında"* gibi "yanlış cevap" kategorisinde yer almaktadır.

Tarayıcı Tünelleme Mikroskobu (Scanning Tunneling Microscopy) ve Atomik Kuvvet Mikroskobu (Atomic Force Microscope) gibi teknik olarak karmaşık cihazlar ile nano seviyede atomların varlığı anlaşılabilmektedir. Katılımcılara atomların/tanecikli yapının varlığına kanıt olarak neler gösterilebilir şeklinde yöneltilen anketin son sorusunu Kimya Bölümü öğrencilerinin %50'si ve Kimya Öğretmenliği öğrencilerinin %39'u boş bırakmıştır.

Soruya ancak bir Kimya Bölümü öğrencisi doğru cevaplar verebilmiştir. Kimya Bölümü öğrencilerinin %37'si ve Kimya Öğretmenliği Bölümü öğrencilerinin %61'i soruya *"Maddeyi parçalayarak"* ya da *"Işıkla etkileşime sokarak"* şeklinde yanlış cevaplar vermişlerdir.

TARTIŞMA

Tablo 3'de görüldüğü gibi 1. ve 2. soru haricindeki diğer sorulara %40 ile % 80 arasında değişen oranlarda cevap verilmiştir. Ancak 6, 7, 10. ve 11. sorulara ise öğrencilerin üçte birinden fazlası cevap vermemişlerdir. Burada dikkate edilmesi gereken önemli bir husus öğrencilerin verdikleri cevaplardan anlaşıldığı kadar konuyla ilgili kavram yanılgılarından ziyade bilgi ve fikirlerinin olmamasıdır. Bu durum nanobilim ve nanoteknolojinin öğrencilerin "aşina" olmadığı bir konu olduğunu göstermektedir. Ayrıca nanobilim ve nanoteknoloji örneklemdeki öğrencilerin eğitimlerinin bir parçası olmadığı gibi günlük yaşantılarının dahi bir parçası olmadığını göstermektedir. Başka bir ifadeyle öğrencilerin gerek aldıkları eğitimde ve gerekse kafe, yurt, ev, otobüs ve hatta medya gibi doğal yaşam alanlarında nanobilim ve nanoteknolojinin sıklıkla yer almadığı ya da ilgili kavramlardan bahsedilmediği anlaşılmaktadır. Karataş ve Bodner'ın (2009) öğretmenlerin mühendisliğin doğası ile ilgili düşüncelerini araştırdıkları çalışmada ortaya koydukları gibi bu kavramlar günlük hayatta kullanılıyor olsa da bireylerde yeteri düzeyde farkındalık oluşturulamadığı anlaşılmaktadır.

Bu çalışmadan elde edilen bulgular oldukça şaşırtıcı bulunabilir. Anketteki ilk iki soruya bakıldığında bu soruların doğrudan temel kimya bilgisiyle, başka bir alan bilgisine ihtiyaç duyulmadan, cevaplanabileceği görülmektedir. Ancak bulgular birinci sorunun yalnızca kimya bölümü öğrencilerinin %30 tarafından tam olarak doğru cevaplandırıldığını göstermektedir. Öğrencilerin sahip oldukları kimya bilgisini iki farklı örnek üzerinde uygulamasının istenmesi temel düzey bilişsel bir kazanım olmasına rağmen öğrencilerin çok küçük bir kısmının buna doğru cevabı verebilmesi ve neredeyse yarısının yanlış cevap vermesi başlı başına üzerinde düşünülmesi gereken bir sorun olarak karşımıza çıkmaktadır. Benzer şekilde ikinci sorudaki örneklerin aslında birbirlerinin allotropu oldukları ve kristal yapılarının farklılık gösterdiğinden dolayı farklı fiziksel özelliklere sahip oldukları çok az öğrenci tarafından ifade edilebilmiştir. Bir başka örnek ise onuncu soruda altının makro ölçekteki fiziksel özelliklerinin altın atomları arası etkileşimler sonucu belirlendiğinin ifade edilmesi beklenirken yine öğrencilerin cevapları bu konuda yüzeysel kalmıştır. Maddenin tanecikli yapısı ve tanecikler arası etkileşimler (molekül için ve moleküller arası) konusu ve ilgili kavramlar kimya öğretiminde en önemli ve aynı zamanda öğrencilerin anlamakta zorlandığı konularında başında geldiği ilgili alan yazında da ifade edilmektedir (Ayas, Özmen & Çalik, 2010; Coll & Treagust, 2002; Haidar & Abraham; 1991; Karataş,Ünal, Durland & Bodner, 2013; Novick & Nussbaum, 1981; Özmen, Ayas & Coştu, 2002; Papageorgiou & Johnson, 2005; Valanides, 2000). Aslında bu üç soruya verilen cevaplardan daha sonraki nanoteknolojiye yönelik sorulara verilebilecek cevapların neler olabileceği anlaşılabilmektedir. Çünkü moleküler etkileşimleri tam olarak kavrayamayan bireylerin bunları kullanarak, bugün nanobilimin uğraştığı olguları ve buna bağlı olarak geliştirilen nanoteknolojileri anlamalarını ve açıklamalarını beklemek biraz hayalcilik olacaktır (Karataş ve diğ., 2013). Nitekim öğrencilerin sahip oldukları kavramlar ile ilgili yapılan çalışmalar, temel ve ön koşul kavramlar anlaşılmadan onlarla ilişkili diğer kavramların anlaşılmasının zor olduğunu ortaya koymaktadır (Acar & Tarhan, 2008; Bodner, 1986; Özmen, 2004).

Elde edilen bulgular, nanobilim ve nanoteknoloji hakkında öğrencilerin bilgi düzeylerinin oldukça düşük olduğunu ve basit temel kimya kavramlarını dahi nanoteknoloji konularına aktaramadıklarını göstermiştir. Öğrencilerin sorulara verdikleri cevaplar tek tek irdelendiğinde bu iddiayı destekler nitelikte kanıtlar görülebilmektedir. Öğrencilerin çoğu metal bir paranın neden kum gibi dağılmadığını yorumlayamamış, bağlardan kaynaklandığını bilmelerine rağmen soru hakkında bilimsel olarak doğru kabul edilebilecek bir fikir beyan edememişlerdir. Öğrencilere kalem, elmas yüzük, araba lastiği ve kömürün ortak noktası sorulduğunda karbon cevabının ötesine geçebilen öğrenci sayısı çok az olmuştur. Nanoteknolojiyi çok açık bir şekilde akla getirebilecek bir soru olan '*Hangi tür makineler bir hücre içerisine sığabilecek kadar küçük olabilir?'* sorusuna öğrencilerin büyük bir kısmının cevabı mikro boyutta makineler olabilir şeklinde olmuştur ve öğrenciler hücre içine sığabilecek denmiş olmasına rağmen bunun nano boyutlarda olabileceğini düşünememişlerdir. Öğrencilere '*DNA gibi hareket eden bir robotu nasıl yapabiliriz?*' sorusu yöneltildiğinde öğrenciler sadece *'ileri bir teknoloji ile'* olabileceği şeklinde fikirlerini belirtmişler ancak ilginç bir şekilde nanobilim ve nanoteknolojiyle bunu ilişkilendirmek öğrencilerin aklına gelmemiştir. Benzer şekilde, öğrenciler biyokimya bilgileri ile nanoteknolojiyi ilişkilendirememişlerdir. İlköğretim fen bilimleri derslerinden üniversitede verilen temel kimya derslerine kadar sıkça değinilen karışımlar konusu ile ilişkili olan strafor, sis, süt, jöle, lateks boya ve çeliğin ortak noktasının sorulduğu soruda dahi öğrencilerin çoğu doğru cevaplar verememişlerdir. Öğrencilere '*CD'nin arka yüzeyinde neden rengârenk bir yansıma görülür ve bu renklerin depolanan müzikle alakası var mıdır?'* şeklinde soru yöneltilmiş, öğrenciler bu soru hakkında bir yorum getirememişlerdir. Başka bir ifadeyle, derslerde görmüş oldukları konularla teknolojik kavramları yan yana düşünüp yorumlayamamışlardır. '*Kir ve suyun yapışıp kalmadığından emin olunarak camı nasıl temiz tutabiliriz?'* şeklindeki soruya ise öğrenci cevapları "camı kaplayabiliriz" ifadesinden öteye geçememiştir. Öğrenciler bu kaplamanın nasıl olabileceği ve bunun nanoteknoloji ile nasıl bir ilişkisi olabileceği hakkında yorum getirememişlerdir. Bu örneklerin hepsinde görüldüğü gibi katılımcılar sahip oldukları temel kimya bilgilerini ve tecrübelerini yeni bir duruma aktarmakta veya transfer etmekte zorluk çekmektedirler. Bu durum çağdaş eğitimin en temel amaçlarından biri olan bir alandaki bilgilerin ilişkili diğer alanlara uygulanabilmesini öğrencilerimizin yeterince yapamadığını göstermektedir. Bunun sebebi kimya bilgilerinin yalnızca kimya bağlamı üzerinde öğretilmesi olabilir (Bransford, Brown & Cocking, 2004). Dolayısıyla orta- ve yükseköğretimde kimya konularının farklı bağlamlara ilişkilendirilerek verilmesinin, bilgilerin daha geniş bir çerçevede uygulama bulmayı kolaylaştıracağı düşünülmektedir (Borh & Richardson-Klavehn, 1989).

Son olarak, sınırlılıkları olmayan hiç bir araştırma yoktur. Bu çalışmada da bazı sınırlılıklar göze çarpmaktadır. Bunlardan en önemlisi, veri toplama aracı olarak açık-uçlu soruları içeren bir anketin tek başına kullanılmasıdır. Bu durum, çalışmadan elde edilen bulguların geçerliği üzerinde kuşkular oluşturabilir. Ancak, anketin ve elde edilen verilerin yapı, kapsam ve görünüş geçerliğini arttırmak için anketin geliştirilmesi, Türkçeye uyarlanması, uygulanması ve analizlerinde titiz adımlar atılmıştır (Creswell 2003). Daha önce de belirtildiği gibi bu adımlar çalışma tasarımının ve anketin uzmanlar tarafından değerlendirilmesi, pilot bir çalışmanın gerçekleştirilmesi ve elde edilen bulguların araştırmacılar tarafından kontrol edilerek ortak bir kararın ortaya konması şekilde sıralanabilir. Bu sayede tekil bir veri kaynağından elde edilen sonuçların geçerliği ve güvenirliği arttırılmıştır.

SONUÇ

Bu çalışmada Doğu Karadeniz'de yer alan köklü bir üniversitenin Fen Fakültesi Kimya Bölümünde ve Eğitim Fakültesi Kimya Öğretmenliği programında öğrenim gören öğrencilerin nanobilim ve nanoteknoloji hakkında bilgi düzeyleri ve öğrencilerin kimya bilgilerini nanoteknoloji konularına transfer edip edemedikleri incelenmiştir. Çalışma sonucuna göre kimya programına devam eden öğrencilerin daha iyi olmakla birlikte her iki programdaki öğrencilerin nanobilim ve nanoteknoloji hakkında bilgi seviyelerinin oldukça düşük olduğu ve temel kimya bilgilerini nanoteknoloji konularına yeterince transfer edemedikleri belirlenmiştir. Örnek olarak, moleküllerlerin kristal yapılarını ve moleküller arası etkileşimleri maddelerin fiziksel özellikleri ile ilişkilendirememektedirler.

Burada üzerinde durulması gereken önemli noktalardan birisi de katılımcıların yanlış anlama ya da kavram yanılgısından ziyade konu hakkında farkındalıklarının çok düşük olarak bulunmasıdır. Bu durum üniversite eğitimlerinde belli bir seviyeyi geçmiş kimya alanına hâkim olması gereken öğrencilerin günlük yaşamlarında nanobilim ve nanoteknolojinin fazla bir yer tutmadığını göstermektedir. Nanobilim ve nanoteknoloji ile yakın ilişkili olan bir alandaki öğrencilerden elde edilen sonuçlar diğer alanlardaki üniversite öğrencilerinin genel durumu hakkında düşündürürken bilgi de vermektedir. Başka bir ifadeyle, araştırmadan elde edilen bulgular incelendiğinde hızla gelişen bir alan olan nanoteknoloji hakkında, nano seviyedeki parçacıklar arası ilişikleri irdeleyen bir disiplin olan kimya eğitimi alan öğrencilerin dahi çok fazla bilgisinin olmadığı ve eğitim sistemimizde gelişmekte olan bu disipline göre kendisini uyarlayamadığı görülmektedir.

ÖNERİLER

Çalışmadan elde edilen sonuçlar değerlendirildiğinde kimya bölümü ve kimya öğretmenliği öğrencilerinin nanobilim ve nanoteknoloji hakkında bilgi düzeylerinin geliştirilmesi ve kimya bilgilerini nanoteknoloji konularına transfer edebilmeleri için aşağıda bazı önerilerde bulunulmuştur:

- Kimya eğitimi veren üniversitelerin kimya öğretim programlarına 'Nanoteknoloji' adı altında yeni bir ders eklenmesinin öğrencilerin bu konudaki eksikliğini gidermek için iyi bir başlangıç olacağı düşünülmektedir. Öğretim programlarına böyle bir dersin eklenip-eklenilmemesine bakmaksınız temel kimya konuları ve ilgili dersler çerçevesinde nanoteknolojilere ve bunların bilimsel alt yapısına dair daha çok ve farklı bağlamlarda atıflarda bulunulmasının öğrencilerin hem öğrendikleri konuları bir bağlama dayandırmada hem de nanobilim ve nanoteknolojide daha geniş bir ufuk sahibi olmalarında faydalı olacağına inanılmaktadır. İlişkili olarak, ilköğretim ve ortaöğretim fen öğretim programlarında, disiplinler arası bir alan olan, nanobilim ve nanoteknolojiye daha fazla yer verilmesi gerekmektedir. Böylece öğrencilerin farkındalık düzeyi arttırılabileceği gibi, bazılarının kariyer planları içerisine bu alanları alması mümkün olabilir.
- Genelde bütün eğitim seviyesindeki öğrenciler için ve özelde de Kimya alanındaki (Kimya, Kimya Mühendisliği, Kimya Öğretmenli vb.) öğrenciler için okul dışı ortamlarda (müzeler ve bilim merkezleri, bilim şenlikleri, yaz kampları, TV programları, seminer ve paneller, vb.) bu konuya ilgilerini çekebilmek ve onları bilgilendirebilmek için nanobilim ve nanoteknoloji hakkında etkinlikler düzenlenmesinin büyük faydalar sağlayacağı düşünülmektedir.
- Nanobilim ve nanoteknoloji konuları hem fen alanında hem de fen eğitiminde yeni bir araştırma alanı görünümündedir. Araştırmacıların bu alanlara yönlendirilmesinin bu alandaki eksikliğin kısa sürede giderilmesinde yardımcı olacağı düşünülmektedir. Bu nedenle yönlendirici konumundaki kurum ve kuruluşların (TÜBİTAK, MEB, YÖK vb.) bu alana öncelik vererek teşvik etmeleri gerekmektedir. Aksi takdirde 21.yy endüstri atılımında geride kalabiliriz.

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Undergraduate Chemistry Students' Understanding Level of Nano-Science and Nano-Technology

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Key Words: Chemistry; Pre-Service Chemistry Teacher Training; Nano-Science; Nano-Technology; Chemistry Knowledge.

SYNOPSIS

INTRODUCTION

Nano-science is interested in atomic and molecular structures and interactions among these structures whose size is between 1 and 100 nanometer (Katz, Shipway & Willner, 2004; Laherto, 2010; Liz-Marzan & Kamat, 2004; Whitesides, 2005). *Nano-technology*, on the other hand, involves in designing, producing, and using products in several industries including electronics, pharmaceuticals, textile, cosmetics, etc. by utilizing interaction in atomic and/or molecular level (Bowman & Hodge, 2007; Foley & Hersam, 2006). Thus, nano-technology has been emerging as an inter-disciplinary field (Ratner & Ratner, 2003; Tessman, 2009). From a historical perspective, it can be said that we are witnessing a scientific and technological revolution in 21st century (Özdoğan, Demir & Seventekin, 2006; Wansom, Mason, Hersam, Drane, Light, Cormia, Stevens & Bodner, 2009) that will generate over 2.6 trillion dollars of revenues in industry by the end of 2014 (Foley & Hersam, 2006).

Societies that would like to get a share from nano-technology and related industries have invested a lot of money and human resources for nano-technology education (Roco & Bainbridge, 2003; Wanson et al., 2009). Therefore, educational research and associated regulations have been put in action at primary, secondary and tertiary levels in the US and Europe (Laherto, 2010; Wansom et al., 2009).

One of the problems of nano-science and technology educations is to determine content for teaching. Many nano-science and technology educations have a consensus over "Big Ideas" which include following topics and concepts (Daly, Hutchinson & Bryan, 2007; Hingant & Albe, 2010; Hutchinson, 2007; Hutchinson, Bodner & Bryan, 2011; Light et al., 2007; Stevens, Sutherland, Schank & Krajcik, 2007; Stevens, Sutherland & Krajcik, 2009; Tessman, 2009; Wansom et al., 2009):

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- Size and scale
- Structure of matter
- Forces and interaction
- Quantum effects
- Size dependent features
- Self assembly
- Tools
- Models and simulations
- Science, technology and society

Even though there have been a tremendous effort on research and education for nano-science and technology in the US and Europe, our country has left behind of this movement. To catch up this movement we need to invest more sources into nano-science and technology and its education in order to improve nano-science and technology awareness from primary to tertiary education. One of the early steps of this process is to determine current status. Thus, we decided to investigate undergraduate chemistry students and pre-service chemistry teachers and their nano-science and technology knowledge. As Liz-Marzan and Kamat (2004) stated that chemistry is directly related to nano-science and producing nano-structures and materials requires high chemistry knowledge. Therefore, determining undergraduate chemistry students' and pre-service chemistry teachers' understanding of nano-science and technology would provide valuable information regarding overall awareness level as chemistry is related field with nano-science and technology.

PURPOSE of the RESEARCH

The purpose of this study is to determine undergraduate chemistry students and pre-service chemistry teachers' basic nano-science and technology understanding level based on Big Ideas framework.

METHODOLOGY

The study was conducted at a university located in East Black Sea region of Turkey. The participants were selected from third and fourth year students enrolled in department of chemistry of faculty of science (N=30) and in division of chemistry education, department of secondary science and mathematics education of faculty of education (N=23). A questionnaire with 11 open-ended items was administrated to the participants to collect data. The questionnaire were developed by Hutchinson (2007) based on "Big Ideas" framework and translated into Turkish by the researchers. A pilot study was conducted with six students while adapting the questionnaire to Turkish context.

The participants' responses to the questionnaire were analyzed by sorting out each response to one of the following categories: Correct response, partly correct response, wrong response, and no response or unrelated response. This rubric was developed based on the guidelines reported by Abraham and his colleagues (1994).

FINDINGS

The participants' responses to the questionnaire were analyzed item by item based on the rubric explained above and presented in Table 1. As seen in Table 1, percentages of correct responses are very low. There is no correct response for items number 3, 4, 6, 8, and 10. The first item in the questionnaire asks why a metal coin does not fall apart like sand. This item is directly related to chemistry and can be answered easily by employing basic chemistry knowledge. However, only 30% of chemistry students' responses were correct and around 40% of the total responses were wrong. A few quotes from wrong responses are presented below:

"Because its melting point is to high"
"The structure of the metal is more stable"
"Because of the alloys in the metal structure"

Table 1. *The Participants' Responses to the Questionnaire*

Item No	Correct Response				Partly Correct Response				Wrong Response				No Response			
	SC		SE		SC		SE		SC		SE		SC		SE	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
1	9	30	-	-	9	30	10	43	11	37	11	48	1	3	2	9
2	4	13	2	9	24	80	18	78	1	3	3	13	1	3	-	-
3	-	-	-	-	15	50	4	17	11	37	8	35	4	13	11	48
4	-	-	-	-	4	13	1	4	19	63	18	78	7	23	4	17
5	-	-	1	4	8	27	4	17	15	50	6	26	7	23	12	52
6	-	-	-	-	-	-	-	-	10	33	10	43	20	67	13	57
7	1	3	-	-	6	20	10	43	6	20	6	26	17	57	7	30
8	-	-	-	-	5	17	2	9	17	57	14	61	8	27	7	30
9	1	3	-	-	3	10	-	-	20	67	15	65	6	20	8	35
10	-	-	-	-	-	-	-	-	22	73	13	57	8	27	10	43
11	1	3	-	-	3	10	-	-	11	37	14	61	15	50	9	39

SC: Faculty of Science, Department of Chemistry SE: Faculty of Education, Division of Chemistry Education

Another question that can be answered by employing general chemistry knowledge asks the commonality among a pencil, a diamond ring, a tire, and coal. As seen in Table 1, a few of the participants' responses are correct. Many responses fall under "partly correct" category such as "All contains carbon," and "They are made out of carbon atoms." These responses focused on carbon atom, but did not mention crystal structure.

The participants' responses for other questions which are about nanotechnology applications including nanobots, colors of a CD, self cleaning walls, etc. were no better than the first two questions. As seen in Table 1, many participants did not respond to the items.

CONCLUSION

Based on the results, it is found that even though the participants from faculty of science showed better performance, the participants in both groups had low level of understanding about nano-scale science and technology as well as related concepts. It was also found that the participants cannot transfer their chemistry knowledge to explain nano-scale phenomena. They cannot, for example, link crystal structures of molecules and inter-molecular interactions to physical properties of matter.

Another important conclusion is that the participants did not have high percentage of misunderstandings or misconceptions about nano-scale science and technology, but rather their awareness level is too low. In other words, nano-scale science and technology is not part of their neither academic nor personal life. Therefore, it is concluded that even chemistry students do not have adequate level of understanding about nano-science and technology which is one of the emerging field of study related to chemistry. This also implied that educational system does not adapt itself this new field.

SUGGESTIONS

Based on the conclusions it is suggested that integration of nano-science and technology into chemistry programs is necessary either as a separate course of as a topic of regular chemistry courses. It is also suggested that out of school settings including museums, science centers, science fairs, summer camps, seminars, TV shows, and other media should be utilized to increase nano-science and technology awareness of students at all ages.

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Fen Öğrenmede Zihinsel Risk Alma ve Yordayıcılarına İlişkin Algı Ölçeği Türkçe Formunun Uyarlanması: Geçerlik ve Güvenirlik Çalışması

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ÖZET

Zihinsel risk alma davranışı, fen bilimlerine yönelik ilgi ve yaratıcı öz-yeterlik gibi değişkenler ile ilişkisi olduğu ifade edilen bir değişkendir. Bu önemine rağmen ülkemizde, özellikle de ortaokul düzeyinde bu konu üzerine yapılan çalışmaların sayısı sınırlıdır. Bu durumun standartlaştırılmış ölçme aracı eksikliği ile ilgili olduğu düşünülmektedir. Bu araştırmada, fen öğrenmede zihinsel risk alma ve yordayıcılarına ilişkin algı ölçeği uyarlama çalışması yapmak amaçlanmıştır. Çalışmanın örneklemi iki farklı gruptan oluşmaktadır (N=864). Açımlayıcı faktör analizinin yapıldığı birinci örneklem grubunda 449, doğrulayıcı faktör analizinin yapıldığı grupta ise 415 öğrenci yer almıştır. Araştırmada uyarlanan ölçek Beghetto (2009) tarafından geliştirilmiş, Likert tipte bir ölçektir. Ölçek, zihinsel risk alma ve 3 yordayıcısını (fene yönelik ilgi, yaratıcı öz-yeterlik, öğretmen desteğine yönelik algı) içermektedir. Bu tür bir uygulama ile bütüncül bir ölçek uyarlaması yapılacağı düşünülmektedir. Ölçekten elde edilen verilerin açıklayıcı faktör analizi, karşıt gruplar yöntemi ve güvenirlik analizleri SPSS programı ile doğrulayıcı faktör analizi ise AMOS programları kullanılarak yapılmıştır. Araçtan elde edilen verilerin geçerlik ve güvenirlik düzeyleri, ölçeğin Türk kültüründe kullanılabilir olduğu görüşünü desteklemektedir. Uyarlanan ölçeğin sonuçlarının, orijinal ölçekle benzer özellikler taşıdığı, yapı geçerliğine sahip olduğu ve güvenirlik düzeyinin sosyal bilimler için yeterli olduğu sonuçlarına ulaşılmıştır.

Anahtar Kelimeler: Fen Eğitimi; Zihinsel Risk Alma; Yaratıcılık; İlgi; Öğretmen Desteği; Geçerlik; Güvenirlik.

GİRİŞ

Fen; gözlenen doğayı ve doğa olaylarını sistemli bir şekilde inceleme ve henüz gözlenmemiş olayları kestirme gayretleri (Çepni, 2011) olarak tanımlanmaktadır. Bu yönüyle oldukça geniş bir kapsama sahip olan fen dersi, içeriği gereği soru sormak, açıklamada bulunmak ve onaylamak gibi zihinsel risk almayı gerektiren bir etkileşim ortamıdır. Çünkü öğrencilerin, sonuçları hakkında kesin bilgi sahibi bulunmadıkları ve alternatif çözümler konusunda bilgilerinin olmadığı durumlara ilişkin girişimlerde bulunmaları gerekmektedir. Risk alma davranışı, bireylerin sonuçlarını tahmin edemedikleri, daha önce üzerinde performans göstermedikleri ve alternatiflerden haberdar olmadıkları durumlarda tepkide veya

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tahminde bulunmaya isteklilik olarak tanımlanabilir. Risk alma farklı alanlarda farklı anlamlar taşımakla birlikte, genel anlamda sonuçları tahmin edilemeyen veya olumsuz sonuçlar üretebileceği düşünülen tehditlere rağmen düşüncelerini ifade etme, girişimde bulunma ve savunma yeteneği olarak da ifade edilmektedir (Denrell, 2007; Feldman, 2003; Peled, 1997). Yapılan çalışmalar insanların çoğunun risk alma eğilimi bulunduğunu ve risk almanın normal dağılıma benzer bir yapısı olduğunu göstermektedir (Arnett, 1992; Greene ve diğ., 2000). Trimpop (1994) da yine normal dağılım eğrisinden hareketle, her zaman risk alanlar ile hiçbir koşulda risk almayanların, dağılımın uçlarında olduklarını; yani sayılarının çok az olduğunu belirtmiştir.

Bilişsel veya akademik risk alma toleransı olarak da ele alınan bu beceri; bir bireyin itibar, dürüstlük, güvenirlik, onur ve zekâ gibi özellikleri ile ilgili negatif değerlendirilebilecek tehditlere rağmen düşüncelerini ifade etme ve savunma yeteneği olarak tanımlanmaktadır (Feldman, 2003). Risk alma becerisinin artmasında bir işi planlama, birlikte çalışma ve bir işi başarma gibi faaliyetlerin etkili olduğunu belirten Kaptan ve Korkmaz (2002), böylece öğrencilerin kendi yeteneklerine ilişkin olumlu eğilim göstereceklerini ifade etmişlerdir. Özellikle gençlerin risk alma davranışlarının diğer gruplara göre oldukça yüksek olduğu dikkate alındığında (Steinberg, 2004), karar vermenin önemli faktörlerinden biri olan bu becerinin öğretilmesine ve geliştirilmesine yönelik çabaların olduğu görülmektedir. Risk almanın mantıksal akıl yürütüme, psiko-sosyal ve duyuşsal faktörlerden etkilenen bir yapısının olması, bu becerinin kompleksliğini artırmada etkili olmaktadır. Bireylerin deneyim farklılıklarının ve uyaranlarının farklı olması da risk alma davranışlarıyla ilgilidir (Trimpop, 1994). Bu farklılıkları oluşturmada öğretmenlerin desteği oldukça önemlidir (Beghetto, 2009). Çünkü öğretmenlerin oluşturdukları sınıf ortamı ve öğrencilere sundukları fırsatlar, hem bireysel beceri ve yeteneklerini ortaya çıkarmada hem de risk alarak başarıya odaklanmada anahtar rol oynamaktadır (Miller ve Byrnes, 1997).

Risk almanın farklı türleri olduğunu söyleyen Neihart (1999), bu türleri beşe ayırmıştır. Bunlar: a) zihinsel risk alma, b) sosyal risk alma, c) duygusal risk alma, d) fiziksel risk alma ve e) manevi risk almadır. Eğitimde risk alma daha çok zihinsel risk alma ile ilgili bir durumdur. Zihinsel risk almada, öğrencilerin bir konu veya bir problem hakkında derinlemesine düşünmesi, bu düşüncelerini başkalarıyla paylaşarak eleştirilerini dinlemeleri ve çözüm için bu deneyimlerini geliştirmeleri amaçlanır (Dweck, 2000; Weiner, 1994). Korkmaz (2002)'a göre zihinsel risk alma, öğrencilerin öğrenme zorluk ve güçlükleriyle mücadele etme istekliliği veya isteksizliğini gösteren bir davranıştır. Clifford ve Chou (1991)'ya göre okullarda öğrencilerin karşılaşabilecekleri zihinsel risklerden bazılarının; sınıfta öğretmen veya arkadaşlarına sorular sorma, işlenen konular hakkında açıklamalar yapma, cevabını bilmedikleri halde soruları cevaplama eğilimi gösterme, sonucundan emin olunmayan durumlar için sorumluluk alma davranışları olabileceği ileri sürülmektedir. Bu çalışmada Beghetto (2009)'nun zihinsel risk alma ile ilgili olduğunu belirttiği yukarıda da değinilen değişkenlere ilişkin açıklamalar ayrıntılı olarak aşağıda yapılmıştır.

Fen Başarısı ve Zihinsel Risk Alma

Birçok araştırmada, fen alanındaki başarı ile risk alma arasında ilişki olduğu ifade edilmektedir (Meyer, Turner & Spencer, 1997; Peled, 1997; Tay, Özkan & Tay, 2009). Ulusal ve uluslararası sınav sonuçları ve çeşitli araştırmalar, fen bilimleri alanındaki başarı açısından ülkemizin olumsuz durumunu ortaya koymaktadır (Berberoğlu & Kalender, 2005; Ceylan ve Berberoğlu, 2007; MEB, 2011; ÖSYM, 2011, 2014; Sarıer, 2010). Fen derslerindeki başarının belirli bir kısmının fen derslerinde zihinsel risk alma davranışı ile bağlantısı olduğu, ulusal ve uluslararası çalışmalarla ortaya konulmuştur. Meyer, Turner ve Spencer (1997), risk almaktan kaçınan ve risk almaya gönüllü olan 5. ve 6. sınıfta öğrenim gören 14 öğrenciyle yaptıkları araştırmada, risk alma davranışı göstermeye eğilimli olan öğrencilerin, projeler yapma fırsatına oldukça olumlu yaklaştıklarını ve işbirliği içinde amaç yönelimli olarak çalışmalarını yürüttüklerini ifade etmiştir. Diğer bir çalışmada Peled (1997), başarı düzeyleri farklı olan 6. sınıf öğrencilerini karşılaştırmış ve başarılı öğrencilerin yeni çalışma konularında risk alma davranışı açısından istekli olduklarını belirtmiştir. Tay, Özkan ve Tay (2009) ise, üstün yetenekli öğrencilerle yaptıkları çalışmada 4.,5.,6., ve 7. sınıf öğrencilerinin yüksek risk alma düzeyine sahip olduklarını, bu özelliklerinin problem çözmede de yüksek düzeyde becerili olmaları ile anlamlı bir ilişki gösterdiğini belirtmişlerdir.

Fene Yönelik Motivasyon, İlgi ve Zihinsel Risk Alma

Yapılan araştırmalarda ölçülü risk almanın, bireylerin motivasyonunu artırmada etkili olduğu ve buna bağlı olarak başarının yükselmesine katkı sağladığı belirtilmiştir (Beghetto, 2009; House, 2002). Risk alma bir içsel motivasyon unsuru olarak görülmektedir. İçsel motivasyonun öğrenmede dışsal motivasyondan daha etkili olduğu ve bu iki motivasyon türünün birbirleri arasında negatif ilişki olduğu ileri sürülmektedir (Mendler, 2000; Rogers, Ludington & Graham, 1999). Bu sonuçlara göre dışsal motivasyon yerine içsel motivasyonun artırılmasının, risk alma davranışının gelişmesinde katkı sağlayacağı ileri sürülmektedir. Örneğin; bir öğrenci bir ödül veya derece için bir şeyler yapmaya veya risk almaya yönlendirildiğinde, bu görevi minimum düzeyde başarmaya odaklanacaktır. Oysa bu durumu kendisi için gerekli olan bir ihtiyaç olarak görmesi, hedeflerinin büyümesine katkı sağlayacaktır. Buna bağlı olarak öğrencilerin motive oldukları konu ve alanlara daha fazla ilgi duyacakları söylenebilir. İlgi düzeyi ile risk almanın ilişkili olduğu ve öğrencilerin fene yönelik ilgileri arttıkça zihinsel risk almaya yönelik isteklerinin de arttığı belirtilmektedir (Beghetto, 2009; Renninger, 2000). Çünkü ilgi düzeyi yüksek olan öğrenciler, içlerindeki harekete geçiren güç sayesinde kendilerine verilen işleri kısa sürede bitirmek isterler (Hunter & Csikszentmihalyi, 2003).

Öz-yeterlik ve Zihinsel Risk Alma

Risk alma davranışının yaratıcı öz-yeterlikle de ilişkisi olduğu yapılan araştırmalarla ortaya konulmuştur. Yaratıcı öz-yeterlik, yaratıcı çaba ve performansın önemli bir öncüsü olarak görülmektedir (Mathisen & Bronnick, 2009). Fende yaratıcı öz-yeterlik, fendeki yeni kavramlara uyum sağlamak, yeni fikirler üretmek, çözümleri uygulamak gibi süreçlerle karakterize edilmektedir (Beghetto, 2006). Bandura (1997), öz-yeterlik inancı yüksek olan bireylerin risk almaya istekli olduklarını ve birçok keşif yapan Edison'un yüksek öz-yeterliği sayesinde ve riskler alarak amaçlarına ulaştığını belirtmiştir. Risk almanın yaratıcılıkla yüksek ilişkisi olduğunu gösteren araştırmalar, bütün alanlarda olduğu gibi, risk alma davranışının fen alanında da ayırt edici bir özellik olduğuna işaret etmektedir (Farley, 1991; Feldman, 2003).

Bilişsel ve duyuşsal özelliklerle yüksek ilişkisi olduğu kabul edilen zihinsel risk alma davranışıyla ilgili ülkemizde az sayıda araştırma yapılmıştır (Korkmaz, 2002; Tay, Özkan & Tay, 2009). Bu durum, önceki paragraflarda izah edilen zihinsel risk almanın fen öğrenmedeki önemi ile tezat oluşturmaktadır. Zihinsel risk alma davranışı ile ilgili nicel çalışmalarda kullanılmak üzere geliştirilecek veya uyarlanacak bir ölçeğin yetersiz olan araştırmaların niceliğini ve buna bağlı olarak niteliğini artırmaya katkı sağlayacağı düşünülmektedir. Bu bağlamda fen eğitiminde zihinsel risk alma becerisini ilköğretim düzeyindeki 585 öğrenciden toplanan verilere göre inceleyen Beghetto (2009)'nun geliştirdiği ölçeğin dilimize uyarlanması, bu ihtiyacı karşılamaya yönelik bir çaba olacaktır. Beghetto çalışmasında, fene yönelik ilgi, öz-yeterlik ve öğretmen desteğinin zihinsel risk alma ile bağlantısını ortaya koymuştur. İlgili çalışmada zihinsel risk alma ile fen yönelik ilgi, fendeki yaratıcı öz-yeterlik ve öğretmen desteği algısı arasında pozitif ilişkisi olduğuna vurgu yapılmıştır. Zihinsel risk alma davranışının bu yordayıcıları ile beraber incelenmesinin daha bütüncül bir bakış açısı ve geçerlilik açısından avantajlar sağlayacağı düşünülmektedir. Beghetto'nun çalışmasında ele alınan değişkenlerin bütüncül olarak dikkate alınması, ülkemizdeki az sayıdaki çalışmasın artmasına katkı sağlamak için daha açıklayıcı bir çerçeve sunacaktır. Bu sebeple bu araştırmanın temel problemi; ortaokul öğrencilerinin fen derslerindeki zihinsel risk alma becerilerini ve bu becerinin yordayıcılarından olan yaratıcı öz-yeterlik, ilgi ve öğretmen desteği algısını ölçmek amacıyla Beghetto tarafından geliştirilen ölçme aracının Türkçe uyarlamasını yapmaktır.

YÖNTEM

Bu araştırma, Türkçeye uyarlaması yapılan Zihinsel Risk Alma ve Yordayıcılarına yönelik bir ölçme aracının metodolojik geçerlik ve güvenirlik çalışmasıdır.

a) Örneklem

Çalışma için toplanan veriler, Açımlayıcı Faktör Analizi (AFA) ve Doğrulayıcı Faktör Analizi (DFA) için iki ayrı gruptan elde edilmiş ve analizler bu iki örneklemden elde edilen verilere göre ayrı ayrı yapılmıştır. Araştırmanın verileri, 8 farklı ortaokulda öğrenim gören öğrencilerden elde edilmiştir. Bu okullar 2 farklı il ve 1 ilçe merkezinde yer alan ve benzer özellikler (öğrenci ve öğretmen profilleri) gösteren eğitim kurumlarıdır. Örneklemden veri toplama süreci araştırmacılar tarafından her bir okul ve sınıfta, ders öğretmenlerinin gözetiminde bizzat gerçekleştirilmiştir.

AFA örneklemi: Çalışmanın örneklemini, orta büyüklükteki bir il ve ilçe merkezindeki 4 ortaokulda öğrenim gören 449 öğrenci oluşturmuştur. Burada yapılan örnekleme yöntemi, "uygun" örnekleme olup, rastgele seçimin mümkün olmadığı durumlarda bireylere zamandan, enerjiden ve ekonomiden kazanç sağlama kolaylığını vermektedir (Cohen, Manion & Morrison, 2007). Araştırmada verilerin toplandığı öğrencilerin demografik özelliklerine ilişkin bilgiler aşağıda sunulmuştur:

Tablo 1. *AFA Analizi İçin Örnekleme Giren Öğrencilere İlişkin Betimsel İstatistik Sonuçları*

Sınıf / Cinsiyet	6		7		8		Toplam	
	f	%	f	%	f	%	f	%
Kız	67	50,8	78	52,3	70	52,2	215	51,8
Erkek	65	49,2	71	47,7	64	47,8	200	48,2
Toplam	132	31,8	149	35,9	134	32,3	415	100

DFA Örneklemi: Bu analizin verileri orta büyüklükteki bir il ve ilçe merkezdeki dört farklı ortaokulunun 6-8. sınıflarında öğrenim gören ve uygun örnekleme yöntemine göre seçilen 415 öğrenciden elde edilmiştir. AFA ve DFA örneklemi farklı okullardaki öğrencilerden meydana gelmiştir.

Tablo 2. *DFA Analizi İçin Örnekleme Giren Öğrencilere İlişkin Betimsel İstatistik Sonuçları*

Sınıf / Cinsiyet	6		7		8		Toplam	
	f	%	f	%	f	%	f	%
Kız	65	45,8	73	49,7	83	51,9	221	49,2
Erkek	77	54,2	74	50,3	77	48,1	228	50,8
Toplam	142	31,6	147	32,7	160	35,6	449	100

Yukarıdaki iki tabloya göre öğrencilerin cinsiyetlerine ve sınıf düzeylerine göre dağılımlarının birbirine yakın olduğu; bunun da kullanılan örnekleme yönteminin sınırlılıklarını azaltmada yararlı olacağı ileri sürülebilir. Veri toplanan örneklemin büyüklüğünün faktör analizi yapmak için uygun olup olmadığına ilişkin Comrey ve Lee

(1992) tarafından önerilen sınıflandırmalar şu şekildedir: "0-100 arası: çok kötü", "101-200 arası: kötü", "201-300 arası: orta", "301-500 arası: iyi", "501-1000 arası: çok iyi", "1000 ve daha fazlası: mükemmel". Buna göre, bu araştırmada kullanılan örneklemin (N=415 ve N=449), faktör analizi için "iyi" düzeydeki derecelendirmeye sahip olduğu söylenebilir. Ayrıca elde edilen verilerin faktör analizine uygunluğunu test etmek için "Kaiser-Meyer-Olkin (KMO)" katsayısı ve Barlett'in Küresellik Testi (BKT) değerleri hesaplanmıştır. AFA analizi örneklemi için KMO katsayısı 0,86 ve BTS değeri 2524,63 olarak belirlenirken; DFA örnekleminde elde edilen veriler için KMO katsayısı 0,89 ve BTS değeri 2718,46 olarak tespit edilmiştir. Bu değerlere göre bu araştırmada veri toplanan öğrenci sayısının, geçerlik ve güvenirlik çalışması yapmak için yeterli olduğu söylenebilir.

b) Veri Toplama Aracı

Araştırmada kullanılan *Fen Öğrenmede Zihinsel Risk Alma ve Yordayıcılarına İlişkin Algı Ölçeği (FÖZRAY)* Beghetto (2009) tarafından geliştirilmiştir. Bu ölçek Amerika Birleşik Devletleri'nde 585 ilköğretim öğrencisine uygulanmış ve dört faktörden (zihinsel risk alma, yaratıcı öz-yeterlik, fene yönelik ilgi ve öğretmen desteği) oluştuğu ifade edilmiştir. İlgili çalışmada faktörlere göre güvenirlik katsayılarının sırasıyla şu şekilde olduğu belirtilmiştir: 0,80; 0,77; 0,83; 0,77. Beghetto ayrıca ölçeğin yapısı için faktör analizi ve promax döndürmesi yapmıştır. Bu analizlerde dört faktörü doğrulamış ve bu dört faktörün birlikte varyansın %49,5'unu açıkladığını ifade etmiştir. Bu ölçeğin Türkçeye uyarlanabilmesine yönelik gerekli izinler 2010 yılında Beghetto'dan e-posta yoluyla alınmıştır.

Beghetto (2009) ölçek geliştirme sürecinde iki farklı veri kaynağından yararlanmıştır. Bunlar; öğrencilerin kâğıt-kalem anketleri ve öğretmenlerin öğrencilerinin fen yeteneklerine ilişkin belirledikleri puanlarıdır. Bu çalışmalara göre geliştirilen Likert tipi ölçeğin seçenekleri 1 (tamamen yanlış) ile 5 (tamamen doğru) şeklindedir. Ölçeğin aralık genişliği, "dizi genişliği/yapılacak grup sayısı" (Tekin, 1996) formülü ile hesaplanması göz önünde tutularak, araştırma bulgularının değerlendirilmesinde esas alınan aritmetik ortalama aralıkları; "1,00-1,80; Tamamen yanlış", "1,81-2,60; Çoğunlukla yanlış", "2,61-3,40; Kararsızım/Biraz doğru-Biraz yanlış", "3,41-4,20; Çoğunlukla doğru" ve "4,21-5,00; Tamamen doğru" şeklindedir. Ölçekteki puanlar, 1,00 ile 5,00 arasında olduğundan, puanlar 5,00'e yaklaştıkça öğrencilerin maddeye katılım düzeylerinin yüksek, 1,00'e yaklaştıkça düşük olduğu kabul edilmiştir. Ölçekte olumsuz cümle köküne sahip madde bulunmamaktadır. Bu ölçekteki maddeler; öğrencilerin zihinsel risk alma, fene yönelik ilgi, fene yönelik yaratıcı öz-yeterlik ve öğretmen desteğine yönelik algılama boyutlarına yöneliktir. Bu boyutlara ilişkin açıklamalar Beghetto'un çalışması temel alınarak yapılmıştır:

Zihinsel Risk Alma: Güvenirlik düzeyi 0,80 olan bu boyutta, öğrencilerin zihinsel risk alma düzeylerini belirlemek için kullanılan 6 madde vardır. Bu maddeler, öğrencilerin fen öğrenme ortamlarında kullandıkları zihinsel risk alma davranışlarını (fikirlerini paylaşma, soru sorma, yeni şeyler öğrenme ve çabalama için istekli olma vb.) belirlemek amacına yöneliktir.

Fene Yönelik İlgi: Bu boyutta yer alan dört madde öğrencilerin fen öğrenmeye yönelik bireysel ilgilerini ölçmek amacıyla kullanılmıştır. Schiefele (1991)'in kişisel ilgilerle ilgili tanımı temel alınarak yazılan bu maddeler "Feni seviyorum" gibi özel içerik odaklı duyuşsal temelli ve "Fen benim için önemlidir" gibi değer temelli unsurları içermektedir (Akt: Beghetto, 2009). Bu dört maddenin iç tutarlılık katsayısı 0,77 olarak belirlenmiştir.

Yaratıcı Öz-yeterlik: Öğrencilerin fen alanında yaratıcı öz-yeterlik düzeylerini belirlemek için kullanılan beş maddeden oluşan bu boyutun güvenirlik katsayısı 0,83'tür. Bu faktördeki maddeler öğrencilerin fen alanında yeni ve yararlı fikirler üretme yetenekleri ve fen alanında iyi bir hayal dünyasına sahip olup olmadıkları hakkındaki inançlarını belirlemek amacıyla kullanılmıştır. Bu maddeler Beghetto (2009) tarafından, Tierney ve Farmer (2002)'in yaratıcı öz-yeterlik literatürüne bağlı olarak, fen alanındaki yaratıcı öz-yeterlik düzeylerini belirlemek amacıyla geliştirilmiştir.

Öğretmen Desteğine Yönelik Algı: Bu boyuttaki üç maddenin güvenirlik katsayısı 0,77 olarak belirlenmiştir. Bu maddeler Bandura (1997), Minstrell ve Kraus (2005) ve Nickerson (1999)'ın çalışmaları referans alınarak hazırlanmış ve fen eğitiminde zihinsel risk alma ile ilişkili olduğundan ölçme aracına katılmıştır.

c) Verilerin Analizi

Ölçme aracının alt faktörlerini ve güvenirlik düzeyini belirlemek amacıyla bilgisayar ortamına aktarılan verilerde ilk olarak yanlış veya eksik veri girişi olup olmadığı kontrol edilmiştir. Belirlenen yanlışlar, maksimum ve minimum değerler kontrol edildikten sonra düzeltilmiş, bazı öğrencilerin cevap vermedikleri eksik veriler (toplam verinin 0,01'i) ise regresyon düzeltmesi ile tamamlanmıştır. Bu düzeydeki eksikliklerde düzeltme yapılması, istatistiksel analizler üzerinde önemli bir etki yapmamaktadır (Little & Rubin, 1987; Özdamar, 2002). Fakat bu eksiklik bütün verilerin %5'inden daha fazla olduğunda bu işlemin yapılması yerine ölçme aracının tekrar uygulanmasının gerektiği ifade edilmektedir (Hair, Anderson, Tatham & Black, 1998). Bu araştırmada eksik veri oranı belirlenen ölçütten daha düşük olduğundan regresyon düzeltmesi ile tamamlanması işlemi yapılmıştır. Regresyon düzeltmesi, hiçbir işlem yapmama veya ortalama puanı atama yöntemlerine göre daha avantajlıdır. Çünkü regresyon düzeltmesi ile doğal veri setinden tahmin edilen, daha hassas hesaplanmış doğal veriler, kayıp veri yerine atanır. Ortalama atama durumunda ise dağılımın uçlarındaki değerleri temsil etme düzeyi daha düşük olan değerler atanmaktadır. Bu düzeltme işleminden sonra ölçme aracının geçerlik ve güvenirlik düzeyini test etmek için aşağıdaki işlemler yapılmıştır:

Dil ve Anlam Geçerliği: Ölçeğin dil geçerliği, her bir maddenin İngilizce-Türkçe uyumu test edilerek incelenmiştir. Bu amaçla İngilizce (1 Doç. Dr., 1 Yrd. Doç. Dr, 1. Öğr. Gör; toplam 3 uzman) ve eğitim bilimleri/alan eğitimcilerinden (1 Doç. Dr., 2 Yrd. Doç. Dr; toplam 3 uzman) meydana gelen uzmanların ölçek maddelerini eşzamanlı olarak çevirmeleri sağlanmıştır. Bu işlemde "doğrudan çeviri" tekniği kullanılmıştır. Daha sonra bu çevirilerin birbiri ile uyumu incelenmiş, benzer anlam ve ifadeler olduğunda madde aynen kabul edilmiş; farklı anlam ve ifadelerde ise maddeler tekrar incelenerek oyçokluğuna göre karar verilmiştir.

Yapı Geçerliği: Türkçeye uyarlanan ölçeğin çevirisinden sonra ortaokullarda uygulanarak elde edilen veriler açımlayıcı faktör analizi için SPSS ve doğrulayıcı faktör analizi için AMOS programları ile analiz edilmiştir. Ölçeğin yapı geçerliğini test etmek için faktör analizleri ve karşıt gruplar tekniği kullanılmıştır. Faktör analizi, değişken grupları arasındaki ilişkileri analiz eden, daha az sayıdaki faktörlerle hipotezlere dayalı değişkenlerin oluşturulmasını sağlayan ve bu amaçları gerçekleştirmek için farklı işlemlerin yapıldığı genel bir tekniktir (Brown, 2006). İki tür faktör analizi vardır: Açımlayıcı ve doğrulayıcı faktör analizi. Bu çalışmada, açımlayıcı faktör analizi ile madde-faktör ilişkileri, doğrulayıcı faktör analizi ile de faktörler arası ilişkiler test edilmiştir. Bu iki faktör analizinin temel farkı, ölçme işleminde toplanan verilerin analizine yönelik amacın farklılık göstermesinden kaynaklanır (Gillaspy, 1996). Açımlayıcı faktör analizi (AFA), ölçme aracındaki faktörlerin sayısı hakkında kesin bir bilgi bulunmadığında, ölçme aracının genel olarak hangi faktörlere sahip olduğunu belirlemek amacıyla yapılan istatistiksel işlemleri kapsar (Crocker & Algina, 1986). Beghetto (2009), geliştirdiği ölçekte alt faktörleri açıklamış olmasına rağmen bu çalışmada faktörlerin uygun olup olmadığı AFA ile tekrar test edilmiştir. Doğrulayıcı faktör analizi (DFA) ise, ölçeğin faktör yapısının çeşitli değişkenlere göre farklılık gösterip göstermediğini belirlemek amacıyla yapılan ve daha karmaşık işlemleri içeren analizlerden meydana gelir (Tabachnick & Fidell, 2001). DFA, önceden belirlenmiş veya kurgulanmış bir yapının toplanan verilerle ne derece doğrulandığını incelemeyi amaçlar. AFA'da belirli bir ön beklenti veya denence olmaksızın faktör yükleri (ağırlıkları) temelinde verinin faktör yapısı belirlenirken, DFA belirli değişkenlerin bir kuram temelinde önceden belirlenmiş faktörler üzerinde ağırlıklı olarak yer alacağı şeklindeki bir öngörünün sınanmasına dayanır. Beghetto (2009) tarafından geliştirilen ölçeğin orijinal faktör yük değerleri Tablo 3'te verilmiştir. Açımlayıcı ve doğrulayıcı faktör analizine ek olarak, yapı geçerliği için ayrıca karşıt gruplar tekniğine göre alt ve üst gruptaki öğrencilerin puanları bağımsız gruplar için t-testi ile karşılaştırılmıştır.

Açımlayıcı faktör analizi için faktör yükü 0,30'dan büyük olan maddeler değerlendirilmeye alınmıştır. Ayrıca özdeğeri 1'den büyük olan faktörler üzerinde işlem yapılmıştır (Tabachnick & Fidel, 2001). Doğrulayıcı faktör analizi ile hem AFA analizi sonucunda çıkan sonuçların hem de Baghetto (2009)'nun uygulama sonuçları ve faktörlerinin karşılaştırılması yapılmış; ayrıca uyum indeksleri (fit index) incelenmiştir. Bu analizler sonunda orijinal ölçekte yer alan 18 maddenin, ölçme aracının yapısına uygun olduğu belirlenmiştir.

Kapsam Geçerliği: Bu araştırmada kullanılan ölçek, uyarlaması yapılan bir ölçek olduğundan, ölçtüğü varsayılan kapsamı iyi bir şekilde örneklediği ve zihinsel risk alma davranışını ortaya koymak için kapsam geçerliğinin var olduğu kabul edilmiştir.

Güvenirlik: FAZRÖY'ün güvenirlik düzeyini belirlemek için Cronbach Alfa yöntemi kullanılmıştır. Bu analizle ölçeğin iç tutarlılık düzeyini tespit etmek amaçlanmıştır. Güvenirlik düzeyi hem AFA hem de DFA örneklemi için toplanan veriler için ayrı ayrı yapılmıştır (Bkz. Tablo 7). Ayrıca Beghetto (2009) tarafından geliştirilen ölçeğin alt faktörlerinin güvenirlik katsayıları, bu araştırma verileriyle karşılaştırmak amacıyla Tablo 7'de verilmiştir

BULGULAR ve YORUMLAR

Bu bölümde ölçme aracının geçerlik ve güvenirlik düzeylerini belirlemeye yönelik istatistiksel analiz bulgularına yer verilmiştir.

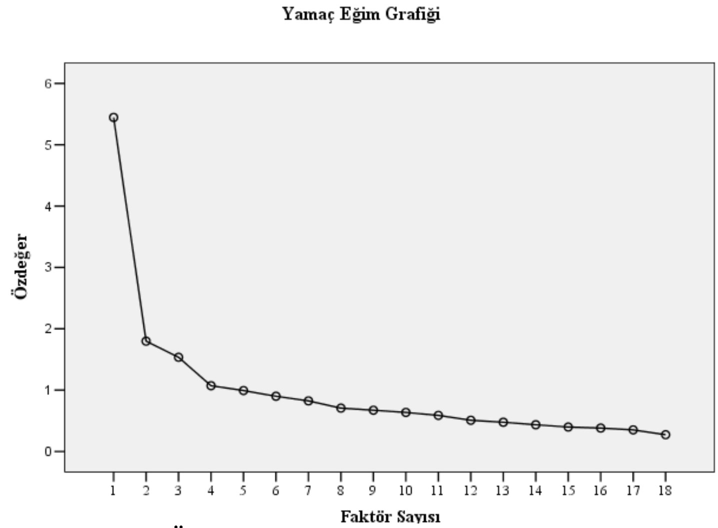
Açımlayıcı Faktör Analizi (AFA)'ne İlişkin Bulgular

Çalışmada FÖZRAY'ın yapı geçerliğini belirlemek için yapılması gereken ilk analiz açımlayıcı faktör analizidir. Bu analizin yapılabilmesi için ilk olarak örneklemden toplanan verilerin faktör analizine uygunluğu test edilir. Daha sonra ise faktör analizi yapılarak, çalışmada incelenen değişken veya değişkenlerin temel bileşenlerinin neler olduğuna ilişkin çeşitli kanıtlar toplanır. Bu amaçla ilk olarak toplanan verilerin faktör analizine uygun olup olmadığı belirlenmeye çalışılmıştır. Kullanılan istatistiklerden Kaiser-Mayer-Olkin (KMO) ve Barlett'in Küresellik Testleri (Barlett's Test of Sphericity-BTS) verilerin bu uygunluğa sahip olup olmadığını ortaya koyar. KMO istatistiğinin sonuçları 0,00-1,00 arasında değer alır. Bu istatistikle elde edilen değer 0,50 ile 1,00 arasında olduğunda uygulanan faktör analizinin, verilerin faktörlere ayrılmasında güvenilir sonuçlar verdiğini gösterirken; 0,00 ile 0,49 arasında olan değerler verilerin faktör analizi için uygun olmadığını göstermektedir. Field (2002)'e göre KMO istatistiğindeki 0,50 ve üzeri için kritik aralıklar şu şekilde sınıflandırılmaktadır. "0,50-0,70 arası: orta", "0,70-0,80 arası: iyi", "0,80-0,90 arası: çok iyi" ve "0,90 ve üzeri: mükemmel". Bu araştırmada toplanan verileri için hesaplanan KMO sonucu 0,86 olarak belirlenmiştir. Field'in sınıflandırmasına göre bu değerin, verilere faktör analizi uygulanması için "çok iyi" kategorisinde olduğu anlamına gelmektedir.

BTS ise araştırmada incelenen değişkenlerin faktör analizi yapmak için yeterli korelasyonu gösterip göstermediğini belirlemek amacıyla yapılır ve bu istatistikte elde edilen değerin 0,05'den daha düşük olması beklenir (Field, 2002; Leech, Barrett & Morgan, 2005).

BTS sonucu 0,00'a ne kadar yakın olursa verilerin faktörlenebilirlik özelliğinin yüksek olduğu; dolayısı ile faktör analizi yapmak için uygun bir veri setinin bulunduğu anlaşılmaktadır. Bu araştırma için toplanan verilerden elde edilen BTS sonucunun 0,99 güven aralığında anlamlı sonuç verdiği belirlenmiştir ($B(153)=2524,63$; $p < 0,01$).

Yapılan analizler sonrasında elde edilen KMO ve BTS sonuçlarının faktör analizi yapmak için uygun olduğu belirlendiğinden, bu faktör yapısını ortaya çıkarmak için döndürülmemiş temel bileşenler analizi uygulanmıştır (Tabachnick ve Fidell, 2001). Bu analizin sonuçları ölçme aracının, Beghetto (2009) tarafından açıklandığı gibi, 4 faktör üzerine kurulabileceğini göstermiştir. Toplam açıklanan varyans ve ortak varyans tablosu (Bkz. Tablo 4) incelendiğinde ölçme aracının, öz değeri 1,00'den büyük dört faktör üzerine toplandığı belirlenmiştir. Ortak varyans, bir değişkendeki faktör yük değerlerinin kareleri toplamıdır (Büyüköztürk, 2002). Aşağıdaki grafik, dört faktör üzerine kurulan FÖZRAY ölçeğinin özdeğeri 1'den büyük (olası) faktör yapısını göstermektedir:



Şekil 1. *FÖZRAY'ın Yamaç Eğim (Scree Plot) Grafiği*

Yamaç eğim grafiğinde özdeğeri 1,00'in üzerinde dört faktör olduğu görülmektedir. Buradan, ölçeğin tahminen 4 faktörden meydana gelebileceğine karar verilmiştir. Stevens (2002)'a göre, 200'den fazla katılımcıdan toplanan veriler, faktör seçiminin güvenilirliği için oldukça uygun ölçüt sağlamaktadır (Akt: Field & Miles, 2010). Fakat yamaç eğim grafikleri bu işlem için kullanışlı olmakla birlikte, sadece bu eğime bakarak faktörler hakkında karar verilmesi önerilmemektedir (Field, 2002). Bu sınırlılığı ortadan kaldırmak ve en uygun faktör seçimini yapabilmek amacıyla Kaiser Normalizasyonlu Promax döndürmesi ve Maksimum Olabilirlik (Maximum Likelihood) işlemleri uygulanmıştır. Maksimum Olabilirlik yöntemi, veriler normallik şartını sağladığında kullanılması önerilen faktör belirleme yöntemlerinden biridir (Costello ve Osborne, 2005). Promax rotasyonu yapılırken, genelde faktör yüklerinin alt kesim noktası 0,30 olan maddeler işleme alınır. Comrey ve Lee (1992)'ye göre faktör yükleri için kritik aralıklar şu şekilde sınıflandırılmaktadır: "0,32-0,44 arası: kötü", "0,45-0,54 arası: normal", "0,55-0,62 arası: iyi", "0,63-0,70 arası: çok iyi" ve "0,70-1,00: mükemmel". Ölçekteki faktörlerde yer alan maddeler ve bunların sahip oldukları faktör yükleri ve yukarıdaki aralıklara göre kategorileri ile Beghetto (2009)'nun çalışmasının değerleri Tablo 3'te gösterilmiştir.

Tablo 3. *Döndürülmüş Temel Bileşenler Analizi Yöntemine Göre FÖZRAY'daki Maddelerin Orijinal ve Uyarlanan Çalışmadaki Faktör Yük Değerleri*

Maddeler	Orijinal Çalışmanın Faktör Yükleri	Uyarlama Çalışmasının Faktör Yükleri
Faktör2: Zihinsel Risk Alma		
Madde1	0,53	0,56
Madde2	0,50	0,39
Madde3	0,69	0,63
Madde4	0,79	0,47
Madde5	0,63	0,49
Madde6	0,51	0,45
Faktör3: Fene Yönelik İlgi		
Madde7	0,88	0,97
Madde8	0,41	0,55
Madde9	0,67	0,62
Madde10	0,67	0,68
Faktör1: Fende Yaratıcılık Yeterliliği		
Madde11	0,70	0,90
Madde12	0,69	0,69
Madde13	0,81	0,73
Madde14	0,58	0,43
Madde15	0,56	0,33
Faktör4: Fene Yönelik Öğretmen Desteği Algısı		
Madde16	0,58	0,65
Madde17	0,89	0,79
Madde18	0,56	0,61

Tablo 3'e göre bu çalışmada, promax rotasyonu ile elde edilen faktör yüklerinin, 3 madde için (2, 14 ve 15. maddeler) 0,32-0,44 arasında "kötü", 3 madde için (4, 5 ve 6. madde) 0,45-0,54 arasında "normal", 4 madde için (1, 8, 9 ve18. maddeler) 0,55 -0,62 arasında "iyi", 4 madde (3, 10, 12 ve 16. maddeler) için 0,63 -0,70 arasında "çok iyi" ve 4 madde (7, 11, 13 ve 17. maddeler) için ise 0,71 ve üzerinde "mükemmel" değişim gösterdiği belirlenmiştir.

Tablo 4. *FÖZRAY'ın Alt Boyutlarına İlişkin Varyans Sonuçları*

Faktörler	**Madde Numaraları**	**Açıklanan Varyans Değerleri**
Faktör 1	11, 12, 13, 14, 15	26,61
Faktör 2	1, 2, 3, 4, 5, 6	8,05
Faktör 3	7, 8, 9, 10	5,07
Faktör 4	16, 17, 18	3,09
Toplam	18	42,82

Tablo 4 incelendiğinde, FÖZRAY'ı oluşturan dört faktörün maddelerdeki toplam varyansın yaklaşık %43'lük kısmını açıkladığı görülmektedir. Maddelerle ilgili olarak tanımlanan dört faktörün varyanslarının 26,61 ile 3,09 arasında değiştiği gözlenmiştir. Bu işlemler sonunda, ölçeğin dört alt faktörden ve toplam 18 maddeden oluştuğu ve bütün maddelerin Beghetto (2009) tarafından önerilen faktörlere yüklendiği belirlenmiştir. Bu dört faktör içinde en yüksek varyans değerine sahip olan Faktör-1 (fende yaratıcılık yeteneği), toplam varyansın %27'lik kısmını açıklamaktadır. Ölçeğin, "zihinsel risk alma" faktörünü meydana getiren Faktör-2 ise 6 maddeden oluşmaktadır ve bu faktörün açıkladığı varyans %8; "fene yönelik ilgi" faktörünü oluşturan üçüncü faktörün varyansının toplam varyans içindeki oranı %5'tir. Üç maddeden meydana gelen ve dördüncü faktör olan "fene yönelik öğretmen desteği algısı"nın ise toplam varyans içinde %3 ile en düşük değere sahip olduğu görülmektedir. Scherer (1988)'e göre faktör analizi yapıldığında açıklanan varyansın %40 ile %60 arasında olması kabul edilebilir bir değerdir. Buna göre araştırmada elde edilen sonuçların yeterli varyans değerlerine sahip olduğu ileri sürülebilir.

Yapı Geçerliği İçin Karşıt Gruplar Yöntemine İlişkin Bulgular

Tablo 5. *FÖZRAY'ın Yapı Geçerliğine Yönelik Karşıt Gruplar Yöntemine İlişkin Bağımsız Gruplar İçin T-Testi Sonuçları*

	Grup	N	$\bar{X}$	S	sd	t
Faktör 1	Üst	122	4,52	0,24	242	32,10*
	Alt	122	2,49	0,66		
Faktör 2	Üst	122	4,77	0,16	242	31,25*
	Alt	122	3,11	0,56		
Faktör 3	Üst	122	4,31	0,17	242	21,43*
	Alt	122	3,35	0,46		
Faktör 4	Üst	122	4,64	0,27	242	38,42*
	Alt	122	2,30	0,62		
Toplam	Üst	122	4,55	0,18	242	37,00*
	Alt	122	3,09	0,40		

* $p < 0,01$

Tablo 5'e göre örneklemde yer alan alt ve üst gruplardaki öğrencilerin fende zihinsel risk alma ve yordayıcılarına ilişkin puanları arasında hem toplam puan hem de dört alt boyutun her biri açısından anlamlı düzeyde farklılık bulunduğu ($p < 0,05$) ve bu farklılığın üst gruptaki öğrenciler lehine olduğu belirlenmiştir. Ayrıca standart sapma değerine göre üst grupta yer alan öğrencilerin ilgili konudaki benzeşiklik düzeylerinin alt gruptakilere göre daha yüksek olduğu tespit edilmiştir. Bu sonuç karşıt gruplar yöntemine göre ölçme aracının yapı geçerliğinin yüksek olduğuna ilişkin kanıt olarak kabul edilebilir.

Doğrulayıcı Faktör Analizi (DFA)'ne İlişkin Bulgular

DFA özellikle başka kültürlerde ve örneklemlerde geliştirilmiş ölçme araçlarının uyarlanmasında kullanılan bir geçerlik belirleme yöntemidir. Sümer (2000)'e göre DFA, kuramsal bir temelden destek alarak pek çok değişkenden oluşturulan faktörlerin gerçek verilerle ne derece uyumlu olduğunu değerlendirmek amacıyla kullanılan bir analizdir. Bir başka ifadeyle DFA, önceden belirlenmiş veya kurgulanmış bir yapının, başka bir örneklemden toplanan verilerle ne derece doğrulandığını incelemeyi amaçlar. Böylece DFA, belirli değişkenlerin bir kuram temelinde önceden belirlenmiş faktörler üzerinde ağırlıklı olarak yer alacağı şeklindeki bir öngörünün sınanmasına dayanır.

Bu analiz için örneklemin yeterli olup olmadığı KMO ve BTS kullanılarak belirlenmiştir. Geliştirilen bu ölçme aracının KMO katsayısı 0,89 olduğu belirlenmiştir. Bu örneklemden elde edilen veriler için BTS testi yüksek düzeyde (% 99 güven aralığında) anlamlıdır ($B(153)=2718,46$; $p < 0,01$). Bu sonuçlara göre, verilerin doğrulayıcı faktör analizi yapmak için uygun olduğu ifade edilebilir. Bu analiz için veriler Mardia'nın çoklu yönlü normallik testi ile analiz edilmiştir (Khattree ve Naik, 1999). Bu analiz sonucunda verilerin belirlenen normallik için kritik değer olan 10'un üzerinde olması (47,21) nedeniyle verileri çoğaltma işlemi (bootstrap) uygulanmıştır. Bu analizde var olan veri seti içerisinden rastgele seçilen 200 yeni veri rastgele üretilmiştir. Verilerin dağılımını normalleştiren bu işlemle birlikte DFA'nın parametrik istatistiklere uygunluğu artmıştır. Bu üretilen veriler için ki-kare dağılımı aşağıdaki gibidir:

```
89,739     |*
96,305     |*
102,872    |****
109,439    |**********
116,006    |*******
122,573    |**********                 N = 200
129,140    |*****************          Art. Ort = 133,645
135,707    |**************             Se= 1,221
142,274    |**************
148,841    |*********
155,407    |*******
161,974    |******
168,541    |**
175,108    |*
181,675    |*
```

Şekil 2. *Verileri Çoğaltma Işlemine Göre Ortaya Çıkan Dağılım*

DFA'da sınanan modelin uyum yeterliğini belirlemek için pek çok uyum indeksi kullanılabilir. Uyum indekslerinin kuramsal model ile gerçek veriler arasındaki uyumu değerlendirmede birbirlerine göre güçlü ve zayıf yönlerinin olması nedeniyle modelin uyumunun ortaya konulması için birçok uyum indeksi değerinin kullanılması önerilmektedir (Büyüköztürk ve diğ., 2004). Söz konusu uyum indekslerinden en sık kullanılanları şunlardır: Ki-kare uyum (chi-square goodness), iyilik uyum indeksi (goodness of fit index-GFI), karşılaştırmalı uyum indeksi (comparative fit index-CFI), yaklaşık hata kalanlarının ortalama karekökü (the root mean square residual-RMR) ve yaklaşık hataların ortalama kareköküdür (root mean square error of approximation-RMSEA). Bu indeksler ve özelliklerine ilişkin açıklamalar şu şekildedir:

- *Ki-kare uyum indeksi*, gözlenen korelasyon matrisinin, kuramsal korelasyon matrisinden ne derece uzaklaştığının bir ölçüsüdür. Model ile veri iyi uyum gösteriyorsa, elde edilen değer düşük çıkar. Buna bağlı olarak χ^2/sd değeri 5'den küçük bir değer alırsa, model ile veri setinin uyumlu olduğu anlaşılır.
- *GFI*, model ile verinin uyumunu gösteren bir başka indekstir. Bu değerin 0,90 ile 1,00 arasında olması, model-veri uyumunun yeterli olduğunun bir göstergesi kabul edilir.
- *CFI*, model tarafından tahmin edilen kovaryans matrisi ile gözlenen kovaryans matrisini karşılaştıran ve Bentler'in Karşılaştırmalı Uyum İndeksi olarak bilinen bir indekstir. Bu indeksin 0,90 ile 1,00 arasında olması, bu matrislerin uyumlu olduğu anlamına gelmektedir.
- *RMR,* tahmin edilen ve gözlenen kovaryans matriksleri arasındaki farklara göre işlem yapan bir uyum indeksidir. Bu iki model arasındaki farkın azlığı, modelin uygunluğunu gösterir. Bu indeksin değeri 0'a yaklaştıkça üretilen modelin iyi uyum gösterdiği kabul edilir.
- *RMSEA* ise, maksimum parametre tahminleri ile örneklemin kovaryans matrikslerinin ne kadar uyumlu olduğunu gösteren bir indekstir. Bu indeksin 0,00 ile 0,10 arasında olması uyum olduğunun bir göstergesidir (Barrett, 2007; Brown ve Cudeck, 1993; Byrne, 1994).

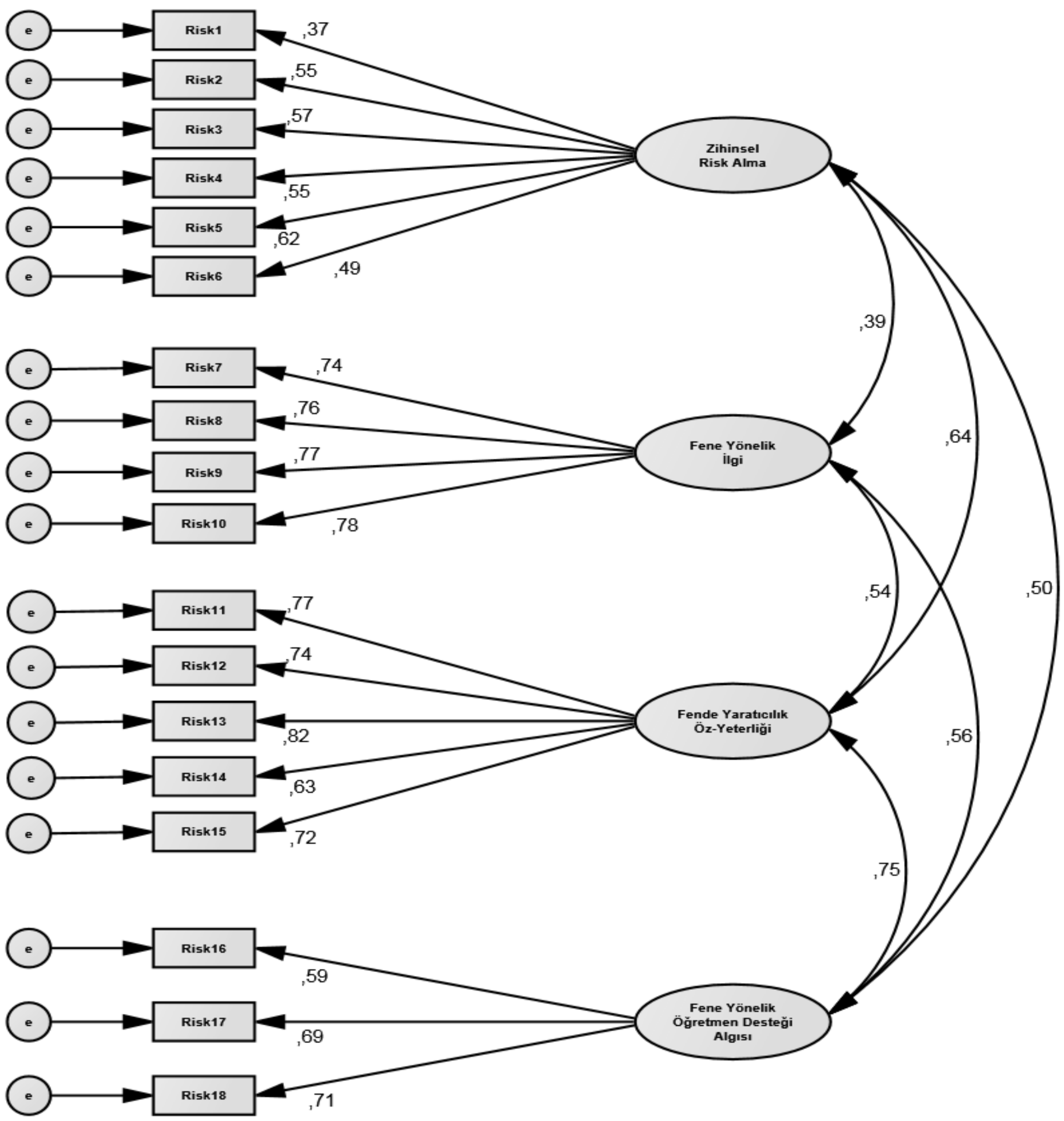
CFI ve RMSEA bazı araştırmalarda birlikte kullanılırken, bazı araştırmalarda ayrı kullanılan indekslerdir. Rigdon (1996), bu iki fit indeksinin varsayımları ve sonuçları üzerinde yaptığı araştırmada, CFI'nın açımlayıcı faktör analizleri, RMSEA'nın ise doğrulayıcı faktör analizleri için daha uygun olduğunu ifade etmiştir. Fakat yaygınlık anlamında, doğrulayıcı faktör analizi çalışmalarında her iki indeksin birlikte kullanıldığı araştırmaların daha fazla olduğu görüldüğünden, bu araştırmada her ikisine de yer verilmiştir. Tablo 6'da modele ilişkin faktör analizinde en çok kullanılan uyum indekslerinden elde edilen değerler verilmiştir.

Tablo 6. *Risk Alma Ölçeğinin Uyum (Fit) İndekslerine İlişkin Değerler*

Uyum İndeksi	χ^2	sd	χ^2/sd	p*	GFI	CFI	RMR	RMSEA
Değer	288,03	129	2,23	0,01	0,93	0,94	0,05	0,06

* *Bollen-Stine bootstrap değeridir.*

DFA'nde elde edilen modelin uyum indeksleri incelenmiş ve Minimum Ki-kare değerinin 129 serbestlik derecesinde 288,03 (p=0,01) olduğu görülmüştür. Uyum indeksi değerleri ise RMSEA=0,06; CFI=0,90; GFI=0,92 ve RMR=0,05 olarak bulunmuştur. Bu uyum indeksi değerleri modelin uyumlu olduğunu ortaya koymaktadır (Hooper, Coughlan ve Mullen, 2008; Schermelleh-Engel ve Moosbrugger, 2003). Modele ilişkin parametre tahminleri Şekil 3'te görülmektedir.



Şekil 3. *FÖZRAY'ın Yapısal Eşitlik Modeline İlişkin Parametre Tahminleri*

Şekil 3'te görüldüğü gibi DFA sonucu elde edilen faktör yükleri, faktör-madde ve faktörler arası ilişkiler yeterli düzeydedir. Doğrulayıcı faktör analizi sonuçları Beghetto (2009)'un önerdiği teorik yapı ile uyum göstermektedir.

Ölçme Aracının Güvenirlik Düzeyine İlişkin Bulgular

Tablo 7'de, Beghetto (2009) tarafından geliştirilen ve bu çalışmada uyarlanan ölçekle AFA ve DFA analizleri için iki örneklem grubundan toplanan verilere göre beş alt boyutuna yüklenen madde sayıları ve her bir faktöre yönelik Cronbach Alpha güvenilirlik katsayıları verilmiştir.

Tablo 7. *FÖZRAY'ın Maddelerinin Orijinal ve Uyarlama Çalışmasındaki Alt Boyutlarının Cronbach Alfa Katsayı Sonuçları*

Faktörler	Madde Sayısı	Orijinal Çalışmanın Güvenirlik Katsayıları	DFA Örneklemi İçin Güvenirlik Katsayıları	AFA Örneklemi İçin Güvenirlik Katsayıları
Faktör 1	5	0,83	0,85	0,81
Faktör 2	6	0,80	0,69	0,69
Faktör 3	4	0,77	0,84	0,80
Faktör 4	3	0,77	0,71	0,71
Toplam	18		0,87	0,86

Yapılan güvenilirlik çalışmaları sonucunda, iki farklı örneklemden toplanan verilere göre ölçeğin toplam Cronbach Alpha iç tutarlılık katsayılarının 0,87 ve 0,86 olduğu tespit edilmiştir. Ayrıca ölçme aracındaki her bir alt boyut için de iç tutarlılık katsayıları da hesaplanmıştır. Yapılan analizler sonunda, her iki örneklem grubu için de ölçme aracının alt boyutlarına göre en yüksek güvenirlik düzeyi Faktör1 ve Faktör3'te, en düşük güvenirlik düzeyi ise Faktör2'de meydana gelmiştir. Uyarlama çalışmasında elde edilen katsayılar, ölçme aracının güvenilir sonuçlar verebilen bir araç olduğu konusunda yeterli olduğunu göstermektedir (Büyüköztürk, 2002).

TARTIŞMA ve SONUÇ

Yapılan çalışmada, "Fen Öğrenmede Zihinsel Risk Alma ve Yordayıcılarına İlişkin Algı Ölçeği"nin Türkçe uyarlaması yapılmıştır. Bu ölçme aracının geçerlik düzeyini belirlemek için farklı yöntem ve istatistiksel analizler kullanılmıştır. Araştırmada kullanılan ölçek İngilizceden uyarlandığından, ilk olarak dil ve anlam geçerliği üzerinde durulmuş ve bu özelliklerin uygun olduğu belirlendikten sonra veri toplama aşamasına geçilmiştir. Ölçeğin yapı geçerliği üç farklı şekilde incelenmiştir. Birinci yöntem faktör analizleri (açımlayıcı ve doğrulayıcı), ikinci yöntem ise karşıt gruplar yöntemidir. Bu iki yöntem sonucunda da ölçme aracının yapı geçerliğinin uygulanabilir düzeyde olduğu tespit edilmiştir. Son olarak ölçme aracının güvenirlik düzeyi incelenmiş ve kabul edilebilir düzeyde tutarlılığa sahip olduğu belirlenmiştir. Bu sonuçlara göre, akademik risk alma ve yordayıcılarını içeren bu ölçeğin, ülke olarak düşük başarı gösterdiğimiz fen eğitiminde birbiri ile ilişkisi olan birden çok değişkeni ölçebilecek özellikleri kapsaması nedeniyle önemli bir veri toplama aracı olacağı ileri sürülebilir.

Ulusal ve uluslararası sınav sonuçlarının fen alanı için ülkemizde önemli uyarılar verdiği açıkça görülmektedir. Bu sınavlarda öğrencilerin düşük düzeyde başarı gösterdikleri, hem bu sınavların sonuçları ile hem de yapılan çalışmalarla ortaya konulmuştur (Berberoğlu & Kalender, 2005; Ceylan & Berberoğlu, 2007; MEB, 2011; ÖSYM, 2011, 2014; Sarıer, 2010). Bu durumun sebeplerinden birinin, öğrencilerin zihinsel risk alma düzeyleri ile ilgili olduğu ileri sürülebilir. Çünkü uyarlanan ölçme aracının alt faktörlerini oluşturan yaratıcılık öz-yeterliği, fene yönelik ilgi ve öğretmen desteği algısı ile zihinsel risk alma arasında pozitif ve yüksek düzeyli korelasyon olması, bunlara bağlı olarak akademik başarının da etkilenen bir boyut olma olasılığını artırmaktadır. Schiefele, Krapp ve Winteler (1992) öğrencilerin başarıları üç faktörün etkili olduğunu ifade etmişlerdir. Bu faktörler: Öğrenci özellikleri (yetenek, kişilik, ilgi, tutum, vb.), sosyal ortam (sosyo-ekonomik düzey, aile yapısı vb.) ve okul şartları (eğitim kalitesi, fiziksel imkânlar vb.). Bu çalışmada ele alınan boyutlar öğrenci özellikleri (öz-yeterlik, risk alma ve ilgi) ve okul şartları (öğretmen desteği) ile ilgili faktörlerin alt boyutlarını içermektedir. Bu yönüyle uyarlaması yapılan ölçeğin, aşağıda belirtildiği gibi öğrenci ve okula yönelik özellikler arasında bir ilişki kurmak açısından önemli bilgiler verdiği düşünülmektedir.

Motivasyonun alt boyutlarından biri olan öz-yeterlik (Rogers ve diğ., 1999) ile başarı arasında oldukça yüksek bir ilişki olduğu ve öz-yeterliğin başarının önemli yordayıcılarından biri olduğu birçok araştırma ile ortaya çıkarılmıştır (Beghetto, 2007; Pajares & Miller, 1994; Pintrich & DeGroot, 1990; Plucker, Beghetto & Dow, 2004; Zimmerman, Bandura & Martinez-Pons, 1992). Beghetto (2009) öğrencilerin yaratıcılıklarını gösterebilecekleri ortamlar olmadan öğrencilerin başarılarını artırmanın ve risk alma davranışını geliştirmenin oldukça zor olduğunu belirtmiştir. Bunun yanında yaratıcı öz-yeterliği yüksek olan öğrencilerin bütün konu alanlarında akademik yetenekleri hakkında olumlu tutuma sahip oldukları ifade edilmiştir (Beghetto, 2006).

Başarı ile ilgi arasında da ilişki olduğu ve fene yönelik ilgisi yüksek olan öğrencilerin başarılarının da yüksek olma olasılığının bulunduğu istatistik temelli araştırma sonuçlarıyla desteklenmektedir. Her ne kadar ilgisi yüksek olan öğrencilerin kesinlikle başarılı olacaklarına ilişkin kanıtlar fazla değilse de, bu öğrencilerin başarılı olma olasılıklarının ilgisi düşük öğrencilerin başarılı olma olasılığından daha yüksek olduğu söylenebilir (Ainley, Hidi & Berndroff, 2002; Harackiewicz, Barron, Tauer & Elliot, 2002; Hidi, Renninger & Krapp, 2004; Schiefele, Krapp & Winteler, 1992). Beghetto (2009) da öğrencilerin fen öğrenmeye yönelik ilgileri üzerinde risk alma istekliliklerinin önemli bir faktör olduğunu; diğer faktörler kontrol altına alındığında bu değişkenler arasındaki ilişkinin yüksek olduğunu belirtmiştir. Öğrencilerin fen öğrenmeye yönelik ilgilerini sağlayarak başarılarını artırmada öğretmen desteğinin önemli olduğuna yönelik araştırmalar bulunmaktadır. Bu araştırmalarda öğretmenden destek alan öğrencilerin sınıflarında daha aktif oldukları, derse katılımlarının, ilgilerinin ve sosyal sorumluluk bilinçlerinin arttığı ifade edilmiştir (Hidi & Renninger, 2006; Karabenick & Sharma, 1994; Wentzel, 1998). Beghetto (2009), öğretmenlerin sınıflarında oluşturdukları ortamların, öğrencilerin hem başarılarına hem de risk alma düzeylerine etki ettiğini; dolayısı ile öğretmenlerin yeni stratejiler denemelerinin, sorular sormalarının, fikirleri paylaşacak ortamlar oluşturmalarının katkısı olacağını belirtmiştir. Bu araştırmadaki bulgular ile ilgili literatürdeki bulgular, bilişsel ve duyuşsal faktörler arasında çok yönlü ilişkinin olduğunu göstermektedir.

Zihinsel risk alma ile akademik başarı arasında da ilişki olduğunu ifade eden Beghetto (2009), öğrencilerin yaşlarının artması ile risk alma davranışlarının düştüğünü ifade etmiştir. Bunun sosyal politikalar, iyi derece alma, mükemmel sınav sonuçları ve hatasız öğrenme gibi baskıların bir eseri olduğunu literatürle de destekleyen Beghetto, araştırmada uyarlanan ölçeğin alt boyutlarının birbiri ile ilişkisini göstererek çoklu karşılaştırma imkânı sağlamıştır. Ülkemizde de merkezi sınav sonuçları incelendiğinde, SBS (Seviye Belirleme Sınavı) ve OGS (Ortaöğretime Geçiş Sınavı)'de öğrencilerin fen başarı düzeyleri ile ÖSS (Öğrenci Seçme Sınavı), YGS (Yükseköğretime Geçiş Sınavı) veya LYS (Lisans Yerleştirme Sınavı)'deki başarıları kıyaslandığında, ortaöğretim sonunda daha düşük başarı gösterdikleri görülmektedir (MEB, 2011; ÖSYM, 2011, 2014). Bu veriler, öğrencilerin yaşları arttıkça fen alanındaki başarılarının düştüğü anlamına gelebilir. Buna bağlı olarak Beghetto'nun belirttiği zihinsel risk alma davranışının yaş arttıkça azalması, bu değişkenlerin (akademik başarı-zihinsel risk alma) birbiri ile ilişkili olduğu hipotezini desteklemektedir.

Bu çalışma kapsamında uyarlanan ölçme aracını oluşturan alt faktörler arasındaki ilişkinin yüksek çıkması, zihinsel risk almanın yanında ilişkili olduğu kabul edilen diğer özelliklerin de ölçülebileceği geçerlik ve güvenirlik düzeyi yüksek bir araç niteliğini taşıdığını göstermektedir. Zihinsel risk alma ile yüksek korelasyon gösteren fende yaratıcılık öz-yeterliği; bu iki değişken arasında yüksek düzeyli bir ilişki olduğunu; dolayısı ile fene yönelik öz-yeterliği yüksek öğrencilerin risk alma düzeylerinin de artacağını göstermektedir (Beghetto & Baxter, 2012). Benzer şekilde fene yönelik ilgi ve öğretmen desteği algısı ile zihinsel risk alma arasındaki ilişkinin güçlü olması da, bu özelliklerin ayrı ayrı incelenmesi yerine uyarlanan ölçekte olduğu gibi birlikte ele alınmasının avantaj sağlayacağını göstermektedir. Böylece fenni öğreten ve öğrenenlerle birlikte diğer ilgililerin de yararlanabilecekleri çok boyutlu bir araç uygulama imkânları olacaktır. Bu araçtan elde edilecek verilerle, düşük fen başarısına sahip öğrencilerin bu dört boyutla ilgili eksikliklerinin belirlenmesi mümkün olabilir. Bunun yanında yüksek fen başarısına sahip öğrencilerin güçlü yönleri belirlenerek eğitimin niteliğini artırıcı dönütler elde edebilirler. Aynı zamanda bu ölçek kullanılarak ülkemizde ilkokul ve ortaokul düzeyinde eksik olan "zihinsel risk alma" davranışına ilişkin çalışmaların sayısının arttırılması da sağlanabilir.

Bu araştırma, ölçek uyarlama çalışması olup, "zihinsel risk alma ve bu beceriyi yordayan" davranışlara odaklıdır. Bu araştırmanın sonuçlarının "yol analizi" gibi yöntemlerle neden-sonuç ilişkisi odaklı bir şekilde irdelenmesi gerekmektedir. Ayrıca "zihinsel risk alma"nın üç yordayıcısına ek olarak literatürde önemli olduğu belirtilen ama bu çalışmanın kapsamına girmeyen diğer muhtemel yordayıcıların da (iç ve dış motivasyon, öz-yeterlik, eleştirel düşünme, yardım alma, öz-düzenleme, kaygı vb.) incelenmesinin, ilgili konuda var olan literatür eksikliğinin azaltılması açısından yararlı olacağı düşünülmektedir.

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Adapting Turkish Form of Intellectual Risk-Taking and Perceptions About its Predictors Scale in Science Education: The Validity and Reliability Study

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SYNOPSIS

INTRODUCTION

Science is to investigate observed nature and natural events systematically and to attempt for making inferences about non-observed events (Çepni, 2011). By its open-ended nature, science requires asking questions, making explanations and appreciating ideas. These activities require taking risk, risk taking behaviour has different definitions but it generally involves expressing and advocating ideas in spite of existence of threats and no insights about final results of the actions (Denrell, 2007; Feldman, 2003; Peled, 1997). Risk taking behavior is distributed normally in population (Arnett, 1992; Greene & diğ., 2000). One type of risk taking is intellectual risk taking that means taking intellectual risks due the fact that you do not know about final outcome of the activity. Intellectual risk-taking is ability of saying and advocating ideas in spite of threats to intelligence, honour, reliability and righteous (Feldman, 2003). Clifford and Chou (1991) gave examples of some intellectual risk-taking situations in classrooms that asking questions to other children, making explanations about topics, giving answers to questions and taking responsibility in situations of which conclusions cannot be predicted, are some of intellectual risk-taking behaviours. Previous studies claimed that distribution of risk-taking behaviour in society is like normal distribution (Arnett, 1992; Greene et al., 2000). Trimpop (1994) say that people taking risk and non-risk takers are found in the opposite extreme poles of the distribution. Steinberg (2004) suggested preparation of young people to take appropriate risks by teaching the ability to them. Since studies provided evidence that intellectual risk-taking contributes to motivation to learn, to study in groups collaboratively and to solving problems effectively (House, 2002; Meyer, Turner & Spencer, 1997; Tay, Özkan & Tay 2009). Intellectual risk-taking is a variable that is associated with

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many important variables including interest and creative self-efficacy regarding learning science. Studies have showed that science achievement is associated with risk taking (Tay, Özkan & Tay 2009). The researchers have found that gifted students who are high level risk takers have high achievement scores and problem solving ability. Meyer, Turner and Spencer (1997) have studied with 14 students in 5th and 6th grades. They have observed that advanced risk takers approach to project studies positively. Beghetto (2009) sees intellectual risk taking as a part of internal motivation. He also suggests that advanced risk taking behaviour increases motivation and as such contributes to achievement.

PURPOSE of the RESEARCH

In spite of the importance of intellectual risk-taking, number of the studies in Turkey is very limited. It is thought that the insufficiency in the number of the studies is related to lack of the instruments on cognitive risk-taking. The purpose for this study is to adapt an instrument on cognitive risk-taking and its correlates in learning science.

METHODOLOGY

In this study adaptation of intellectual risk taking and its predictors scale was carried out. The data of the study were collected from two different sample groups due to the fact that adaptation process needed applying two different factor analysis for investigating factor structure of the instrument .The sample of the study included two different groups (N=864); one (449, 6., 7., and 8. grade elementary students) for confirmatory factor analysis and one (415, 6., 7., and 8. grade elementary students) for exploratory factor analysis. Descriptive values about the samples are represented in Table 1.

Table 1. *Descriptive Data of The Participants in Two Different Groups of The Study*

Grade / Gender	6		7		8		Total		Analysis Type
	f	%	f	%	f	%	f	%	
Female	67	50.8	78	52.3	70	52.2	215	51.8	Exploratory FA
Male	65	49.2	71	47.7	64	47.8	200	48.2	
Total	132	31.8	149	35.9	134	32.3	415	100	
Female	65	45.8	73	49.7	83	51.9	221	49.2	Confirmatory FA
Male	77	54.2	74	50.3	77	48.1	228	50.8	
Total	142	31.6	147	32.7	160	35.6	449	100	

According to table 1, distributions of students across gender and grade level were found to be similar. Then, sufficiency of sample to conduct factor analysis was checked by using Comrey and Lee (1992)'s criteria: 0-100 is very bad, 101-200 is bad, 201-300 is enough, 301-500 is good , 501-1000 is very good and 1000 and above is excellent. When looked at the criteria it is seen that samples of the study are good. Furthermore adequacy of the samples for factor analysis was also checked by values of KMO and Barlett's test. For exploratory factor analysis KMO and Barlett's values are .86 and 2524.63 respectively while KMO and Barlett values for confirmatory factor analysis are .89 and 2718.46 respectively. The results supported adequacy of the samples for making factor analysis. The adapted instrument was developed by Beghetto (2009) and it was a Likert type instrument. The instrument is made of four factors including cognitive risk-taking and its three correlates (interest in science, creative self-efficacy in learning science and beliefs about teacher support in learning science). By taking into account the correlates of a variable, it was thought that more holistic adaptation could be achieved. The data collected by the instrument was analyzed by using SPSS for making exploratory factor analysis; Cronbach's alpha calculation, and opposite group comparison while AMOS was used to conduct confirmatory factor analysis. By using them, structure validity and reliability were checked while content and language validities were also done by researchers.

FINDINGS

The findings of the study have two parts as factor analyses results and reliability analysis results. It was found that the scores were reliable and the instrument was valid for using it in Turkish culture. It was found that the characteristics of adapted instrument had similar characteristics with the original instrument in terms of construct validity and reliability, and validity and reliability level were found to be appropriate for social sciences. For exploratory factor analysis, KMO and Barlett' test results showed factorability of the scores and following analysis gave four-factor solutions with 18 items. At the same time the four-factor structure explained 43% of total variance in intellectual risk-taking and its predictors. Table 2 shows exploratory factor analysis results.

Table 2. *Results of Rotated Principle Components Analysis and Results of Non-Adapted Instrument*

Items	Factor loadings of original instrument	Factor loadings of adapted instrument
Factor2: Intellectual Risk Taking		
Item 1	0.53	0.56
Item 2	0.50	0.39
Item 3	0.69	0.63
Item 4	0.79	0.47
Item 5	0.63	0.49
Item 6	0.51	0.45
Factor 3: Interest in science		
Item 7	0.88	0.97
Item 8	0.41	0.55
Item 9	0.67	0.62
Item 10	0.67	0.68
Factor 1: Self-efficacy in scienctific creativity		
Item 11	0.70	0.90
Item 12	0.69	0.69
Item 13	0.81	0.73
Item 14	0.58	0.43
Item 15	0.56	0.33
Factor4: Perception about teacher support		
Item 16	0.58	0.65
Item 17	0.89	0.79
Item 18	0.56	0.61

Then comparison of lowest and highest scorers was done and it was found that there were statistically significant differences in scores of the students in terms of four factors. This was also accepted as a support for structure validity. After these processes, confirmatory factor analysis were done for four-factor solutions and the results showed that fit index values were in accepted ranges, the findings on confirmatory factor analysis are shown in Table 3.

Table 3. *Confirmatory Factor Analysis Findings*

Indexes	χ^2	**Sd**	χ^2**/sd**	**p***	**GFI**	**CFI**	**RMR**	**RMSEA**
Value	288.03	129	2.23	0.01	0.93	0.94	0.05	0.06

** Bollen-Stine bootstrap value*

After checking factor structure of the instrument, reliability analysis was done and results showed acceptable reliability confidents for the factors and whole instrument scores

(.69-.85). By approaching instrument adaptation process holistically, researchers using the instruments have more opportunity of looking the problem from different angles at the same time. High correlations between different measurable factors such as self-efficacy and intellectual risk-taking indicate existence of related factors in the same package to explain a problem. For example low achievement can be explained by low self-efficacy (Beghetto, 2007; Pajares & Miller, 1994; Pintrich & DeGroot, 1990; Plucker, Beghetto & Dow, 2004; Zimmerman, Bandura & Martinez-Pons, 1992) but also low intellectual risk-taking might be another reason (Beghetto, 2009) so looking the related factors in studying problems might give advantages. At the same time adapting such an instrument by using a rigorous method might contribute its power in studying achievement and problematic sides of science education.

CONCLUSION and SUGGESTIONS

Based on the results of this study it can be recommended that studying the correlational relationships between the variables of the instrument might be extended by using path analysis for establishing cause-effect relationship. Also other important variables out of the variables in this study might be investigated for contributing holistic nature of the instrument. One of the important insufficiencies in this research is to study predictions made by the scores of the instrument on educationally focused variable. By studying the prediction importance of intellectual risk-taking and its predictors in terms of important variables such as achievement and science process skills might be enlightened.

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Ek/Appendix

Fen Öğrenmede Zihinsel Risk Alma ve Yordayıcılarına İlişkin Algı Ölçeği

o	**Maddeler**
	Faktör2: Zihinsel Risk Alma
1	Fen derslerinde çok iyi olmasam bile yeni şeyler yapmayı severim
2	Fen derslerinde doğru olduğundan emin olmasam bile fikirlerimi paylaşırım
3	Fen derslerinde nasıl yapılacağını bilmesem bile yeni şeyler yapmayı denerim
4	Fen derslerinde bir sonuca ulaşamayacağımı bilsem bile birşeyler yapmanın yeni yollarını bulmaya çalışırım
5	Fen derslerinde yanlış yapma ihtimalim olsa bile yeni şeyler öğrenmeyi denerim
6	Fen derslerinde diğer öğrenciler benim onlar kadar zeki olmadığımı düşünse bile sorular sorarım
	Faktör3: Fene Yönelik İlgi
7	Fen dersini severim
8	Fen dersi benim için önemlidir
9	Fen derslerinde yaptıklarımızdan hoşlanırım
10	Fen dersi en gözde derslerimden biridir
	Faktör1: Fende Yaratıcılık Yeterliliği
11	Fen dersinde yeni fikirler ortaya atma konusunda iyiyimdir
12	Fen derslerinde hayal gücümü iyi kullanırım
13	Fen derslerinde çok güzel fikirler üretirim
14	Kendime ait fen deneylerini oluşturmakta iyiyimdir
15	Fen problemleri için yeni çözüm yolları bulmada iyiyimdir
	Faktör4: Fene Yönelik Öğretmen Desteği Algısı
16	Öğretmenlerim fen derslerinde fikirlerime gerçekten değer verirler
17	Öğretmenlerim fen derslerinde çok yaratıcı fikirlerim olduğunu söylerler
18	Öğretmenlerim fen derslerinde başarılı olduğumu söylerler