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The representational levels: Influences and contributions to research in chemical education

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ABSTRACT

Chemistry is considered a difficult subject to study since it comprises microscopic, macroscopic, and symbolic components. This paper provides a comprehensive review of the literature on the representational levels (macroscopic, microscopic, and symbolic) that involve models of thinking in chemistry, and it summarizes what is currently known and provides guidance for further research. This work reports the outcomes of theoretical and empirical studies about the representative levels in chemistry, science, and teacher education. The outcomes present a major concern around the difficulties and abilities of high school and undergraduate students in understanding chemistry in all the representational levels. Nevertheless, few studies were found about the teaching of educational programs, which shows that scientific studies on this topic are still lacking.

Keywords: Chemistry Education; Representational Levels; Visualization.

INTRODUCTION

Chemistry is conceived by many people as a difficult subject, since it is composed of abstract concepts and topics. The complex and abstract nature of chemistry makes learning and teaching difficult for students and teachers (Johnstone, 1991; 1993; Nakhleh, 1992; Gabel, 1998; Treagust & Chittleborough, 2001). Sabelli and Livshits (1995) pointed out that, unlike other scientific subjects, when we see chemical reactions (cooking, moving cars, sunburning, healing), we do not see the chemistry we are taught, and therefore we do not see chemistry at all.

The formation of most chemical concepts and explanations of chemical phenomena rely on understanding the microscopic world that is connected with the phenomenological world, both of which are communicated with symbols. Thus, conceptual understanding in chemistry includes the ability to represent and translate chemical problems using macroscopic (observable), microscopic (particulate), and symbolic forms of representation (Gabel & Bunce, 1994).

Because of the complex nature of chemistry, Johnstone (1991, 1993 & 2000) proposed a model of thinking in chemistry that consists of three modes, addressed as *levels of thought*: the macroscopic, the sub-microscopic, and the symbolic. This multilevel way of thinking can

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be represented by the corners of a triangle (Figure 1) where the sub-micro and symbolic modes are at the base of the triangle, and the macro mode at the apex.

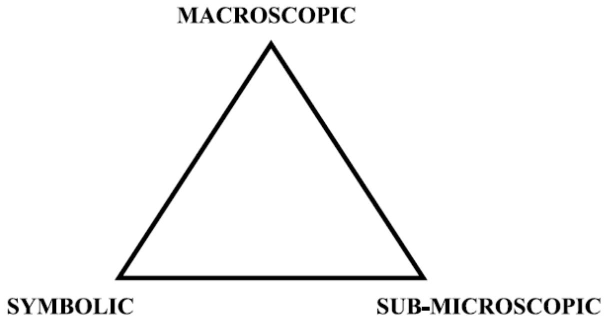

Figure 1. *The three representational levels in chemistry (Johnstone, 1991).*

According to Johnstone (1991), the macroscopic level is concrete and corresponds to observable chemical objects that may or may not be part of students' everyday experiences, but students can observe chemical phenomena by experiments. The sub-micro is also real but is abstract; it forms the particulate level, which can be used to describe what is observed at the macroscopic level as the movement of electrons, molecules, particles, or atoms. The symbolic level represents chemical and macroscopic phenomena by the use of chemical equations, mathematical equations, graphs, reaction mechanisms, analogies, and model kits. A minimum level of modeling ability or representational competence is required to use these symbols to learn and understand chemistry. Thus, the study of chemistry is based on the theory of the particulate nature of matter, the sub-microscopic level of matter. But most things encountered in the world, and on which we form many of our concepts, are macro in nature. That is, we see the macroscopic and use models to represent the sub-microscopic and symbolic levels. According to this aspect of the chemistry study, Johnstone (2000) asserts:

> On the macro level, chemistry is what you do in the laboratory or in the kitchen (…). This is the experiential situation to which we are accustomed in most aspects of life. But chemistry, to be more fully understood, has to move to the sub-micro situation where the behavior of substances is interpreted in terms of the unseen and recorded in some representational language. This is at once the strength of our subject as an intellectual pursuit, and the weakness of our subject when we try to teach it, or more importantly, when beginners (students) try to learn it (p.11).

Gabel (1999) says that chemical phenomena, which are studied at the macroscopic level, can also be studied at the sub-microscopic level, but are generally described at this level to solve complicated problems. The same occurs at the symbolic level. However, students are apparently able to understand complex ideas when asked to express the relationships between all the representational levels (Jansoon, Coll & Somsook, 2009).

According to Johnstone (2000), a good understanding of chemistry requires the ability to integrate these levels. However, acquiring this ability is a big challenge for the teaching of chemistry. Students often have trouble connecting the different representational levels, making the threefold manner of representing chemistry the main obstacle to their learning (Johnstone, 1991; Treagust, Chittleborough & Mamiala, 2003). In this respect, the utilization of visual tools for teaching chemistry is required to promote visualization capacities and understanding of representations.

The use of pictures, concrete models, photos, graphics, diagrams, computational programs, and other kind of visualizations tools has increased strongly in the last years in science education. Studies have tried to prove that the use of these tools for chemistry learning can improve students' representational capacity and understanding of chemical phenomena by illustrating ideas that words cannot describe. Nevertheless, visual tools can't replace the teacher's role. Teachers are responsible for introducing activities that use visual tools, and thus, their practice will also determine students' ability to perceive, understand, and shift among the visual representations. Therefore, investigations into the role of teachers and the characteristics of their practice, as well as works that shows the importance of teachers' training, are also significant to understanding aspects of chemistry education and the teacher's part in chemistry learning in all the representational levels.

Sirhan (2007) emphasizes that chemistry has to be taught in a simple way. The key lies in seeing chemistry from the point of view of the student to avoid confusion and misunderstandings. According to the author, teachers have to know what the learners already know and how they came to acquire the knowledge, presenting material in a way that is consistent with students' learning and linking concepts so the learner can make a coherent whole of key ideas.

Students and professionals face difficulties learning and teaching chemistry, and studies on this topic are necessary. This study aims to review and discuss theoretically the studies on the macroscopic, microscopic, and symbolic representative levels and their contributions to chemistry education.

METHODOLOGY

A literature review was carried out in this article aiming to convey to the reader knowledge and ideas that have been established on the representational levels in chemistry education. A database search identified articles related to representational levels in chemistry education published up to 2011. After that, those articles related to representational levels in chemistry issues and teacher education were selected. The keywords used for selection were chemistry representation, representative level, visualization, teacher education program, visual abilities, and science education. The articles selected were from 10 peer-reviewed science-education journals, as shown in Table 1.

The articles were selected by their content and relevance to the study. The performed steps of the literature review were done according to Taylor (2010):

- Organizing the literature selection and review by relating it directly to the research focus;
- Synthesizing results into a summary of what is and is not known;
- Identifying areas of controversy in the literature;
- Raising questions that need further research.

Once the articles were identified and collected, we conducted a qualitative analysis identifying the objectives and primary research outcomes for each paper. This process was conducted with the purpose of organizing the papers under subheadings. For example, the works that have exposed a theoretical work or a review of visualization or the representative levels were placed under the subheading "Theoretical approach to visualization and the representational levels." Articles emphasizing instruction with or without the use of computer or multimedia tools, but linking with the instructions of teachers, were located under the subheading "Influence of different instructions on student learning." Papers that put emphasis on developing an assessment of multimedia tools and its effects on learning were placed under the subheading "Multimedia tools that lead students to understand chemistry in all the levels." Papers located under the subheading "Students' abilities and difficulties in shifting among the representational levels" focused on the abilities of students in understanding chemistry completely and shifting among the levels, with some instruction assistance or not. Only one paper in this review fit under the subheading “Teacher training to work among the representational levels.”

These categories are somewhat flexible because many papers have multiple outcomes. In these cases, papers were placed in the most suitable category. Some articles were put in more than one category, as appropriate for their outcomes.

Table 1. *Journal search results*

Journal	Number of studies selected
Chemical Education: Research and Practice in Europe	2
Chemistry Education: Research and Practice	3
International Journal of Environmental & Science Education	1
International Journal of Science Education	5
Journal of Chemical Education	3
Journal of Chemical Educator	1
Journal of Research in Science Teaching	4
Journal of Science Educational and Technology	1
Science Education	4
University Chemistry Education	1
Science Education International	1
Total	26

FINDINGS

A major concern of teachers and researchers in chemistry education is the difficulties and abilities of high school and undergraduate students in understanding chemistry at all representational levels. Thus, many studies present research about methodologies and tools, such as computer programs, that can help these students obtain a complete learning of chemistry. Nevertheless, these tools cannot replace the teacher’s role. Thus, studies are also conducted to analyze the influence of teacher interventions in student learning. The works found in the literature review were placed under the subheadings (Table 2) “Theoretical approach to visualization and the representational levels,” “Students’ abilities and difficulties in shifting among the representational levels,” “Influence of different instructions in student learning,” “Multimedia tools that lead students to understand chemistry in all the levels,” and “Teacher training to work among the representational levels.” Each category with the synthesis of the articles is detailed below.

Table 2. *Summary of studies related to five different categories.*

Theoretical approach to visualization and the representational levels	Cook (2006) Johnstone (1993, 2000) Wu and Shah (2004)
Students’ abilities and difficulties in shifting among the representational levels	Bodner and Domin (2000) Chandrasegaran, Treagust, and Mocerino (2007) Cook, Wiebe, and Carter (2008) Ferk et al. (2003) Grosslight et al. (1991) Hinton and Nakhleh (1999) Jaber and BouJaoude (2011) Jansoon, Coll, and Somsook (2009) Rappoport and Ashkenazi (2008) Chittleborough and Treagust (2007)

Table 2. Continued..

Influence of different instructions on student learning	Ardac and Akaygun (2005) Barnea and Dori (2000) Treagust, Chittleborough, and Mamiala (2003) Wu (2003) Cook (2011) Dori and Sasson (2008)
Multimedia tools that lead students to understand chemistry in all the levels	Ardac and Akaygun (2004) Barnea and Dori (1999) Tasker and Dalton(2006) Wu, Krajcik, and Soloway (2001) Russell et al. (1997)
Teacher training to work among the representational levels	Barnea and Dori (2000)

DISCUSSION

Theoretical approach to visualization and the representational levels

Theoretical works are important to show the advance of theory and the many views on the topic. Some articles found in the research describe theoretical approaches to visualization and the representational levels. The papers emphasize the characteristics of chemistry education: the difficulties of learning chemistry and how the use of representations can help students understand chemistry on the macroscopic, submicroscopic, and symbolic levels.

Two studies reviewed here (Johnstone, 1993; 2000) show a part of Johnstone's work and how it has increased over the years. Johnstone focused on the difficulties presented by students when learning chemistry. Johnstone's triangle was the starting point in many studies about the representational levels in chemistry learning.

In order to draw a personal view on the development of chemistry teaching and the forces that have affected its growth, Johnstone (1993) discussed the problems and difficulties related to chemistry teaching in recent years. According to the author, chemistry has three basic components: macrochemistry, sub-microchemistry, and representational chemistry. Much of the old chemistry and actual chemistry teaching concerns only the macro and representational corners of the triangle, so the triangle's interior is like a black hole for most people. Going into the psychology, Johnstone asserts that to expect learners to come readily into the chemical triangle and be able to switch rapidly around it to link the levels (corners) is to ask for overloading the working memory. Chemistry is an intellectual endeavor that must be designed carefully by teachers to be learned more effectively by students.

Johnstone (2000) explores the possibilities for the curriculum, the gradual development of concepts, the function of laboratory work, and the place of quantitative ideas. Chemistry is a difficult subject for students, and its difficulty may lie in the intrinsic nature of the subject; the psychology of forming most chemical concepts is quite different from that of the normal world. Johnstone highlights that we are trying to share our beautiful subject with young people in an apparently logical way and, at the same time, conflicting with what psychology knows about the way we learn. Therefore, the author emphasizes the necessity of harmonizing a logical approach and a psychological approach in the teaching of chemistry, which can be achieved by using information processing and the chemistry triangle.

Besides the works of Johnstone, Cook (2006) made another theoretical approach to the representational levels. The article presents instructional design considerations, provides empirical evidence, and integrates theoretical concepts related to cognitive loads. According to the author, learners have a limited working memory, and instructional representations should be designed with the goal of reducing unnecessary cognitive load. In this context, individual differences have to be considered, since they are critical in determining the impact that visual representation will have on learners' cognitive structures and processes. Presentations with visual representations are widely used for displaying learning materials, but not all of these presentations necessarily lead to better learning results. Thus, Cook asserts that multiple representations of information using the same modality, or multiple representations of information in visual and verbal modes, must be physically and/or temporally integrated so students may extract information out of all the representations, leading to a more complete understanding.

Wu and Shah (2004) have also done a literature review on correlational studies of spatial abilities and chemistry learning, students' conceptual errors and difficulties in understand visual representations, and visualization tools that have been designed to help overcome these limitations. They concluded that visuospatial abilities and more general reasoning skills are relevant to chemistry learning. Some of these students' conceptual errors in chemistry are due to difficulties in operating on the internal and external visuospatial representations. Furthermore, some visualization tools have been effective in helping students overcome the kinds of conceptual errors that may arise from difficulties in using visuospatial representations. Based on the review, the authors suggested five design principles: (1) provide multiple representations and descriptions, (2) make linked referential connections visible, (3) present the dynamic and interactive nature of chemistry, (4) promote the transformation between 2D and 3D, and (5) reduce cognitive load by making information explicit and integrating information for students. These principles could guide educators and designers to develop chemistry-learning tools that help students understand chemistry concepts and practice their representational skills through supporting their visuospatial thinking.

The articles presented in this section show a concern about the overload of working memory. While Johnstone (1993) emphasized that relation between the corners of the triangle can overload the working memory, Wu and Shah (2004) and Cook (2006) highlight that the development of visual abilities and the use of representation can reduce cognitive loads in working memory. On the other hand, the authors also show the necessity of developing a chemistry course that links the three levels. Johnstone's work (2000) doesn't discuss psychological questions about memory but says that the teaching of chemistry has to be planned to harmonize a logical approach and a psychological approach. Thus, the works in this section emphasize the necessity of psychological and practical issues in the teaching/learning of chemistry.

Students' abilities and difficulties in shifting among the representational levels

Inappropriate connections between representational levels are common for students, mainly at the macro and sub-micro levels. They tend to attribute macro properties to sub-micro particles, such as ice molecules being colder than molecules of liquid water. Research that emphasizes students' difficulties and possible solutions is desirable for helping teachers to work chemistry thinking into their instruction. Although chemists and chemical educators are able to operate across the levels quickly and easily, students face many difficulties in operating at all the representational levels.

Rappoport and Ashkenazi (2008) observed this fact when they used a think-aloud interview protocol to study the way students use and connect the representational levels when solving conceptual problems. The research was applied to faculty members and undergraduate chemistry students. After the inquiries, the researchers observed that, while the faculty members explained the problems by integrating the three representational levels, most of the students formed no meaningful connection between the levels and used just the macroscopic and symbolic representation to solve problems, with preference given to the symbolic level. Furthermore, a significant difference was noted in the way they related the representations:

the faculty members were able to deduct the macro and symbolic levels from the microscopic level, while the students tried to deduct the properties of the sub-micro level by the symbolic level. In conclusion, they found that the explanation for this would be the difference in cognitive development between the populations, which allows university students to operate more freely on symbolic terms. It might be that the situations dealt with in university do not lend themselves to representations based on personal experience.

Hinton and Nakhleh (1999) examined the mental representations of chemical reactions used by six students who achieved above-average grades in a college freshman chemistry class at a large Midwestern university. The study revealed that the participants made at least some use of each of the three representations, but some of the students were able to make associations with only macroscopic and symbolic levels. Thus, the researchers reported that chemical phenomena are generally understandable at the macroscopic level and can be interpreted at the symbolic level by undergraduate students. However, it seems students are often unable to connect correctly either of these levels to the sub-microscopic level.

Jaber and BouJaoude (2011) characterized tenth-grade students’ conceptual profiles regarding their understanding of chemical reactions in terms of macro, micro, symbolic levels, and the relations among them at the end of the teaching sequence. They reported that, without appropriate instruction, students usually fail to produce meaningful links across the levels, use only macroscopic and symbolic representations, and confound the microscopic level with the macroscopic level in terms of constructs and language. In their work, they introduced an instruction characterized by macro-micro-symbolic teaching that focuses on the interplay between the levels, integrates various representations, and engages students in an epistemic discourse about the nature of knowing in chemistry. Findings indicated that macro-micro-symbolic teaching enhanced students’ conceptual understanding and relational learning of chemical reactions. Thus, they concluded that chemistry instruction in the three levels should become a habit of teaching chemistry, reflected in lesson planning, classroom interaction, and assessment.

Bondner and Domin (2000) used a combination of techniques, including field notes collected in operating classrooms, informal interviews with students in a tutorial environment, and formal structured interviews to study problem-solving in chemistry. The research was applied to groups ranging from freshmen enrolled in general chemistry to sixth-year graduate students in a variety of content domains, including general, organic, inorganic, and physical chemistry. The data obtained were consistent with the notion that the ability to switch between representations or representation systems plays an important role in determining success or failure in chemistry problem-solving. They found that one of the characteristic differences between successful and unsuccessful problem solvers is the number and kinds of representations they bring to the problem. Therefore, according to the authors, encouraging students to use different representations when solving a problem might therefore be a simple way of helping them.

Grosslight et al. (1991) studied seventh- and eleventh-grade honors students’ conceptions of models and their use in science. They found that students in both groups have conceptions of models that are basically consistent with a naive realist epistemology. Students are more likely to think of models as physical copies of reality that embody different spatiotemporal perspectives than as constructed representations that may embody different theoretical perspectives. However, as students’ ideas become more sophisticated, they increasingly include the fact that models are designed for particular purposes, especially to help communication. The authors suggest that students need more experience using models as intellectual tools, more experience in models that provide contrasting conceptual views of phenomena, and more discussions of the roles of models in the service of scientific inquiry, since, according to them, modeling ability is the ability to traverse the three levels of chemical representation of matter.

Chandrasegaran, Tregust, and Mocerino (2007) developed a fifteen-item, two-tier multiple-choice diagnostic instrument to evaluate secondary students' ability to describe and explain seven types of chemical reactions using macroscopic, submicroscopic, and symbolic representations. The instrument was administered to sixty-five ninth-year students after nine months of instruction to evaluate their use of multiple levels of representation. Findings showed that, despite the emphasis on multiple levels of representation during instruction, 14 conceptions were identified that indicated confusion between macroscopic and submicroscopic representations, a tendency to extrapolate bulk macroscopic properties of substances to the submicroscopic level, and limited understanding of the symbolic representational system. On the positive side, analysis of students' responses from the diagnostic test indicated, in several instances, students' ability to use multiple levels of representation to describe and explain the chemical reactions. The authors conclude that the administration of this test to evaluate students' understandings about the use of multiple levels of representation could provide useful information to teachers in planning classroom instruction.

Ferk et al. (2003) studied the meanings attached by students to the different kinds of molecular-structure representations used in chemistry teaching. The accuracy of students' appreciation of 3D molecular structure on the basis of different kinds of representations was studied on primary, secondary, and university students. A computerized Chemical Visualization Test was developed and applied; it consisted of tasks in which the correct perception of different representations of molecular structure and the students' ability to manipulate these mental images in three dimensions were evaluated. The research indicates that students' appreciation of three-dimensional molecular structures differs according to the kind of representation used. To all students the concrete representations seemed to be more useful than abstract representations. However, secondary-school students and university students achieved the best results when using photographs of 3D molecular models or computer-generated models, while primary-school students were better when using concrete 3D models.

Cook, Wiebe and Carter (2008) investigated how high school students (*n*=54) with different levels of prior knowledge transitioned between the macroscopic and molecular representations of the selected cell transport graphics. The research examined how students with high and low levels of prior knowledge interpreted meaning from these graphics with both macroscopic and molecular representations. The researchers were concerned with how frequently these students transitioned from molecular to molecular features, macroscopic to macroscopic features, and macroscopic to molecular features. The findings indicated the role of multiple representations was very different for low- and high-prior-knowledge learners. Low-prior-knowledge students distributed more of their visual attention on macroscopic features, and in turn interpreted the graphics in a very literal way. Their interview responses indicated few instances of using the multiple representations in their interpretation of the graphics. On the other hand, high-prior-knowledge learners were able to connect the information in the representations to their existing schema. From the sequential analysis and interview responses, these learners were more successful in linking the macroscopic and molecular representations to interpret the underlying themes of the graphics. From these results, the authors concluded that low-prior-knowledge learners need more guidance when they view and interpret graphics with macroscopic and molecular representations.

Jansson, Coll and Somsook (2009) investigated and evaluated 414 first-year Thai undergraduate students' understanding of dilution and related concepts by assessing their mental models and how they were able to make connections between the macroscopic and submicroscopic levels. In the work, they probed students' understanding by using the interview-for-events approach, employing open-ended questions, and analyzing student descriptions and drawings. The research findings suggest that the students' mental models of many aspects of dilution chemistry were generally in accord with the scientific conceptualization that is to say, they did not show many alternative conceptions. The more-able students seemed to understand the role and relationships of representations at all three levels using Johnstone's (1991) framework. In particular, they understood the role of macroscopic and sub-microscopic levels of representation and were able to integrate into the other level. In contrast less-able students usually presented their work mostly at the symbolic level followed by the sub-microscopic and macroscopic levels, which were typically not related to the symbolic level. Hence, as might be expected, students' mental models for dilution varied, with more-able students possessing more complete, relational mental models than their less-able peers. In the opinion of the authors, this focus on the symbolic level may be related to the mode of science instruction in Thailand.

Chittleborough and Treagust (2007) examined the modeling abilities of three first-year, non-major chemistry students to understand chemical concepts according to Johnstone's three levels of chemical representations of matter. When chemical models are correctly used, they form links between the symbolic representations and the macroscopic and sub-microscopic levels. The study demonstrates that each of the students' modeling abilities with chemical representations improved with instruction and practice. Furthermore, students who used models and different levels of representation were able to develop higher-order thinking processes of the chemistry they were learning. This is because they were able to use models for testing, predicting, and evaluating their ideas; develop mental pictures of the submicroscopic level of matter; transfer ideas of different levels of representation; create symbolic representations of observed reactions; and appreciate the target of representation or analogue.

The papers presented in this section show that students in various levels of education have more ability to understand and represent chemical content in macroscopic and symbolic levels. Most students had difficulties in understanding chemical content at the microscopic level, and when they tried to represent this level, many put macroscopic characteristics in microscopic representations. The different papers introduce the importance of teaching tools that support students in producing representations and mental models in all the representational levels. Jaber and BouJaoude (2011) emphasize the importance of introducing an instruction characterized by macro-micro-symbolic teaching that focuses on the interplay between the levels. Many authors also emphasize the necessity of encouraging students to produce models in all the representational levels.

Influence of different instructions on student learning

Based on the difficulties presented by students, teachers try to differentiate their instruction with the aim of helping students. But the instruction is not always efficient for all students. Teachers can use some strategies to integrate instructions with methodologies that provide favorable conditions for students to develop chemical concepts and learn at the three levels of representation. Instructions can combine with computerized and dynamic visual instructions (Ardac & Akaygun, 2005); provide opportunities for students to produce mental models using computerized molecular modeling (Barnea & Dori, 2000); employ the notion of intertextuality to conceptualize chemical representations by connecting them to real-life experience (Wu, 2003); and produce meaning by using representations in all the levels (Treagust, Chittleborough & Mamiala, 2003).

Some instructions make use of technological resources to provide a complete understanding of chemistry. Ardac and Akaygun (2005) examine the effectiveness of visually enhanced instruction that emphasizes molecular representations, using visual displays to reflect multilevel thought in chemistry. Fifty-two eighth graders (age range 14–15 years) participated in one of the three instructional conditions (dynamic-individual, dynamic-whole class, and static-whole class) designed to improve molecular understanding of chemical change. The study questions the relative effectiveness of the specified instructional conditions in supporting student progress towards the acceptable particulate models. The results of the study provide a number of implications for instructional practices that are designed to promote conceptual understanding at a molecular level. For such tasks that include the visual display of submicroscopic particles, dynamic visuals would be a better alternative than static visuals, since dynamic visuals enable the display of collective particle motion and convey a complete mental image of changes in matter. Thus, the study highlights that students could have a greater understanding of chemistry between all the representational levels if the suitable instructions were used.

Dori and Sansson (2008) investigated the effect of the case-based, computerized-laboratory (CCL) environment on the acquisition of both chemical understanding and graphing skills of high school honors students via bidirectional visual and textual representations. The case-based computerized laboratory (CCL) is a chemistry-learning environment that integrates computerized experiments with emphasis on scientific inquiry and comprehension of case studies. Students were exposed to visual representations, which included hands-on experiments, real-time graph construction and interpretation, and textual representations of case studies. They found that students in the CCL learning environment significantly improved their graphing skills and chemical understanding retention in the post-evaluation with respect to the pre-questionnaires. The findings emphasize the educational value of combining two related instructions: the case-based method of computerized laboratories, for enhancing students' chemistry understanding and graphing skills, and the development of their ability to bidirectional transfer between textual and visual representations.

Barnea and Dori (2000) investigated how chemistry teachers and high school students who enrolled in a special program perceive the nature and functions of models and representation. Two groups of high school chemistry students (experimental and control) were submitted to different kinds of instruction. The teachers of the experimental group participated in training and developed a computer molecular-modeling (CMM) learning environment via implementing a constructivist approach, whereas the control group teachers taught the topic in the traditional way. The findings indicated a significant difference between the experimental and control groups of the high school students. Experimental-group students scored higher than those of the control group in the model perception questionnaire applied to them. Students' results indicated the effectiveness of the treatment of students' conceptualizing the meanings of models, especially in the domain of chemistry.

Treagust, Chittleborough, and Mamiala (2003) examined the use of submicroscopic and symbolic representations in chemical explanations and verified how they provide meaning. The major interest of the research was the development of students' levels of understanding, conceived as instrumental (knowing how) and relational (knowing why) understanding, as a result of regular Grade 11 chemistry lessons using analogical, anthropomorphic, relational, problem-based, and model-based explanations. The data indicated that effective learning at a relational level of understanding to require simultaneous use of submicroscopic and symbolic representations of chemical explanations.

Wu (2003) investigated how class members interactionally construct meanings of chemical representations by connecting them to real-life experiences, and how the teachers' content knowledge shapes their ways of co-constructing intertextual links with students. Multiple sources of data were collected over seven weeks with the participation of 25 eleventh graders, an experienced teacher, and a student teacher. The teachers applied several discursive strategies to scaffold students, building meaningful links based on their prior knowledge and experiences. During this cycle of activity, students worked with one or two other classmates, and each small group conducted an investigation of a known toxin from a list provided by their teachers. The students' activities showed that they could understand conceptual information on the three levels of chemistry and revealed that the students' chemistry thinking could move among phenomena, representations, and concepts.

We cannot think about instruction without taking into account the teacher's performance in class—that is, how the teacher used visualization and the representative levels to make students understand chemical content. Cook (2011) investigated how seven high school science teachers used visual representations in their teaching. A case study approach was used in the research. The findings suggest that science teachers take into account multiple considerations when selecting and using graphics in the classroom, including course content, type of visual, realism, learning styles, prior knowledge, and ability level. Among the science courses evaluated, chemistry's visual representations were more abstract in nature. Besides this fact, many of the representations teachers used to teach chemistry were at the molecular level; rarely was their macroscopic counterpart shown. The remainder of the representations used in the course was symbolic—presenting formulas, equations, or structures. The outcomes showed that learner characteristics seemed to be the most influential in the teacher's use of visualizations.

Multimedia tools that lead students to understand chemistry in all the levels

In order to solve the problems associated with the difficulties faced by students in understanding and move between the triplet representational levels, teachers have been using methodologies and tools to help students' learning. As an example, multimedia tools are used to help students understand and move between the triplet representational levels.

Computational programs, stereo-diagrams, dynamic pictures, animations, and simulations have proved to be useful in improving spatial-ability skills. An advantage in using multimedia to learn chemistry is the multiple symbol systems they have that enhances learning. Studies have shown that the combined use of text and animated graphics makes the information more memorable (Ardac & Akaygun, 2004). Other studies have shown that multimedia tools can improve the teaching and learning of chemistry by developing spatial ability, model perception, and chemistry understanding (Barnea & Dori, 1999). This section shows the efficiency of multimedia tools and how some tools can improve the learning of chemistry by using the representational levels.

Ardac and Akaygun (2004) studied the capabilities of computerized environments to enable simultaneous display of molecular representations that correspond to observations at the macroscopic level and to provide an enhanced visual presentation of chemical phenomena at three levels. The study questioned whether the multimedia instructional unit emphasizing the molecular level of representation would improve chemical phenomena conceptualization at the molecular level. The results showed a significantly higher performance by students who received multimedia instruction, and the relative ease with which they could use particulate representations supported the favorable effects of the treatment. Molecular representations were observed to become more refined as the students progressed along the instructional sequence. Furthermore, the results of interview data suggest that the changes observed during the multimedia-based instruction were more than instantaneous and were likely to last over longer periods of time. Fifteen months after the treatment, students who participated in multimedia-based instruction could maintain a relatively high performance level, as evidenced by the more frequent use of particulate representations with less macroscopic interference.

Barnea and Dori (1999) developed a computerized molecular-modeling (CMM) learning environment via implementing a discovery approach in high school chemistry. The CMM contributes to the development of visualization skills via vivid animation of three-dimensional representations. They investigated the effects of molecular-modeling use on students' spatial ability and their understanding of new concepts related to geometric and symbolic representations and perception of the model concept. The study looked at an urban high school in Israel and involved five heterogeneous classes of fifteen-year-old tenth graders who studied chemistry for the first year. Three experimental classes worked with the molecular-modeling software, and two control classes studied the subject in the traditional way. The results demonstrated that the experimental group scored higher than the control group in some of the spatial-ability tests, in the model-perception questionnaire, and in chemistry understanding. This may be attributed to better understanding of chemical bonding and improved three-dimensional perceptions of molecular structure gained from the CMM experience of students in the experimental group.

Tasker and Dalton (2006) discussed and disclosed the utilization of animations to visualize the molecular world by the use of the constructivist *VisChem Learning Design.* Motivated by frustration with the lack of resources in the early 1990s depicting Johnstone's sub-micro level, the *VisChem* project was founded to produce a suite of molecular animations depicting the structures of substances and selected chemical and physical changes. The animations were produced as useful models at this level and paid careful attention to the often-competing demands of scientific accuracy. The *VisChem Learning Design* can be used for any chemistry topic that requires a scientifically acceptable mental model of the molecular world. Resources were developed to link these animations to the macro and symbolic levels, which the authors discuss. The work in the *VisChem* project indicated that animations and simulations can effectively communicate many key features about the molecular level, and these ideas can link the laboratory level to the symbolic level. However, we have also shown that new misconceptions can be generated.

Based on research that emphasizes the difficulties of students in learning symbolic and molecular representations of chemistry, Wu, Krajcic, and Soloway (2001) studied the influence of a computer-based visualizing tool, eChem, on the students' understanding of chemical representation. This tool allows students to build molecular models and view multiple representations simultaneously. The use of eChem was integrated into a six-week unit called the Toxin Project. Multiple sources of data were collected with the participation in 71 eleventh graders at a small public high school over a six-week period. The analysis of video recordings revealed that several features of eChem helped students construct models and translate representations. Students who were highly engaged in discussions while using eChem made referential linkages between visual and conceptual aspects of representations. This in turn may have deepened their understanding of chemical representations and concepts. The research suggests that computerized models can serve as a vehicle for students to generate mental images.

Russel et al. (1997) studied a prototype multimedia program developed to facilitate student-learning in the classroom. Multimedia and Mental Models in Chemistry (4M:CHEM) utilizes a computer split-screen design to show simultaneous videos of real experiments, molecular-level animations, real-time graphs of macroscopic properties or structural diagrams, and chemical equations. These synchronized views enable teachers and students to engage in discussions about connections between macroscopic, microscopic, and symbolic representations. In order to study the advantages of 4M:CHEM in chemistry learning, an initial assessment was conducted in two lecture sections for two one-hour presentations. It showed an increase in students' understanding of characteristics of systems at equilibrium and a marked decrease in misconceptions of chemical equilibrium.

Teacher training to work among the representational levels

Besides the use of visualization, multimedia tools, and other methodologies to improve students' understanding of chemistry between all representational levels, the teacher's role is very important to students' success. In their practice, teachers constantly move between multiple representation modes, each time using the one that is most appropriate for the situation, but for students the integration of the representations is not highlighted. In order to adopt a teaching method that enables students to understand and move between the representational levels, chemistry teachers need to be trained for planning lessons and implementing instruction accordingly.

Therefore, some works cited in other sections emphasize the need of teacher preparation to work at the representative levels. This idea agrees with Jaber and BouJaoude (2011) when they say that teacher-preparation programs ought to be designed to promote teachers' pedagogical content knowledge in this aspect. Also, according to Hinton and Nakleh (1999), in order to develop students' facility in using multiple representations, teachers have to help students become explicitly aware of these representations and provide classroom opportunities for students to use them. They should also develop assessments designed to reveal students' macroscopic, microscopic, and symbolic ideas.

Although we know the importance of the teacher's role in the students' full appreciation of chemical content, there is still a lack of scientific studies related to teacher training to help students understand chemistry completely and move between all levels. Of all the papers mentioned here, only one conducts research focusing on teachers' training programs.

Barnea and Dori (2000) investigated how chemistry teachers and students perceive the nature and functions of models. According to the authors, teachers' perceptions are important; if teachers do not have the necessary understanding of the nature and role of models in the development of a discipline, they probably will not be able to incorporate them properly in their teaching. The research was done in two steps. In the first step, 34 pre- and in-service teachers attended a 14-hour workshop on models, and their model perception was investigated with the model questionnaire. During the training, teachers learned the different meanings of models and experienced various types of models. After this step, some teachers applied what they learned in school, using molecular modeling software for an experimental group, while teaching the subject to the control group in the traditional way. The results of the study indicated that, overall, the in-service training program on models put emphasis on many aspects of the trainees' model perception. The training made teachers realize the role of models, and their initial perception of models was expanded. The most significant outcome of the training is reflected in the school implementation, where a noticeable difference between experimental and control groups was found.

Understanding chemistry on the macroscopic, microscopic, and symbolic levels is necessary for the development of many skills in students: the capacity for abstraction, logical reasoning, and the understanding of natural phenomena and themselves in the world. The researches show the importance of discussing this topic and for researchers to help teachers improve their class work.

For high school students, shifting among the three levels is not an easy task. Some students are more able to do this, but most cannot understand the content in all levels and shift mainly between the macro and symbolic levels. To help these students, teachers have to improve and vary their instructions and aim to achieve understanding in every student. Multimedia tools can help teachers in this task, but the knowledge and ability of teachers to help their students cannot be replaced by technology. Teachers have to be trained to feel prepared for the task of teaching in the three levels.

The studies reviewed for this work show that a lot of research has aimed to improve learning and teaching in the three levels. The outcomes obtained have shown that this topic has raised the interest in many science education researchers. However, there is still a predominance of works about students' difficulties and the methodologies to improve their visual capacities to understand chemistry between all representational levels, since it is a real necessity in chemistry education.

However, a gap can be observed in studies that focus on teachers' training to use the representational levels in their classes, making students understand chemistry completely. This results show the need to direct research to the topic of visualization, highlighting the importance of teachers' training in the learning of chemistry between all representational levels.

CONCLUSION and IMPLICATIONS

Students' acquisition of knowledge without a clear understanding, or the generation of misconceptions, may be attributed to the confusion caused by having to deal simultaneously with the macroscopic, submicroscopic, and symbolic worlds of chemistry. If students understand the role of each level of chemical representation, they can often see how to transfer knowledge from one level to another. Thus, when learners develop relational understanding, they acquire ways to move easily and skillfully within the macro-micro-symbolic triangle, meaningfully linking the various chemical concepts.

This work has presented some general characteristics about visualization and the representative levels in chemistry education topics. The works reviewed here have shown that students face a lot of difficulties in operating at all representational levels; they are able to understand a chemical phenomenon more at the macroscopic and symbolic level, but the microscopic level is difficult to understand without proper explanation and visual methodologies. It was also reported that without appropriate instruction, students usually fail to produce meaningful links across the levels. The use of models and multimedia tools in chemistry classes has helped increase the students' performance on all representational levels, but researchers emphasize that the teacher's role is still very important for the students' success. Nevertheless, there is still a lack of scientific studies related to teacher training to help students understand chemistry at all levels. Most studies focused on the students and not the teacher training. But there is no sense to focus only on students or on resources and materials considering the complexity of this process. Thus, future research showing the role of teachers in chemistry learning at all representational levels is essential, and teachers must support students in activities involving different levels of representation and transitions between these levels. The focus in the majority of these studies is on cognitive approaches, but there is not enough focus on sociocultural approaches.

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Evaluating Effects of an Exhibition Visit on Pre-Service Elementary Teachers' Understandings of Climate Change

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ABSTRACT

This research aims to investigate the extent to which a visit to a climate change exhibition embedded within an environmental education course affects pre-service elementary teachers' understandings about climate change. The sample comprised 58 pre-service teachers, enrolled in the environmental education course offered as part of the Elementary Education program at a private university in Turkey during the 2011/2012 academic year. The course lasted 13 weeks and was composed of various environmental issues as well as an exhibition visit and student reflections. Pre- and post-reflections written by pre-service elementary teachers' were analyzed and coded to examine the effect of the visit on their understanding of climate change. It was found that the course, and specifically the exhibition, had a positive effect on their understanding of climate change and ways in which to ameliorate the problem.

Keywords: Environmental Education; Understanding of Climate Change; Pre-service Elementary Teachers.

INTRODUCTION

Because the planet we inhabit faces serious environmental problems (Barnatt, 2012), educating citizens to be environmentally literate is increasingly important (Roth, 1992); therefore, environmental education (EE) has been added to curricula for early grades right up to higher grades of education (Blumstein & Saylan, 2007). Furthermore, there is a growing emphasis on EE research (Gayford, 2002). However, studies investigating the effectiveness of teaching programs in terms of students' understanding of environmental problems are rare (West, 2015). Although the positive and inevitable outcomes of visiting informal science settings are reported in science education literature (Rickinson et al., 2004), there are few EE researches that have studied the effect of such visits on understandings about environmental problems, in particular climate change. Investigating pre-service elementary teachers' understanding of climate change is significant because they will educate the citizens of the future.

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The climate change theme for the visit was intentionally selected because it is a dynamic and complex problem. The complexity of climate change stems from the long delay between emissions of greenhouse gases (GHGs), their accumulation in the atmosphere, their effect on temperature and climate, and the insufficient changes being made to emission policies (Moxnes & Saysel, 2009). These complexities result in misconceptions about climate change. Even graduate students from prestigious universities like Massachusetts Institute of Technology and Harvard have misconceptions about how GHGs accumulate in the atmosphere (Sterman & Sweeney, 2002).

Most recent literature focuses on perceptions, knowledge, and understandings about climate change (Bord, O'Connor, & Fisher, 2000; O'Connor, Bord, & Fisher, 1999), the gaps between environmental knowledge, environmental awareness and pro-environmental behavior (Kollmuss & Agyeman, 2002) and the actions people take in order to mitigate climate change (Whitmarsh, 2009). However, studies which investigate the impact of teaching methods on pre-service teachers' learning about climate change are rare.

The method chosen to investigate in this study was a visit because research in science education highlights the impact of visits on various learning outcomes. Visiting a science center or museum is reported to be enjoyed by students (Lucas, 2000), to foster knowledge and teaching (Bamberger & Tal, 2008), and to increase attitudes towards protecting wildlife (Hughes, Packer, & Ballantyne, 2011). There are also researches that show the benefits that visiting botanic gardens (Sellmann & Bogner, 2013) and other informal learning settings (Palmer, 2002) can have on students' understandings of environmental issues. However, there are few studies which have investigated the effect of visiting informal learning settings on students' understandings of climate change. Moreover, Yavuz-Topaloğlu and Balkan-Kıyıcı (2015) have highlighted the scarcity of studies about 'out-of-school' learning in Turkey.

The study presented here contributes to EE literature in a curricular way. The purpose of the study is to examine to what extent a visit to an exhibition embedded within an EE course affects pre-service elementary teachers' understandings about climate change. This effect will be determined by comparing reflections of the attending and non-attending pre-service teachers. By pointing out this effect, it will be possible to improve EE courses at education faculties.

Theoratical Background

Teaching Pre-Service Teachers Climate Change

Scientists argue that climate change negatively impacts human life and natural systems and continuously leads to problems such as drought, flood, heavy precipitation, disease, and so forth (IPCC, 2001). Educating children about climate change can decrease their vulnerability while supporting them to contribute to the sustainability of the Earth (UNICEF, 2013). In this sense, as pre-service teachers will educate children, teaching them about climate change is crucial.

There are various studies that have been conducted with pre-service teachers about environmental problems related to climate change, such as their misconceptions regarding the greenhouse effect, ozone depletion, and acid rain (Groves & Pugh, 1999; Khalid, 2001) and their knowledge, beliefs, attitudes, and awareness of climate change (Boon, 2014; Dal, et al., 2015).

Liu et al. (2015) argued that teachers who were concerned about climate change generally found it necessary to teach their students about climate change and its causes and effects; however, teachers who were more skeptical about climate change did not tend to teach their students about this. These researchers noted that the more aware the teachers were of climate change the more importance they placed on teaching their students about how human activities affect the climate. In light of this finding, the importance of investigating pre-service teachers' understandings of climate change and testing how a specific educational method affects their understandings can be inferred.

Boon (2010) showed that there were similarities between secondary school students' and pre-service teachers' understandings of climate change and that those pre-service teachers' understandings were unacceptably low. The study stressed the need to develop teacher education programs that foster pre-service teachers' knowledge and understandings about climate change. The study presented in this paper meets this need by embedding an exhibition visit within an environmental education course for the purpose of improving the course.

Informal Science Learning and Visiting Exhibitions on Climate Change

The National Science Teachers Association (NSTA) advocates for museums, zoos, nature and environmental programs, and other science-rich cultural institutions to be used as informal science learning settings by valuing different and science-rich contexts and the availability of everyday experiences (NSTA Board of Directors, 2012). Science educators agree that informal learning settings, such as science museums, zoos, and botanical gardens, provide visitors with opportunities to enrich their scientific background (Bamberger & Tal, 2006; Falk, Storksdieck, & Dierking, 2007).

Hayden et al. (2011) highlighted the significance of informal science settings when teaching *supercomplex* issues as they integrate knowledge, interaction, and communication. Environmental scientists, as well science educators, emphasize the complex structure of climate change (Lambert, Lindgren, & Bleicher, 2012; Lombardi & Sinatra, 2013) which is regarded as today's most salient socio-scientific issue (Klosterman & Sadler 2010). Hayden et al. (2011) advocate that museums can educate people about the complex structure of climate change with the use of interactive exhibits. They suggest that viewing attractive images and models about climate change in a museum is more beneficial than being bombarded with a tremendous amount of scientific data in class.

Koepfler, Heimlich, and Yocco (2010) conducted a study with visitors to two different science museums about the content of climate change exhibitions in the museums. They found that all the visitors were motivated to have a scientific conversation about climate change using proper terminology such as *mitigation*, *adaptation*, and *greenhouse gases*. During their visits, they were able to identify evidence of the human impact on climate change. The general tendency was for the visitors to be introduced to the problem and then informed about solutions that they could engage in. An important conclusion of Koepfler et al.'s study (2010) was that the visitors realized the severity of climate change, however they preferred to focus on what actions they could take to have less impact on climate change rather than on its discouraging facts.

Research Questions

This research aims to investigate the effects of an exhibition visit on pre-service elementary teachers' understandings of climate change. The study presented here addresses the following research questions:

1. To what extent did the exhibition visit embedded within the environmental education program affect pre-service elementary teachers' understandings of climate change?

2. How did the EE course affect the participants' understandings of climate change?

3. Was there any significant difference between the understandings of participants who attended the exhibition and those who did not?

METHODOLOGY

a) Research Design

This study comprises an experimental design in two ways. Firstly, the research incorporates a one group pre-test–post-test design by collecting reflections at the beginning and end of the EE course. This allows for the effectiveness of the treatment implemented in the study, in terms of participants' understandings of climate change, to be tested. This design is also known as *repeated measures* of experimental design. In this design, the participants take part in the same treatment (the independent variable) (McLeod, 2007). Secondly, in order to investigate whether there was a significant difference between the understandings of participants who attended the exhibition and those who did not, *independent measures* of experimental design were utilized. In this design, different participants take part in each condition of the independent variable (McLeod, 2007). In this research, both quantitative and qualitative analyses were implemented to enable deeper insight and more comprehensive comparisons to be made between the pre- and post-reflections.

b) Sample

The sample comprised 58 students (8 males and 50 females) enrolled in an EE course in the Elementary Education program at a private university in Turkey in the spring semester of 2011/2012. When asked about their hometown, 71% described it as metropolitan, 22% as rural, 3% as a small town, 2% as a village, and 2% did not respond. When asked about the education level of their parents, 10% described their mothers as university graduates, 31% as high school graduates, 16% as middle school graduates, 38% as primary school graduates, and 5% did not respond. Two percent described their fathers as doctoral graduates, 19% as university graduates, 39% as high school graduates, 17% as middle school graduates, 21% as primary school graduates, and 2% did not respond.

c) Procedure

The treatment was implemented in the EE course that lasted 13 weeks. During the first five weeks, basic concepts and information about ecology and the historical development and causes of environmental problems were introduced. During the next five weeks, the pre-service teachers worked in groups (with three or four members) to prepare and deliver presentations about current environmental problems as listed below.

1. Water pollution
2. Air pollution
3. Soil pollution and erosion
4. Radioactive pollution
5. The depletion of the ozone layer
6. The loss of biological diversity
7. Waste
8. Energy
9. Hormone-injected foods and genetically modified organisms
10. Global warming

At the beginning of the term, the pre-service teachers submitted pre-reflections on the issue of climate change. After the presentations, the participants attended an exhibition about climate change. Participation in the exhibition visit was voluntary, but all participants were required to submit their post-reflection on climate change at the end of the term. 33 pre-service teachers volunteered to participate in the visit, while 25 did not.

The exhibition was located for a few months in Santral Istanbul at the Bilgi University campus. The main purpose of the exhibition was to increase attendees' awareness and knowledge about climate change. The participants visited the exhibition for two hours. The exhibition included a half-hour seminar and a one-and-a-half hour presentation of models, videos, posters, and a graph showing the increase in atmospheric CO_2 and global temperature. Various models were exhibited, including those representing floods in some cities, (e.g. Manhattan after a sea level rise triggered by pressing buttons), bleached coral reefs, polar bears and polar foxes that lost their habitats, and so forth. The duration of each video was about five minutes and they were presented on monitors throughout the exhibition. These videos gave brief information about the changes taking place in some regions because of global warming and climate change. The posters were about various environmental problems, such as pollution (air, water, soil, and radioactive), erosion, the depletion of the ozone layer, the loss of biological diversity, waste, renewable and non-renewable energy sources, genetically modified foods, and global warming. It took approximately 45 minutes to read all of the posters. The posters also gave information about green buildings, energy saving bands in roads, and recycling. There were also employees giving information about these posters and models. The CO_2 and temperature graph was presented on a large wall and in front of each year there was a model representing a phenomenon that happened during those years. For example, there were peaks in both CO_2 level and temperature in the 1880s and in front this there was a model of a steam engine to represent the Second Industrial Revolution. The graph showed another peak in the 2000s in front of which there was a computer to represent their common usage in homes. The visitors to the exhibition were divided into two groups. One group listened to the seminar first and then visited the presentation and the other group visited the presentation first and then listened to the seminar.

d) Instruments

Pre-and post-reflections were the instruments used in this study. In their reflections, the participants were asked to write about the definitions, causes, and possible consequences of climate change, as well as their suggestions for preventing climate change. These constituted the categories for the coding. In their post-reflections, visitors were asked to write about their impressions of the exhibition, including what most attracted their attention. The reflections were coded and evaluated by the first and the second authors of this paper. Agreement percentages for each code were calculated and the two experts were found to be in 75–99% agreement. After separate coding, the two raters discussed their discrepancies and eventually reached total agreement (100%) in order to determine the codes listed in Tables 2–5.

e) Data Analysis

Various codes emerged from the participants' explanations for the definitions, causes, and consequences of climate change, and their suggestions for possible solutions (as listed in Tables 2–5). In addition to these four categories, the visitors' impressions of the visit were also coded by the researchers.

The McNemar test was used to analyze the codes that emerged from the participants' pre- and post-reflections. This test was used to investigate whether there were significant differences in dichotomous variables for the dependent samples (Laerd Statistics, 2013). Chi-square testing was used to compare the data of exhibition visitors and non-visitors. This test can be applied when there are two categorical variables within a single population (Stat Trek, 2016).

FINDINGS

The reflections were analyzed according to four categories: definitions, causes, and consequence of climate change, and suggestions for solutions to the problems of climate change. Specified codes, their frequencies, and percentages are reported in separate tables according to category. Tables 1–4 provide a general overview for the four categories. Further statistical analyses are included in the following pages.

Table 1. *Frequency distributions for definitions of climate change*

		CODES		
		Change	Long-term	Weather Conditions
Pre-Reflection	Frequency	16	6	17
	Percentage (%)	27.5	10.3	29.3
Post-Reflection	Frequency	46	34	47
	Percentage (%)	79.3	58.6	81

Table 5 shows the statistically significant results of the changes in pre-service elementary teachers' understandings of climate change throughout the course for those who attended the exhibition and those who did not, with a .05 confidence interval. It was found that the EE course resulted in significant changes in specified categories for both visitors and non-visitors to the exhibition.

Table 2. *Frequency distributions for causes of climate change*

		CODES								
		GHGs	Name of GHGs	Source of GHGs	Natural Causes	Defores-tation	Industry	Global Warming	Ozone Depletion	Irreg. Urban.
Pre-Ref.	Fre.	31	13	12	4	5	13	10	9	5
	Perc. (%)	53.4	22.4	20.6	6.8	8.6	22.4	17.2	15.5	8.6
Post-Ref.	Fre.	51	36	41	24	28	31	6	9	11
	Perc. (%)	87.9	62	70.6	41.3	48.2	53.4	10.3	15.5	18.9

Table 3. *Frequency distributions for consequences of climate change*

		CODES								
		Melting of Glaciers	Rising Sea Level	Global Warming	Droughts	Floods	Famine	Diseases & Deaths	Extinction of Species	Disc. about Turkey
Pre-Ref.	Fre.	18	18	26	24	22	11	18	22	8
	Perc. (%)	31	31	44.8	41.3	37.9	18.9	31	37.9	13.7
Post-Ref.	Fre.	40	38	41	37	33	13	30	34	12
	Perc. (%)	68.9	65.5	70.6	63.7	56.8	22.4	51.7	58.6	20.6

Two groups were formed according to participation in the exhibition; the visitors group (n=33) and the non-visitors group (n=25). For deeper analyses between visitors and non-visitors, a Chi-square test was used to compare the data for each. At the beginning of the course, the number of students who did not attend the exhibition identified the importance of the role of organizations, foundations, and governments in finding solutions to climate change as significantly higher than those who attended the exhibition ($p<0.05$) (Table 6). These students might attribute the solving of environmental problems to be the role of organizations, foundations and governments and underestimate individual efforts. This result can be accepted as an indication of their unwillingness to act environmentally. No significant difference was found between the two groups in terms of the other categories ($p>0.05$).

Table 4. *Frequency distributions of suggestions for climate change*

		CODES						
		Saving Energy	Renew. Energy	Public Transport	Green Buildings	Foresta-tion	Organi-zations	Waste Man.
Pre-Ref.	Fre.	15	7	5	1	11	13	0
	Perc. (%)	25.8	12	8.6	1.7	18.9	22.4	0
Post-Ref.	Fre.	29	38	30	8	28	23	8
	Perc. (%)	50	65.5	51.7	13.7	48.2	46.5	13.7

Table 6 also shows Chi-Square analyses of the categories that emerged from the participants' post-reflections. Pearson Chi-square value was used to analyze the data for the categories of names of the gases and individual efforts. Continuity correction value was utilized to interpret the result of the category of irregular urbanization because in one of the cells the observed value was less than five. Table 6 reveals that the participants who attended the exhibition visit scored significantly higher than those who did not in terms of knowing the names of greenhouse gases, knowing irregular urbanization to be a factor affecting climate change and for suggesting individual efforts as solutions to environmental problems.

Apart from the quantitative findings, the reflections include some indicative phrases that enable comparisons between the pre- and post-reflections to be made. Firstly, it should be noted that the pre-service teachers were free to utilize any reliable information found in print or on the Internet. As indicated by the results of statistical tests, the participants seemed to learn from the EE course, and their essays reflect their learning. The pre-reflections include several direct and in-direct quotations from various resources, while the post-reflections mostly contain the participants own statements and fewer references. The post-reflections of the visitor group referred to the exhibition while giving information on climate change.

In addition to their selection of references, the designation of the four categories also differed between the pre- and post-reflections. Definitions, causes, consequences, and suggestions could be identified clearly in the post-reflections. This clarity, or lack of it, might underlie the frequency differences shown in Table 5. Because it is a complex environmental problem, understanding the structure of climate change and identifying its causes and consequences is difficult. In the post-reflections, there were clear statements like 'global warming is not a cause, but a consequence of climate change' that might represent understandings about climate change. The terminology used in the pre- and the post-reflections differed. For example, some participants referred to GHGs as 'harmful gases' in their pre-reflections, while this phrase was not used in the post-reflections.

Table 5. *McNemar test results for the reflection categories wrt visitors and non-visitors*

		Visitors		Non-Visitors	
		N	Sig. (2-tailed)	N	Sig. (2-tailed)
Definition	Change	33	0.00*	25	0.01*
	Weather conditions	33	0.00*	25	0.01*
	Long time	33	0.00*	25	0.00*
Causes	Name of gases	33	0.00*		
	Sources of gases	33	0.00*	25	0.02*
	Natural causes	33	0.03*	25	0.00*
	Forest de.	33	0.01*	25	0.02*
	Industrialization			25	0.03*
Consequences	Glacier melting	33	0.04*		
	Destroying habitats	33	0.02*		
Solutions	Renewable energy	33	0.00*	25	0.01*
	Saving natural sources	33	0.02*		
	Individual efforts	33	0.00*	25	0.00*
	Public transport.	33	0.00*	25	0.04*
	Green buildings	33	0.03*		
	Forestation			25	0.02*
	Organizations			25	0.00*

*p<0.05

Table 6. *Chi-square test results between visitors and non-visitors*

Reflection	Codes	Category	Pearson Chi-Square Value	df	Asympt. Sig. (2 sided)
Pre-reflection	Solution	Organizations	5.25	1	0.02
Post-reflection	Cause	Name of the gases	9.54	1	0.00
Post-reflection	Cause	Irregular Urbanization	9.15	1	0.00
Post-reflection	Solution	Individual Efforts	4.58	1	0.03

*p<0.05

Table 7. *Impressions about exhibition*

Themes	Visitors (%)
Polar bears	63.64
Models	48.48
Green buildings	18.18
Energy platforms	15.15
Polar fox	12.12
Recycled materials	12.12
CO_2 graph	9.09
Pressing the button	9.09
Other	33.33
Not identified	12.12

DISCUSSION and CONCLUSION

Today we all know that EE plays a crucial role in educating environmentally literate citizens. To achieve this, most teacher education curricula have incorporated EE courses into their programs (Doğança, 2007; Powers, 2004). While there is a growing body of research about EE, there is also a need for more research into the effectiveness of the methods and activities used in these courses (Loubser, 2015). The study presented here addresses this need.

Elementary teacher education programs in the universities of Turkey include EE courses. These courses enable pre-service teachers to be informed and aware of environmental problems facing the world. In addition, there is a growing amount of literature about pre-service teachers and EE. Tuncer, et al. (2009) found that pre-service teachers' environmental background is positively related to their environmental literacy and attitude. The results of a study by Saribas, Teksoz, and Ertepinar (2014) showed that pre-service elementary teachers do not have sufficient environmental knowledge and self-efficacy beliefs related to EE. Saribas (2015) emphasized the importance of teacher education programs leading the cooperation between Turkish authorities, schools, and education faculties. The study presented in this paper contributes to teacher education literature on EE by revealing the impact of an intervention implemented in the EE course of a pre-service elementary teaching program.

The results of this study revealed that the EE course, with its focus on various environmental problems, seems to have had an impact on pre-service elementary teachers' understandings of climate change. Throughout the course they also improved their understandings about reducing and coping with climate change, including the use of renewable energy sources, public transportation, and the importance of individual effort. This result is consistent with literature that has examined the impact of EE on various learning outcomes (Doğança & Saysel, 2013; Grotzer & Basca, 2003; Hungerford & Volk, 1990).

The most distinctive aspect of the study presented here is organizing an exhibition visit and asking the volunteer visitors to write reflections after the visit, with all the pre-service elementary teachers writing reflections before and after the course. The exhibition, which included a seminar and presentations of models, videos, posters, and a graph showing the increase in atmospheric CO_2 and global temperature, seems to have had an influence on the pre-service teachers' understandings and awareness about environmental issues. This is evidenced as they show more knowledge about the definitions, causes, and consequences of climate change, and suggestions for solutions to the problems of climate change compared to their pre-reflections and the non-attendees.

A comparison of the reflections of the visitors and non-visitors reveals that the visitors were able to name more greenhouse gases and identify the negative effect of irregular urbanization and the importance of individual effort in solving environmental problems than non-visitors. Koepfler, Heimlich, and Yocco (2010) also concluded that the participant visitors in their study were able to select appropriate climate change terminology and were eager to take part in solutions to climate change. These findings were in line with the content of the climate change exhibition. Hence, it is appropriate to conclude that the exhibition visit had a positive impact on the visitor groups' understandings of climate change.

Another finding of this study relates to the tendency of students to assign the responsibility for solving environmental problems to organizations, foundations, and governments. This evasion of responsibility could have a negative influence on students' desire to take individual action. In consequence, students' beliefs should also be taken into account when designing EE curricula. Similarly, continuing efforts must be taken to overcome students' tendencies to be reluctant about solving environmental problems.

The pre-service elementary teachers' reflections indicate that affective appeals in the climate change exhibition attracted more attention than intellectual appeals. This result shows, as previously suggested by Hayden et al. (2011), that informal learning environments such as exhibitions presenting models and pictures with dramatic content can be more instructive than purely intellectual content. This finding can also be explained by the backgrounds of the participants in this study. These participants had limited backgrounds in science and EE and most of them chose to answer the questions about social sciences during the university entrance exam. The effectiveness of different affective and intellectual appeals on different samples of students warrants further investigation.

This study presents an alternative design for an EE course for pre-service teachers with the inclusion of a visit to an exhibition. Okur-Berberoğlu (2015) suggests the construction of outdoor education centers and outdoor education programs within universities. Having an informal learning environment within a university would probably increase the integration of these environments into teaching courses. A comparison of pre-service teachers studying in universities with and without informal learning environments in terms of specific content knowledge (e.g. climate change) and based on the theme of the centers or affective domains (e.g. self-efficacy in science teaching or attitudes towards informal learning, environmental attitudes) could be further research topics.

The data of this study were reflections written by pre-service elementary teachers at the beginning and end of an EE course. Interviews with some participants have resulted in deeper insight into understandings of climate change. Further research examining the effect of implementing different methods in EE courses on various outcomes at different grade levels is still required.

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Are We Asking the Same Questions in Different Contexts: Translation Techniques in Cross-Culture Studies in Science Education?

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ABSTRACT

Translating an existing research instrument into another language is cheaper and faster than developing a new instrument. This may explain why many science educators have translated instruments developed and validated in English into different languages for measuring the variable(s) of interest for different cultures. The quality of the translation technique may affect the validity of the results in science education studies. This study aimed at exploring the science education researchers' research instrument translation techniques: a) as a major purpose study, b) to be used in cross-cultural studies, and c) to measure variable(s) of interest in different culture. Articles published in three journals were selected for review, namely: Research in Science Education (105 issues), International Journal of Science Education (347 issues), and International Journal of Science and Mathematics Education (60 issues). The analysis revealed that a forward translation of the quantitative instruments from the source language to the target language is the most commonly used translation technique by the science education researchers (61.5 %). However, it may not ensure cultural equivalence for the target instrument when researchers use it in cross-cultural studies. Thus, consensus among science educators on how to translate an instrument, which is validated in one culture, to be used in a different culture is needed. Based on the findings, some educational implications of interest for the translation approaches are discussed.

Key Words: Cross-culture Studies; Cultural Validity; Translation Techniques; Forward Translation; Back Translation; Collaborative Translation; Combined Translation Approach.

INTRODUCTION

However, the method of description and measurement of any construct should be developed from the perspective of the cultures under investigation (Marshella, 1978). The efforts, cost, and time required to have representative researchers from all cultures involved may cause this to be impossible. This may explain why choosing an instrument to be translated or adapted and used for measuring the variable of interest which has been developed in another culture. For example, Huang and Yore (2004) translated a questionnaire

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from English to Mandarin to collect data about students' attitude, environmental behavior, and emotional dispositions in Taiwan. Taconis and Kessels (2009) translated a questionnaire from German to Dutch to investigate the relationship between the typical representative of the science culture (the science prototype) and students' self-image as being linked to not choosing science as a major.

Hambleton and Kanjee (1995) mentioned there are three reasons for translating or adapting instruments to be used in a different culture: a) to enhance fairness in assessment by allowing persons to be assessed in the language of their choice, b) to reduce costs and save time in developing new tests, and c) to facilitate comparative studies across national, ethnic, and culture groups. For example, the International Association for the Evaluation of Educational Achievement (IEA) conducted Trends in International Mathematics and Science Study (TIMSS) in 2003 in more than 45 countries, which involved preparing mathematics and science tests in over 30 languages (Hambleton, 2005; Mullis, et al., 2007) and 50 countries participated in 2007 (Martin et al., 2008).

Hambleton (2005) suggested that an adaptation for an instrument is different from a translation of the same instrument because it entails deciding whether or not the instrument can be used to measure the same phenomena in a different culture, choosing translators, identifying modifications should be done according the target culture, and check for equivalency between source and translated version. Thus, translation of any instrument is only one step in the adaptation process and is usually used only when the target population has a different mother tongue while the cultural background is the same. However, it is unrealistic to assume that a literal translation is a valid option in cross-culture studies (Tanzer & Sim, 1999).

Unlike translation, adapting a tool from one language to be used in another language is associated with constraints due to the compromise combined with any translation process (Mumford et al., 1991). Thus in the adaptation process for a research tool into a target language, the distortion from the source culture needs to be reduced. A valid adaptation of a tool requires consideration of several dimensions of cross-cultural equivalence: content, semantic, technical, criterion and conceptual (Flaherty et al., 1988). For example, Aldridge and Fraser (2000) developed a Mandarin version of the personal form of the what is Happening in this Class (WIHIC)? Researchers found some English words had no direct meaning in Mandarin. Therefore, they replaced them with other words which had equivalent meanings.

For this reasons abovementioned, guidelines for translating educational and psychological instruments for use across different cultures have been developed by different institutions, for example, the International Test Commission (ITC). Some of the guidelines are related to how to translate tests as well as other assessment materials when measuring samples that use different languages. For example, the standards state,

> Instrument developers/publishers should insure that the adaptation process takes full account of linguistic and cultural differences among the populations for whom adapted versions of the test are intended….Test developers/ publishers should ensure that the data collection design permits the use of appropriate statistical techniques to establish item equivalence between the different language versions of the test (Hambleton, 2001, p. 166).

Previous standards assume that inappropriate translation and/or adaptation procedures may lead to improper conclusions about variable(s) of interest cross different cultures (Bechger et al., 1999; Sireci, 1997; Van de Vijver et al., 1998). For example, Solano-Flores et al. (2001) found that using "and/or" can benefit native English speakers, but using "y/o" in the Spanish version can be confusing to native Spanish speakers. For this reason, the validity of results in cross-culture science education research depends on the quality of the translation and the adaptation technique(s).

Translation techniques

In 1970 Brislin offered four techniques for maintaining the equivalence between original and translated instruments: a) back-translation technique; b) bilingual technique; c) committee approach; and d) pretest procedure.

Back translation is commonly used to check the accuracy of translation in cross-culture studies (Brislin, 1970). Three steps are involved in this technique: 1) a bilingual blindly translates an instrument from the original language to the target language, 2) another translator translates it back into the source language, and 3) The two versions of the instrument (original and back-translated version) are compared for meaning equivalence. The accuracy of the back-translated version is considered an indicator of the accuracy of the target translation (Douglas & Craig, 2007). When the last step reveals problems in meaning equivalence between the original and back translated version, another translator attempts to retranslate the instrument. This procedure continues until attaining a meaning equivalence. The major weakness related to Brislin's classic translation model is that researchers cannot estimate how many independent bilingual translators are needed to achieve to the meaning equivalence between the original and the translated versions (Cha et al., 2007). Moreover, back translation does not necessarily ensure equivalence in meaning in each context. For example, Douglas& Craig (2007) has suggested that since back translation provides a direct or literal translation from source to target language, it is possible to move from one version to another and back again without capturing the intended meaning.

Bilingual translation has been advocated as a preferred technique to achieve equivalence in meaning. In this technique two versions of the instrument should be prepared in source and target languages then both of them should be administrated to bilingual participants (Brislin, 1970). Participants' responses to the two versions are compared. When differences in participants' responses are identified, the researcher should review the items that have discrepancies. Since bilingual speakers do not use languages in the same way as monolingual participants because they are fluent in both languages, their responses may be different from those collected from monolingual population (Sperber et al., 1994).

Collaborative-based translation is a group of bilingual translation from the source to the target language (Brislin, 1970). There are two forms of this collaborative translation: a) a committee approach, and b) a team approach. The committee approach requires bilingual expert science educators to work together as a group while the team approach requires several bilingual expert science educators to make independent parallel translations of the same instrument. In the last case a team of experts is required to work individually, more than a unit, if they are located in different places. A meeting or a virtual discussion is required to review and discuss the differences between the translated versions.

Pretest procedures: After the translation is completed, it is field tested to insure that target population will comprehend all questions (Brislin, 1970). The pilot study can reveal any problems of meaning equivalence between the source and the translated instrument. Qualitative and quantitative techniques can be used in pretest procedures. In qualitative technique the instrument can be administrated to a sample from the target population to get feedback about their understanding of each item in the instrument. On the other hand, in quantitative technique two versions of the instrument should be administrated to a bilingual sample for the target culture, and the differences in responses should be compared.

Factors affecting quality of translation:

Validity of results in cross-culture studies in science education may be affected by quality of translation or adaptation process which can be affected by several factors. Brislin (1970) observed that the quality of translation depends on the language into which bilingual asked to translate. For example, translation to Chamorro is better than translation to Palauan, and French can provide better translation than German. Moreover, Cha et al. (2007) stated that the source language can affect translation quality. Equivalence can be achieved when words in the source instrument are clear. Also, the content can affect translation quality. For example translating a passage in physics or chemistry is easier than translation of passage about certain culture. Therefore, realistic problems which are related to a specific context should be reorganized to adapt the target language. The International Test Commission (ITC) standards state that:

> Effects of cultural differences that are not relevant or important to the main purposes of the study should be minimized as much as possible between the different language versions of the test (Hambleton, 2001, p. 165).

Science process skills which created by Enger and Yager (2001) was translated into Arabic language by the author (in press) to be used with students in Egypt. Egyptian students were not familiar with units such as inch, mile, and Fahrenheit used in the test, so they were replaced with metric units, for example, cm, km, and temperature on the Celsius scale.
A review of literature revealed that one of the most important factors affecting translation quality is the quality of the translators. Hambleton, Sireci, and Robin (1999) suggested that translators should be proficient with respect to principles of good item writing. Hambleton (2001) also stated that being fully proficient in both source and target languages, being familiar with the cultures associated with the different language groups, and knowing the subject matter and testing principles have become parts of the selection criteria for translators. Brislin (1970) suggested some rules, which may help researchers to avoid factors that may affect translation quality and achieve equivalence in meaning. These rules include using simple sentences, avoid detailed description, use active voices instead of passive voices, nouns rather than pronouns, avoiding colloquialisms, decentering, and using proficient translators and being independent.

Focus of this study:

This study is an investigation of translation or adaptation techniques used by researchers in science education to translate an instrument into a different language to be used in cross-cultural studies or as purpose of their studies. Articles published in three journals were selected for review. These journals were: a) Research in Science Education, b) International Journal of Science Education, and c) and International Journal of Science and Mathematics Education.

METHODOLOGY

By the end of 2014, a literature review was conducted to identify research articles which translated instrument(s) to measure variable(s) of interest in different cultures or those developed an instrument into different language as a major study purpose. Different keywords used to conduct a search in EBSCO host database such as translation, adaptation, comparative studies, and cross-cultural studies. The result of this step revealed that over 1500 research articles had at least one keyword. In order to filter the previous results to focus only in quantitative instruments, three terms were used: cultural validity, instrument construction, and instrument validation. The results obtained were reduced to focus only on articles in English language and published in science education journals.

Most research articles translated or adapted instruments located in three science education journals namely a) Research in Science Education, b) International Journal of Science Education, and c) and International Journal of Science and Mathematics Education. Other science education journals had no more than 2, 3, or 4 articles translated quantitative instrument as a part of the study or translated quantitative instrument into different language as a major study purpose. Target articles were reviewed in order to identify translation techniques used.

FINDINGS

A review of the target journals revealed that 39 articles translated instrument(s) to be used to achieve the main purpose of the study or the translation process was the major purpose of the study. Table 1 shows number of studies found in each of the three journals.

Table 1. *Number of Reviewed Studies in Each Journal*

Journal	No. of Issues	No. of reviewed studies
Research in Science Education (1980-2014)	105	8
International Journal of Science Education (1980- 2014)	347	21
International Journal of Science and Mathematics Education (2003-2014)	60	10

Table 1 shows that 53.9 % of the reviewed studies were found in International Journal of Science Education. This percent falls down to be 25.6 % in the International Journal of Science and Mathematics Education and down further to be 20.5 % in Research in Science Education.

The original language of the target instrument(s) was English (34), Turkish (3), Hebrew (1), and German (1). In 34 articles, the target instrument(s) translated from English into different languages, including Chinese (10), Turkish (3), Korean (3), Spanish (2), Indonesian (2), Hebrew (2), Japanese (1), Arabic (1), Dutch (1), French (1), Cree (1), Russian (1), Thai (1), Cantonese (1), Mandarin (1), Tagalog (1), Afrikaans & Xhosa (1), and Malay (1).
Five of the 39 reviewed articles indicated that the translation of the quantitative instrument(s) was the major study purpose while 34 articles indicated that the translation process was only a step to validate the instrument(s) in the target culture and then be used to measure the variable(s) of interest in this culture. Table 2 shows the translation techniques used by researchers in the target journals.

Table 2. *Translation Techniques used in Science Education Articles*

Category	Descriptions	No. of Studies
No information provided	Researchers provided no information about the translation technique(s) used to translate the instrument from the original culture to the target culture.	5

Table 2. *Continued..*

Category	Descriptions	No. of Studies
Direct (Verbal) translation	The instrument was given to the target sample in the presence of a translator.	1
Forward translation	The instrument was translated to the target language from the original language by the researcher(s) and provided **no** information about validity and reliability of the target version.	14
Forward translation with testing	In addition to the forward translation in category (3), researcher(s) provided information about pre-testing the instrument in the target language.	10
Back translation	A bilingual blindly translates instrument from the original language to the target language, 2) another translator translates it back into the original language, and 3) the two versions of the instrument (original and back-translated version) are compared for meaning equivalence.	4
Back translation with mono/ bilingual test	In addition to back translation in category (5), researcher(s) tested the target language version by mono or bilingual subjects.	5

Table 2 shows that of the 39 reviewed articles, 14 studies used forward-only translation, 10 studies used forward translation with pre-test, four studies used back translation, five studies used back translation with pre-test, one article used verbal (direct) translation, and five articles did not specify the translation technique used to translate a quantitative instrument from the original language into the target language.

RESULTS

Many instruments developed and validated in English have been translated into different languages for measuring variable(s) of interest in different cultures. In order to do that, science educators used different approaches such as verbal (direct) translation (Swain, Monk & Johnson, 1999), forward-only translation (Tan et al., 2008), forward translation with test (Huang, 2006), back translation (Taconisa & Kessels, 2009), and back translation with mono and/or bilingual pre-test (Liu & Lederman, 2007).

The current study revealed that forward translation (61.5 %) is the main approach used by science education researchers to translate an instrument from one language into another one to measure variable(s) of interest in a different culture. This percent falls down to be (23%) in back translation and further down to 2.5 % for verbal translation. These results disagree with previous studies. For example, in their review of Journal of International Marketing (52 Issues), Douglas and Craig (2007) found out of 45 articles reviewed 34 articles used back translation approach to check accuracy translation. Maneesriwongul and Dixon (2004) reviewed 5 nursing journals and found out of 47 articles reviewed 31 articles used back translation to achieve meaning equivalence. Therefore, consensus among researchers in Marketing and Nursing on how to translate or adapt an instrument, which is validated in source culture, to be used in a different culture is better than this one among researchers in science education. Translation approaches used by researchers in science education can be grouped into three main categories:

Verbal (Direct) translation

In this case, researchers ask bilingual translator to translate the instrument, item by item, from the source language to the target language. Of 39 reviewed articles, only one study used verbal translation. A sample of Korean science teachers was given a questionnaire about attitudes to the aims of practical work in the presence of a bilingual translator. Collected data were used in cross culture study including three samples from Korea, Egypt and UK. However verbal translation can save time, cost and effort, yet it ***cannot*** ensure meaning, culture, and psychometric equivalence because it depends on the quality and the experience of the bilingual translator. Verbal translation should ***not*** be used to translate an instrument to be used in a different culture or to compare samples in cross culture studies (Brsiln, 1970). Without accurate comparisons of the scores in different cultures, the research results will not be validated. Based on this idea, when an instrument is used to measure the variable of interest in two different cultures, the items must be culturally and psychometrically equivalent to promote a valid score comparison. In other words:

> How do we know we are studying the same phenomena in different contexts; how do we know that our observations and conclusions do not actually refer to “quite different things” which we unjustifiably include in the same conceptual categories? (Nowak, 1976, p.105).

Forward translation

In this approach the instrument(s) was translated from the source language into the target language by the author(s) or other researchers in science education. The last case includes two approaches: a committee approach and a team approach. In the committee approach expert bilingual science educators work together as one unit while in the team approach several bilingual expert science educators work independently to translate the same instrument. Meetings or virtual discussions were held to review and discuss differences between the original and target versions.

Of the 39 reviewed articles, 24 articles used forward translation. In 14 cases researchers provided no information about validity and reliability of the translated instrument(s). While 10 studies conducted pre-test for the translated instrument(s) in the target culture, after doing forward translation, in order to provide an evidence for the validity and reliability of the instrument in the target culture.

Forward translation can save time and cost. Moreover, it can be used, after pre-testing the instrument with monolingual sample, to measure variable(s) of interest in ***only*** the target culture. However some researchers pre-tested the translated instrument in the target culture, forward translation cannot be used in comparison studies because it cannot ensure cultural and psychometric equivalency to promote a valid score comparison. Besides, forward translation can provide researchers with literal translation (Merenda, 2005) and do not help them to avoid culture decentering. At the same time using bilingual subjects to check the appropriateness of the translation is inadequate because they do not use language in the same way as monolingual (Sperber et al., 1994).

The current study revealed that forward translation for the quantitative instruments from the original language into the target language is the most commonly employed translation technique in the reviewed articles (61.5 %). However, this may not ensure cultural and psychometric equivalence for the target instrument when researchers use the translated instrument in cross-culture studies.

Back translation

Four studies used back-only translation to translate the instrument from the source language to the target language. This approach involves three steps: a) the instrument was translated by bilingual science educator(s) from the source language to the target language, b) another translator translates it back into the source language, and c) the original and back-translated versions are compared for meaning equivalence. The accuracy of the back-translated version is considered an indicator of the accuracy of the target translation (Douglas & Craig, 2007). When the last step reveals problems in meaning equivalence between the original and back translated version, another translator attempts to retranslate the instrument. This procedure continues until reaching meaning equivalence. In addition to the previous steps, five studies used pre-test, in conjunction with back translation, to provide an evidence for validity and reliability. In this case qualitative and quantitative techniques were used. In qualitative technique the instrument was administrated to a sample from the target population to get feedback about the respondents' understanding of each item in the instrument. In quantitative technique two versions of the instrument were administrated to a bilingual sample of the target culture, and the differences in responses are compared.

Even though back translation can help researchers to identify problems and errors in translation, it is not sufficient to ensure culture equivalence. For example, Douglas & Craig (2007) suggested that since back translation provides a direct or literal translation from the source to the target language, it is possible to move from one version to another and back again without capturing the intended meaning. Harkness et al. (2003) explained this situation using an example from a German social survey. "Das Leben in vollen Zügen geniessen" is an item in the survey. Literally this was translated into English as "Enjoy life in full trains". When this sentence is translated back into German again, the same exact sentence is generated as the original German translation, which would suggest that the translation is accurate. However, the more suitable translation into English "Live life to the fullest" Not "Enjoy life in full trains." Thus another technique may be needed to obtain appropriate translated instrument. Moreover, in back translation researchers cannot estimate how many independent bilingual translators are needed to attain the meaning equivalence between the original and the translated versions (Cha et al., 2007).

There is a necessity for re-examinig the translated instrument in the target culture. Thus using a well-established translated instrument in a certain language does not remove the need for establishing reliability and validity in the target language. This point is clearly mentioned in the International Test Commission (ITC) *Guidelines for Adapting Educational and Psychological Tests* (Hambleton, 1994). Of the 39 reviewed articles, only 15 articles used pre-test in conjunction with forward translation and back translation. In other words, 61.5 % of the reviewed articles neglected or inadequately addressed culture validity and psychometric equivalence. Transporting of instruments from one culture to another one is the most dangerous practices in the science education assessment during the last half century, which continues to the present days (Merenda, 2005).

Interestingly, 80 % of the studies translated an instrument as a major study purpose used pre-test as illustrated in Table 3.

Table 3. *Pre-test in Studies Translated an instrument as A major/minor purpose study*

	Major purpose study	Minor purpose study
Pre-test	4	11
Without pre-test	1	23
Total	5	34

Among the five studies translated an instrument as a major study purpose, four studies conducted qualitative and quantitative techniques. In qualitative technique the instrument was administrated to a sample from the target culture to receive feedback about the respondents' understanding of each item in the instrument and in quantitative technique two versions of the instrument administrated to a bilingual sample of the target culture, and the differences in responses are compared. Only 32.4 % of the studies translated an instrument as a step to achieve another goal, such as measuring students' attitude and students' achievement, used pre-test. These results agree with what Tanzer and Sim (1999) found out. They observed that translating the original instrument from the source language into target languages without examining cultural validity issues is the most commonly used procedure in cross-culture studies. Moreover, Solano-Flores et al. (2001) mentioned that culture validity has been neglected or inadequately addressed in current assessment practices. In practice, however, translation procedures are rarely viewed as part of the instrument design efforts and often treated as an addendum. Researchers should integrate translation procedures in their studies (Harkness, 2001).

Literature review revealed that in order to achieve both meaning and cultural equivalence, researchers will need to do some modifications. These modifications can be classified according to the type of equivalence being sought: a) a vocabulary equivalence, some words in the original instrument had no direct meaning in the target language therefore researchers used other word(s) to keep the original meaning, b) a grammatical-syntactical equivalence, in some cases, translated items are simpler than the items in the original language, c) an idiomatic equivalence, idioms related to the original culture are replaced with expressions that are more appropriate to the target context. According to the changes required, Tazner and Sim (1999) distinguished between four levels of modifications: a) **Application**; if the target and the original populations have the same cultural and linguistic background, the instrument can be applied without any modifications, b) **Translation**; this option usually used when the target population have a different mother tongue but the cultural background is the same, c) **Adaptation**, in this option some modifications should be done according to the target culture. For example, some instruments contain expressions and/or examples related to the local culture which must be replaced by other expressions and examples from the target culture. d) **Assembly**, in this case, many modifications should be done to the original instrument that, practically speaking, a new instrument is created.

The following example are from a study that examines how culture influences the way in which participants respond to a questionnaire.

> In the Euro barometer, which measures social and political attitudes in the European Union, the French and English scales differ in structure and, to a lesser extent, in semantics. Both uses the semantic dimension of agree, but in the French scale, the use of *d'accord*/*pas d'accord* suggests a unipolar scale, whereas the English scale uses a bipolar construction in which the wording is linguistically symmetrical with the endpoints modified by "strongly." Equally, the "do-not know" category is "cannot choose" in English compared with *ne sais pas* or "do not know" in French (Douglas & Craig, 2007, p.37).

Douglas and Craig's (2007) experience provide an exemplary of how disregarding culture background may lead to misinterpretations.

Recommended translation approach "Combined approach"

Even though forward translation has been used for a long time in cross-culture studies, Brislin (1970) recommended forward translation in conjunction with back translation as a combined technique to check the translation accuracy. Since forward and back translations can provide researchers with literal translation (Merenda, 2005) yet do not help researchers avoid cultural decentering, and at the same time using bilingual subjects alone to check appropriateness of translation is inadequate because they do not use the language in the same way as monolinguals use (Sperber et al., 1994), a combined translation technique of forward translation in conjunction with back translation, collaborative translation, and qualitative & quantitative pre-test is recommended by several studies (Harkness et al., 2003; John et al., 2006; Cha et al., 2007) to achieve meaning and cultural equivalence. Figure 1 shows the three phases for the modified combined approach presented by Cruz, Padilla, and Agustin (2000).

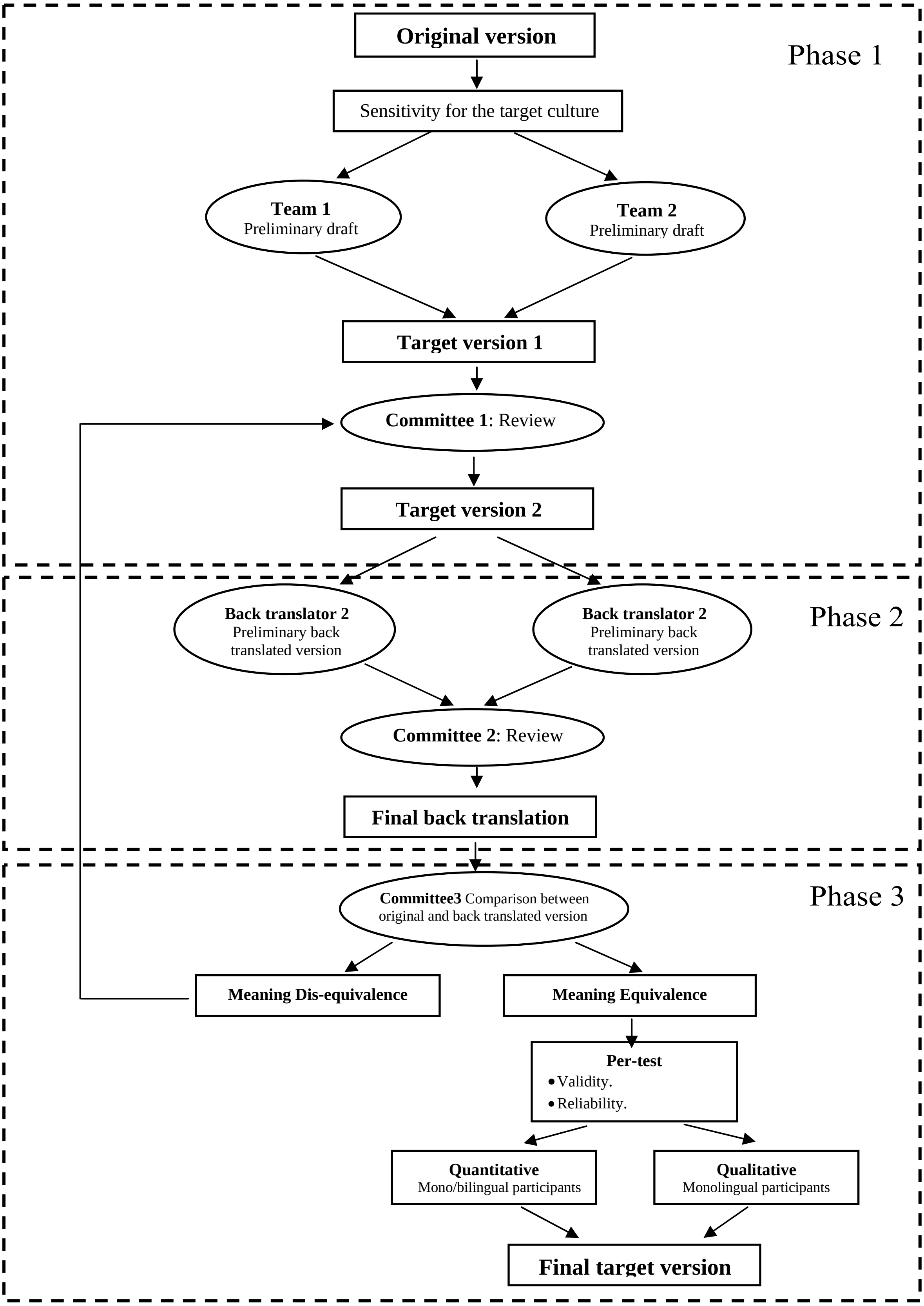

Figure 1: Combined Translation Approach

First phase aims to prepare an initial version of the instrument in the target language "version 2" Thus the relevance and sensitivity of the instrument for the target context should be established through discussion with bilingual science educators. Moreover, two pairs of the translators work as two independent teams to translate the instrument from the source language into the target language. Within each pair of translators there should be a discussion to resolve the inconsistencies. Team one and team two should consist of science educators who are proficient in source and target languages, familiar with the target culture, familiar with knowledge of the subject matter and testing principles as recommended by Hambleton (2001) and have experiences with effective item writing as recommended by Hambleton et al. (1999). A further round of review is necessary to ensure that the source and the target version accurately capture the same meaning. For this reason, a review meeting "committee one" should be held with translators and an independent reviewer to resolve inconsistencies.

Second phase aims to retranslate the instrument from the target language to the source language again "Back translation". Two independent translators retranslate the instrument from the target language to the source language. A review meeting should be held with translators and an independent reviewer to review the final back translation.

Third phase In this stage a monolingual native speaker with a background in science education should check the equivalence in meaning between the source instrument and its back translation. Rather than the literal meaning, the conceptual meaning should be the focus of this step. Problems in conceptual equivalence between the original and the back translated versions should be returned back to the committee one and be incorporated into the final version of the instrument. Once the modifications were done by the committee one, the process should be repeated to ensure that the changes were adequate and the target instrument is ready for the field test.

The purpose of the pre-test is to know do the actual respondents will comprehend all items in the instrument as the translators. Thus a pilot study should be conducted to assess the appropriateness of the translated instrument. In other words, qualitative and quantitative techniques should be used in pre-test procedures. In qualitative technique the instruments "target version" should be administrated to a sample from the target culture consisting of monolingual participants to get a feedback about user's understanding of each item in the instrument. In quantitative technique, the source and the target versions of the instrument should be administrated to a bilingual sample and the target versions should be administrated to a monolingual sample of the target culture, and the differences in responses should be compared.

CONCLUSION

Since there is no perfect technique for translation, using forward translation in conjunction with back-translation method, the team approach or committee approach and the pretest procedure using monolingual and bilingual participants are recommended in this study. The literature review revealed that collaborative work in translation, review, and pretest are necessary for translation or adaptation. Harkness (2003) defined five steps for collaborative-based approach: a) translation, b) review, c) adjudication, d) pretesting, and e) documentation. Douglas and Craig (2007) suggested that documenting translation procedures is desirable when the questionnaire is likely to be repeated annually or semiannually.

To promote a valid comparison between respondents from different cultures, the instrument must be culturally and psychometrically similar as much as possible (Sireci et al., 2006). The validity of results in cross-culture science education research depends on the quality of the translation or the adaptation process. For this reason, there is a need for consensus among the science educators on how to translate or adapt an instrument, which is validated in the source culture, to be used in a different culture. Moreover, studies that which use translated or adapted instrument(s) should provide information about the translation and/or adaptation procedures. In other words, translation or adaptation procedures should be integrated into the study design (Harkness, 2001).

What is already known about this topic

- Translation or adaptation of an existing instrument into another language is cheaper and faster than developing a new instrument.
- Translation/adaptation quality may affect validity of results in cross-culture studies.
- Several translation/adaptation techniques have been created to maintain the meaning equivalence between source and target culture.

What this paper adds

- There is a need for consensus among science educators on how to adapt an instrument to be used in a different culture.
- Cross-culture studies should provide information about translation/adaptation process.
- A combined translation technique of forward translation in conjunction with back translation, collaborative translation, and qualitative & quantitative pre-test presented as an example.
- A combined translation/adaptation technique is ideal to maintain culture and psychometric equivalence.

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*Examination of the Teacher Self-Efficacy of Pre-Service Biology and Science Teachers in Terms of Different Variables

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ABSTRACT

The objective of this study is to determine the teacher and academic self-efficacy of pre-service biology and science teachers and to examine of the teacher self-efficacy of pre-service biology and science teachers in terms of different variables (academic self-efficacy, grade level and academic achievement) The study sample consists of 134 pre-service teachers. In the study, we used the Teacher Self-Efficacy Scale (α= .91) and the Academic Self-Efficacy Scale (α= .87). We used descriptive analyses and regression analysis in the examination of the data. As a result of the descriptive analyses, it was determined that pre-service teachers had high levels of teacher self-efficacy ($\overline{X}$= 166,02), academic self-efficacy ($\overline{X}$ = 21,58), and academic achievement ($\overline{X}$ = 3,41). The study results suggest that pre-service teachers have high levels of teacher self-efficacy and levels of academic self-efficacy. Besides, it was observed that the academic self-efficacy made a significant contribution to the prediction of the belief of teacher self-efficacy and the entire model explained 26% of the variance. Since the results point out the academic self-efficacy as the variable predicting the teacher self-efficacy, it makes us think about the necessity for supporting and developing the pre-service teachers to accomplish an academic task during their education.

Keywords: Academic Self-Efficacy; Pre-service Biology Teacher; Pre-service Science Teacher; Self-Efficacy Belief; Teacher Self-Efficacy.

INTRODUCTION

There are many studies in various fields (such as medicine, psychology, education, business) regarding the belief of self-efficacy due to it's determinative effect on behaviors (Schwarzer, 1993; Tschannen-Moran, Woolfolk Hoy & Hoy, 1998; Bursal, 2008; Özdilek & Bulunuz, 2009; Karaduman & Emrahoğlu, 2011, Timur & Taşar, 2013). Self-efficacy is defined as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" (Bandura, 1994,p. 71). Self-efficacy could be handled as one of the basic psychological structures revealing the different behavioral patterns in individuals. Individuals with a high self-efficacy could manage the events better as they have a higher belief in accomplishment (Schultz and Schultz,

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2007). Bandura (1994) emphasizes the features of individuals with high and low beliefs of self-efficacy as follows: Individuals who believe in their own capacity show a tendency to challenge rather than the behavior of avoidance on difficult tasks. A strong sense of self-efficacy enables individuals to be happy and successful. Individuals with a low belief of self-efficacy, on the other hand, show a lower effort against difficulties. Individuals who are suspicious of their own capacity quickly give up once they encounter with challenging tasks and they have a low level of desire and determination to achieve the specified goals. When they encounter with a challenging task, they recall their personal incapacities instead of the thought of “how to overcome that situation successfully”. Such individuals think more about the obstacles they will encounter with and their negative outcomes (Bandura, 1994).

Bandura (1994) stated that the self-efficacy belief was influenced by various factors in the theory of social learning and summarized these factors under 4 titles as follows: performance accomplishment, vicarious experience, verbal persuasion and emotional arousal. These resources could determine the highness or lowness of accomplishment beliefs in individuals. The researchers suggest that experiences that are gained by individuals through accomplishments form the greatest effect upon developing a strong belief of self-efficacy (Bandura, 1977; Zimmerman, 2000). Accomplishments enable individuals to develop a positive belief of efficacy. Failures, on the other hand, devastate the belief of efficacy especially when they occur before the formation of a healthy belief of efficacy (Bandura, 1994). While individuals with greater accomplishments in their past experiences have stronger self-efficacy, individuals with greater mistakes have weaker self-efficacy. The second way of developing the belief of self-efficacy is the vicarious experiences, in other words learning based on modelling (Bandura, 1977; 1994). Individuals who realize that they achieve as a result of the efforts of others have increased beliefs of efficacy. Similarly, individuals who see the failure of others due to high efforts have lower beliefs of efficacy. Besides, the persistent attitudes of these individuals regarding making an effort become weaker. Verbal persuasion is the third way for individuals to develop their beliefs of self-efficacy. Individuals who are verbally persuaded regarding the success of a task may show a greater effort. The fourth way of strengthening the self-efficacy is the emotional arousal. Increasing the stress of individuals changes their misinterpretations regarding the physical conditions and their negative emotional tendencies (Bandura, 1994).

Playing a determinative role on the behaviors of individuals, the belief of self-efficacy is among the important features to be emphasized in education, as well. İn education beliefs of teacher and academic self-efficacy are given importance (Tschannen-Moran, Hoy & Hoy., 1998, Yılmaz & Gürçay, 2011; Elias & Loomis, 2002; Zimmerhofer, Heukamp & Hornke, 2006). Beliefs of teacher self-efficacy provide us important information about training teachers, who could fulfill the efficacies of teaching, cope with problems and show both desire and self-devotion. As a matter of fact, the researchers stated that the belief of self-efficacy was multidimensional and was associated with different areas (such as conditions related with education, social conditions, as well as conditions related with development, personal psychology and health) (Schwarzer, 1993; Bandura, 1994; Pajares, 1997).

The studies being conducted emphasize the importance of self-efficacy especially in the efficacy of teachers and the effect of teacher efficacy in terms of both education and learning (Tschannen-Moran, Hoy & Hoy., 1998; Çapa, Çakıroğlu & Sarıkaya, 2005, Yılmaz & Gürçay, 2011). Various studies examining the beliefs of teachers suggest that teacher’s belief of self-efficacy shows the belief extent of teachers to believe that they have the capacity of positively affecting the student success and it may explain the personal differences in teacher’s activities (Riggs & Enochs, 1990; Enochs & Riggs, 1990; Gerçek, Yılmaz, Köseoğlu & Soran, 2006).

Teacher efficacy is associated with the belief of efficacy in two areas: efficacy of field information and efficacy of pedagogical field information (Koul & Rubba, 1999). The emotion of insufficiency affects the teacher's insufficiency in one of the aforementioned areas. The better comprehension and recruitment of the beliefs of teacher self-efficacy will apparently increase the quality of educational experiences. As a matter of fact, examining the different variables that explain the teacher self-efficacy and their effects could also contribute to the comprehension and alteration of teacher's behaviors regarding the education. In this context, it is required to support teachers in this aspect starting from the pre-service period.

Having a teacher self-efficacy that is required to struggle with problems being encountered during our education may enable us to gain more qualified educational equipment and to succeed in our profession in the future. In that case, it is required to measure the self-efficacy of a teacher and also her/his belief of self-efficacy regarding the accomplishment of an academic work and to examine the relationships between them in order to explain the behaviors of teachers.

The academic achievement of an individual is affected by factors both in the cognitive and affective areas. One of the affective dimensions affecting the academic achievement is the academic self-efficacy (Ekici, 2012). Today, there are tens of concepts derived from self-efficacy. Academic self-efficacy is also encountered as another concept derived from the self-efficacy, which was suggested by Bandura. The efforts and struggles of individuals regarding the difficult situations in education and their academic achievement are considered important. The studies being conducted underline the importance of handling and examining the academic self-efficacy structures of individuals (Wood & Locke, 1987; House, 1992; Elias & Loomis, 2002; Zimmerhofer, Heukamp & Hornke, 2006). The academic self-efficacy being perceived is related with the belief of students in accomplishing an academic task (Solberg, O'Brien, Villareal, Kennel, & Davis, 1993; Zimmerman, 1995). If a student thinks that her/his effort is not sufficient, she/he will be unable to learn sufficiently and try to pass the exams (Zimmerhofer et al. 2006). Witte (2002) suggests that one of the basic reasons for university students to fail in enhancing their education life is their failure of taking precautions to increase their self-efficacy. Various studies indicated that the belief of academic self-efficacy increased the accomplishment of students and was among the important variables in predicting the academic achievement (House, 1992; Vrugt, Langereis & Hoogstraten, 1997; Elias & Loomis 2002; Ferla, Valcke & Cai, 2009).

The possible performance teachers and pre-service teachers could be predicted through the studies of determining and developing the variables affecting teacher's belief of self-efficacy in education. Besides, the pre-service and inservice educational programs could also be reviewed and enhanced in such a way to involve regultions regarding these structures.

The objective of this study is to determine the teacher self-efficacy and academic self-efficacy of pre-service biology and science teachers and to examine of the teacher self-efficacy of pre-service biology and science teachers in terms of different variables. This study will seek answers to the following questions:

1. What are the teacher self-efficacy levels of pre-service biology and science teachers?
2. What are the academic self-efficacy levels of pre-service biology and science teachers?
3. To what extent do the academic self-efficacy, grade level and academic achievement predict the teacher self-efficacy of pre-service biology and science teachers?

METHODOLOGY

a) Research Design

The relational survey method was used in the study in an attempt to determine the academic self-efficacy, grade level and academic achievement variables predicting the teacher self-efficacy of pre-service biology and science teachers.

b) Participants

The participants of the study was selected according to its convenience for researchers. In this context, the study participants consisted of totally 134 pre-service teachers receiving education in three different state universities (68 from the Department of Biology Education and 66 from the Department of Science Education). While the pre-service teachers receiving education in the 3rd grade comprise 42,5% of the study group, the pre-service teachers receiving education in the 4th grade comprise 57,5%. Regarding the pre-service teachers, 82.8% are female and 17.2% are male. 59% of them have a general academic achievement average of 2.00-2.99, whereas 41% have an average of 3.00-4.00.

c) Data Collection Tools

The data collection tools being used in the study consists of the personal information form, which questions the pre-service teachers about their personal information, as well as the Teacher Self-Efficacy Scale and Academic Self-Efficacy Scale.

Teacher Self-Efficacy Scale (TSS): In the study, we used the "Teacher Self-Efficacy Scale", which was developed by Tschannen-Moran and Woolfolk-Hoy in 2001 year and was adapted into Turkish by Çapa et al. in 2005. Involving 24 items, the scale has three lower dimensions as "Student Participation", "Educational Strategies" and "Classroom Management". The scores to be obtained from the scale vary between 24-216. The Cronbach Alpha reliability coefficient of the entire scale is α= .94. The Cronbach Alpha reliability coefficients of the lower dimensions of the original scale are as follows: α= .91 for the dimension of "Student Participation", α= .90 for the dimension of "Educational Strategies" and α= .87 for the dimension of "Classroom Management" (Tschannen-Moran & Woolfolk Hoy, 2001). The scale was adapted into Turkish with 628 pre-service teachers. The Cronbach Alpha reliability coefficient of the entire scale that was adapted into Turkish was α= .93; and it was determined as α= .82 for the dimension of "Student Participation", α= .86 for the dimension of "Educational Strategies" and α= .84 for the dimension of "Classroom Management" (Çapa, Çakıroğlu & Sarıkaya, 2005). The Teacher Self-Efficacy Scale includes 9 gradings from the insufficient to very sufficient. In this study, the Cronbach Alpha reliability coefficient obtained from the entire "Teacher Self-Efficacy Scale" was α= .97. On the other hand, the Cronbach Alpha reliability coefficient obtained from the dimension of "Student Participation" was α= .93; and it was α= .94 for the dimension of "Educational Strategies" and α= .93 for the dimension of "Classroom Management".

Academic Self-Efficacy Scale (ASS): It was stated that the original scale that was developed by Jerusalem and Schwarzer (1981) in German and involved only one dimension showed a significant structure for the academic self-efficacy. Involving 7 items, the scale has 4 points (completely convenient, convenient, less convenient, completely inconvenient). The scores to be obtained from the scale vary between 7-28. The Cronbach Alpha reliability coefficient of the original scale was determined as α=.87. The researchers tested the validity of the scale based on its correlation with some variables like content, logic and psychology (Jerusalem & Schwarzer 1981). According to the results of the adaptation study, it was determined that the number of items in the original scale remained the same in the Turkish scale and it was unidimensional (Yılmaz, Gürçay & Ekici, 2007). It was also determined that the validity of the scale that was adapted into Turkish supported the data of the original scale. The Cronbach Alpha reliability coefficient of the Turkish scale was determined as α=.79 (Yılmaz, Gürçay & Ekici, 2007). In this study, on the other hand, the Cronbach Alpha reliability coefficient of the scale was determined as α= .70.

Personal Information Form: Personal Information Form being used in the study consists of the form which questions the pre-service teachers about their personal information (as gender, grade level, academic achievement).

c) Data Analysis

The data were analyzed using the SPSS 20.00 statistics package software. In order to determine the descriptive statistics (as mean, standard deviation, skewness and kurtosis) for teacher self-efficacy and academic self-efficacy as well as reliability of scales in the study. We used the Pearson correlation for the analysis of relationships between the teacher self-efficacy levels of students and the academic self-efficacy, grade and academic achievement and conducted the multiple regression analysis to determine the variables predicting the teacher self-efficacy of pre-service teachers.

In the study, we conducted the multiple regression analysis to determine the variables predicting the teacher self-efficacy of pre-service teachers. Before the multiple regression analysis, we checked whether the study data met the assumptions or not. The multiple regression involves assumptions like the sample size, multicollinearity, outlier, normalcy, linearity, homoscedasticity and the independence of the residuals. Regarding the sample size, Tabachnick and Fidell (1996) considered the number of independent variables and presented the following formula; $N > 50 + 8m$ (m = number of independent variables). This study involves three independent variables and the sample size is 134 and since $134 > 74$, the assumption of the sample size is met. We calculated the bivariate correlations between the independent variables for the assumption of multicollinearity (See Table 2). Since all the correlation coefficients were lower than 0.70, this assumption was met. The plots of the predicted values of accomplishment data against residuals, as well as normalcy and linearity, homoscedasticity and independence of residuals met the assumptions. No outliers were observed. In this study, the assumptions that are required to perform a multiple regression are met.

FINDINGS

Table 1 shows the descriptive analysis results regarding the teacher self-efficacy and academic self-efficacy of pre-service teachers. As a result of the descriptive analyses, it was determined that pre-service teachers had high levels of teacher self-efficacy ($\overline{X}$=166,02), academic self-efficacy ($\overline{X}$ = 21,58) and academic achievement ($\overline{X}$ = 3,41).

Table 1. *Results of Descriptive Statistics*

	Teacher Self-Efficacy	Academic Self-Efficacy	Academic Achievement
Arit. Mean	166.02	21.58	3.41
Std. Deviation	29.01	3.20	.49
Skewness	-1.01	.12	.36
Kurtosis	.74	-.71	-1.89
N	134	134	134

Pearson Product-Moment Correlation analysis was conducted to display the relationship between the teacher self-efficacy levels of students and the academic self-efficacy, grade and academic achievement. Table 2 shows the results of the Pearson correlation analysis, which was performed between the teacher self-efficacy and variables (academic self-efficacy, grade and academic achievement). A positive, moderate and significant relationship was determined between the teacher self-efficacy and the academic self-efficacy, which signifies that the increase of the academic self-efficacy will positively affect the teacher self-efficacy. However, no significant relationship was determined between the teacher self-efficacy and the grade and academic achievement of pre-service teachers.

Table 2. *Pearson Correlation Coefficients between the Variables*

	Academic Self-Efficacy	Grade	Academic Achievement
Teacher Self-Efficacy	.50**	-.04	.07
Academic Self-Efficacy		-.02	.07
Grade			.35**

In the multiple regression analysis, the academic self-efficacy, grade and academic achievement were handled as variables predicting the teacher self-efficacy. The dependent variable is the teacher self-efficacy. Table 3 shows the results of the multiple regression analysis. The results show that the academic self-efficacy explains 26% of the teacher self-efficacy and is considered the predicting variable (R^2=0.26, F (3,130) = 14.84, p= 0.00). Among three independent variables, the academic self-efficacy was statistically significant at the level of 0.05; however, the class and accomplishment were excluded from the model. There is a positive relationship between the teacher self-efficacy and academic self-efficacy. This finding shows that the academic self-efficacy is the variable predicting the teacher self-efficacy. Thus, the teacher self-efficacy increases in parallel with the increase of the academic self-efficacy.

Table 3. *Multiple Regression Analysis regarding the Teacher Self-Efficacy*

Model		Beta	T	Sig.
1	AcademicSelf-Efficacy	.49	6.52	.000

The study results suggest that grade and academic achievement remain incapable in explaining the teacher self-efficacy and are unable to predict it.

DISCUSSION

The study results show that biology and science pre-service teachers have high levels of teacher self-efficacy and academic achievement (See Table 1). In other words, this result shows that pre-service teachers could arrange the required behaviors in order to achieve their educational goals. The study results suggest that pre-service teachers have high levels of teacher self-efficacy to arrange the behaviors that are required to achieve certain educational goals and high levels of academic self-efficacy to accomplish an academic task. This condition is considered positive as it makes us think that they will have highly qualified and productive activities concerning their profession in the future, as well.

Some studies suggest that there are behavioral differences between teachers with high and low beliefs of self-efficacy in terms of the grade level use of new methods, and giving feedbacks to students having a difficulty in teaching and learning (Tschannen-Moran & Woolfolk-Hoy, 2001; Özkan et al., 2002). These studies also suggest that teachers with a stronger self-efficacy are more persistent and resistant to learning difficulties compared to weak teachers (Gibson & Dembo, 1984), they become more tolerant towards student's mistakes (Ashton & Webb, 1986) and are more eager to use more teaching methods and teaching materials (Guskey, 1988). Additionally, the researchers state that the high self-efficacy beliefs and high teacher self-efficacy affects the motivation and achievement of students (Schmitz & Schwarzer, 2000; Tschannen-Moran & Woolfolk-Hoy, 2001; Özkan et al., 2002).

The study results show that pre-service teachers have high levels of academic self-efficacy regarding the accomplishment of an academic task. This may make us think that pre-service teachers with high levels of academic self-efficacy will learn better and have more qualified educational achievements and applications. The researchers state too that a student would be unable to learn sufficiently and try to pass the exams in case that she/he considered her/his effort insufficient (Zimmerhofer et al., 2006).

In the study, it was determined that only the academic self-efficacy made a significant contribution among variables predicting the teacher self-efficacy. The academic self-efficacy was observed to be the variable predicting the teacher self-efficacy at the rate of 26% (See Table 3). This may make us think about the necessity for examining how the educational experiences and knowledge of pre-service teachers could affect their profession better. However, the grade and academic achievement of pre-service teachers do not significantly predict the teacher self-efficacy, which may make us think that pre-service teachers could act according to a stronger teacher self-efficacy in order to accomplish an academic task. This may make us think that grade level and high academic achievement was not related to their teacher self-efficacy for the pre-service teachers. In their study that was performed with undergraduate students, Vrugt, Langereis and Hoogstraten (1997) determined that the academic self-efficacy significantly affected the exam performance. Chemers et al. (2001), on the other hand, suggested that the academic self-efficacy was among variables predicting the personal qualities such as the class performance, personal coherence, stress and health.

Considering the study results, no significant correlation was observed between the grades and academic achievements of pre-service teachers and their teacher self-efficacy. According to the results of the multiple regression analysis, it was determined that the class and accomplishment remained incapable in explaining the teacher self-efficacy and were unable to predict it, which may make us think about the necessity for examining how the educational experiences and knowledge of pre-service teachers could affect their profession better.

CONCLUSION

The study results show that pre-service teachers have high levels of teacher self-efficacy regarding their capacity of arranging the behaviors that are required to achieve certain educational goals and academic self-efficacy regarding their capacity of accomplishing an academic task. This condition is considered positive as it makes us think that they will have highly qualified and productive activities concerning their profession in the future, as well. Additionally, since the results point out the academic self-efficacy as the variable predicting the teacher self-efficacy, it makes us think about the necessity for supporting and developing the pre-service teachers to accomplish an academic task during their education. This condition reveals the importance of especially the teacher training programs and the duty of academic lecturers working there. Having information about the factors affecting the teachers' self-efficacy is important in terms of reinforcing the sufficiency perceptions of teachers.

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Conceptual Comprehension of Pre-Service Physics Teachers Towards 1st Law of Thermodynamics

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ABSTRACT

This research is a qualitative study conducted to determine pre-service physics teachers' conceptual comprehension of the first law of thermodynamics. In this study, which was conducted with the participation of 25 students, case study pattern was used, and a holistic single case pattern was adopted. Five open-ended questions which include drawings and explanations were used as data collection tool. In order to support the obtained findings, semi-constructed interviews were done with 20% of pre-service physics teachers. As a result of the findings obtained from content analysis, it was seen that pre-service teachers represent energy mostly as object with potential energy, electric energy, and vibration energy; and it was seen that they think of the world as an insulated place and thus think that there is confined transformational energy within it. When findings of the study are taken into consideration, it is believed that the first law of thermodynamics should be explained by drawing examples from daily life.

Keywords: Physics Education; Pre-Service Teachers; First Law of Thermodynamics; Conceptual Comprehension.

INTRODUCTION

Raising creative and productive individuals who follows latest developments and innovations in technology is possible with education. It is necessary raise individuals who can think analytically, do research and can apply theory into practice in order to meet the needs and demands of people in a world of improved technology (Kayhan, 2009). Thanks to science education, things that happen in nature can be understood, observed, and interpreted by technology (İşman, Baytekin, Balkan, Horzum & Kıyıcı, 2002). In science education, the aim is enable students to have problem solving and scientific skills, to use concepts in relation to daily life and also to train individuals who are science-literate and sensitive to their environment (Ausubel, 1968; Eisen & Stavy, 1988; Tatar & Oktay, 2008). Science-literate individuals can reach information faster, they contribute to the development of technology by generating knowledge, and can use new systems efficiently and productively (Yaşar, 1998). A sub branch of science that examines universal events and approaches them with a fundamental perspective is "physics" (Karakuyu, 2006). A sub branch of physics that focuses on energy, conservation of energy, and transformations of energy is "Thermodynamics." Thermodynamics is a branch of science which examines energy, energy transformations and

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how energy transforms from one kind to another (Çengel & Boles, 1996; Çetinkaya, 1999; Jones & Dugan, 2003; Serway & Beichner, 2008; Yamankaradeniz, 2004). Due to its vast application area and its interdisciplinary nature as well as the fact that it is based on natural phenomena makes thermodynamics a highly significant branch of science. Thermodynamics course is predominantly part of the curricula of science and engineering departments, and it is also part of the curricula of such departments as biochemistry and pharmacy. However, studies show that teaching thermodynamics has not been given enough precedence (Meltzer, 2002; Kirtak, 2010). The first law of thermodynamics which explains the conservation of energy principle is expressed as follows: "Energy cannot be created out of nothing, only different forms can transform into one another" (Bueche & Jerde, 2003; Cebe, 1992). Energy can change form but it can never disappear. For instance, let's take a body of water at a certain altitude; during the flow of this water, the existing potential energy turns into Kinetic energy. The water still has energy; but only the potential energy is said to turn into Kinetic energy. The fact that the first law of thermodynamics explains many events in our lives shows its importance (Çengel & Boles, 2008). One of the topics students find difficult to comprehend is energy, which also covers the first law of thermodynamics (Hırça, 2004; Özmen, Dumanoğlu & Ayas, 2000; Stylianidou, Ormerod, & Ogborn, 2002). Energy can be defined as the ability to do things as well as the ability to move or to generate movement (Selici, 2006). Additionally, the concept of energy, which is the basis of such topics as force, movement, power, is used as wind energy, electric energy, solar energy, chemical energy, binding energy, and mechanical energy (Ellse, 1988). The concept of energy denotes different things in daily language. As energy does not have a simple or concrete definition, everyone uses it differently (Martinas, 2005; Sefton, 2004). In the studies about energy, it was determined that students usually have misconceptions which are defined as knowledge that contradicts with scientific facts especially about energy, energy transformation and energy conservation (Ellse, 1988; Konuk & Kılıç, 1999; Ogborn, 1990; Solomon, 1982; Stylianidou 1997; Stylianidou, Ormerod, & Ogborn, 2002; Trumper, 1998). In many studies on energy, it was seen that students find it difficult to comprehend the concepts related to energy, and that they have misconceptions (Aydoğan, Güneş & Gülçiçek, 2003; Başer & Çataloğlu, 2005; Carlton, 2000; Çoban, Aktamış & Ergin, 2007; Harrison, Grayson, & Treagust, 1999; Sözbilir, 2002). Students' misconceptions and misunderstandings affect their comprehension in the following stages, and they resist change (Hewson & Hewson, 1983). Bearing this in mind, students' misconceptions and misunderstandings constitute the main problem for teachers, researchers, educators, and of course students. When literature on energy is examined, it is seen that another reason for students' difficulty in comprehending energy is the fact that this topic is not paid enough attention to. To have an effective teaching of energy, these studies argue that students' misconceptions and imperfect knowledge should be determined, and then the definition of energy, energy transformation, conservation and transfer should be emphasized and examined for a meaningful teaching (Benzer, Bayrak, Eren & Gürdal, 2014; Çoban, Aktamış & Ergin, 2007; Yürümezoğlu, Ayaz & Çökelez, 2009; White & Gunstone, 1992; Aykutlu & Şen, 2012).

The concept of energy, which is part of the first law of thermodynamics and which has an important place in daily life, is used in movement, heating, and illumination; it is felt and measured by such agents as voice, heat, and light; and it has such kinds as Kinetic, potential, electric, heat, and nuclear energy (Şahan & Tekin, 2007). When literature on energy is examined, it can be seen that many of the misconceptions related to energy are about energy conservation, transmission, transformation, storage, necessity, as well as about abstractness of energy, and the definition of energy (Ellse, 1988; Konuk & Kılıç, 1999; Ogborn, 1990; Solomon, 1982; Stylianidou, 1997; Stylianidou, Ormerod, & Ogborn, 2002; Trumper, 1998). In the studies conducted about students' perception of energy and energy-related concepts, it was determines that they cannot comprehend the difference between different forms of energy and the source of energy, and that they perceive of energy as light, electricity, the sun, technological applications, a characteristic of living beings, and as a means of making life easier, and that there are deficiencies in their mental constructions of energy, source of energy, the form of energy, transformation of energy, and the transference of energy (Çoban, Aktamış & Ergin, 2007; Kaper, & Goedhart, 2002; Kırtak, 2010; Töman & Çimer, 2012; Yürümezoğlu, Ayaz & Çökelez, 2009). In addition to all these, it was revealed in other studies that energy, conservation of energy, and transformation of energy are among the concepts that should be taught to students in a world where science and technology advances rapidly (Benzer, Bayrak, Eren & Gürdal, 2014; Çoban, Aktamış & Ergin, 2007; Yürümezoğlu, Ayaz & Çökelez, 2009). Taking its cue from this, this study aims to determine the conceptual comprehension of pre-service physics teachers, who have taken thermodynamics course. When the importance of teaching the first law of thermodynamics, which is an indispensible part of daily life, is taken into consideration, although very little attention is paid to a detailed analysis of the first law of thermodynamics, it is thought that it is highly important to determine pre-service teachers' conceptual comprehension of the first law of thermodynamics, and it is also believed that such a study would be a significant part of literature. Moreover, it is believed that the study will be effective in exploring the ways that lead to misconceptions about the first law of thermodynamics. In accordance with the aim and significance of the study, an answer was sought for the following question:

1. What is the conceptual comprehension of pre-service physics teachers, who have taken thermodynamics course, of the first law of thermodynamics?

METHODOLOGY

The study was conducted as a qualitative one, and case study pattern, which is one of the qualitative research methods, was used. Case study is a research method which makes it possible to examine an issue in detail so as to answer "why and how" (Yin, 2009; Yıldırım & Şimşek, 2013). Case study refers to a thorough analysis by way of determining in detail the place and time of one or more events, individuals, or groups (McMillan, 2004). In case studies, basic aim is to describe an event. To this end, as the aim is to describe an event out of a real event, whatever is expressed constitutes a meaning and view related to that particular event for the reader (Gall, Gall, & Borg, 1999). Moreover, a holistic single case pattern was adopted in the study. In the holistic single case pattern, there is a single analysis unit such as an institution or a class. This pattern is utilized in studying particular cases (Yıldırım & Şimşek, 2013). In this study the case is pre-service physics teachers' conceptual comprehension of the first law of thermodynamics who have taken thermodynamics course and are juniors.

a) Study Group

Usually, participants in case studies are a group that consists of people who share the same environment and who know each other. For studies conducted in the field of education, students in a class environment are a good example (McMillan, 2004). The participants of this study consists of 25 pre-service teachers who are seniors taking the thermodynamics course during the fall semester of 2014-2015 academic year. Demographic characteristics of pre-service teachers are given in Table 1.

Table 1. *Demographic Characteristics of Pre-service Teachers*

Pre-Service Teachers'	Age	Class	Gender
Ayşe (PT1)	23	3	Female
Ali (PT2)	23	3	Male
Berrin (PT3)	22	3	Female
Hilal (PT4)	23	3	Female
Samet (PT5)	24	3	Male
Ömer (PT6)	23	3	Male
Aynur (PT7)	27	3	Female
Nurdan (PT8)	23	3	Female
Cenk (PT9)	23	3	Male
Burak (PT10)	22	3	Male
Fatma (PT11)	22	3	Female
Deniz (PT12)	23	3	Female
Merve (PT13)	23	3	Female
Betül (PT14)	23	3	Female
Emrah (PT15)	22	3	Male
Selda (PT16)	23	3	Female
Gökçe (PT17)	23	3	Female
Nazlı (PT18)	23	3	Female
Erkan (PT19)	22	3	Male
Cemre (PT20)	24	3	Female
Zeynep (PT21)	24	3	Female
Gizem (PT22)	22	3	Female
Murat (PT23)	23	3	Male
Suna (PT24)	23	3	Female
Berk (PT25)	23	3	Male

In determining the participants, criterion sampling method, which is one of the purposeful sampling methods, was used (Yıldırım & Şimşek, 2013). Criterion sampling is a method the participants are determined so as to meet a series of criteria pre-determined or constructed by the researcher (Patton, 2002). To this end, junior pre-service physics teachers, who meet the criterion by the fact that they have taken thermodynamics course, were selected in accordance with the aim of the study.

b) Data Collection Tool

In this study which was realized by qualitative research methods, an energy concept form which consists of five open-ended questions with drawings and explanations was used as data collection tool in order to determine pre-service physics teachers' conceptual comprehension of the first law of thermodynamics. This energy concept form that consists of open-ended questions was preferred because it is effective in obtaining in-depth information about pre-service physics teachers' views on the topic without being under the influence of anything else (White & Gustone, 1992). Before designing the form, studies which were conducted in Turkey and abroad related directly or indirectly to the topic of this study were researched. After the literature review, and with the views of three experts – one with a PhD in physics and two with PhDs in physics education – it was decided that five questions should be in the form (Yürümezoğlu, Ayaz & Çökelez, 2009; Tekbıyık, 2010; Aydın & Balım, 2005; Töman & Çimer, 2012). While literature was consulted in the design of the questions in the form, some questions were altered partially by the researcher and three experts were consulted as to whether the questions in the form have content validity. Taking its final shape after expert consultation, the form was applied to 20 junior pre-service teachers, who have taken thermodynamics course, as a pilot study during the fall semester of 2013-2014 academic year. Data obtained in the pilot study were analyzed with content analysis method. It was determined that pre-service teachers express energy most frequenly as transformational energy and under the movement theme, and that they have incomplete and incorrect knowledge about the preservation, transformation, and transfer of energy. As a result of the pilot study, it was determined that pre-service teachers have incorrect or incomplete knowledge about the first law of thermodynamics, which is the research problem of this study. In this respect, data gathering tool, which was developed in accordance with expert views, was determined to be acceptable and sufficient in revealing pre-service physics teachers' conceptual understanding of the first law of thermodynamics. Questions in the energy concepts form are given below:

1. How would you illustrate energy?
2. Can we claim that our world is an insulated system? Why? Explain.
3. Can energy be transferred without transformation? Explain by giving examples.
4. How would you explain the melting of ice cubes that rub against one another?
5. How is the energy transformation during the power generation at a dam?

c) Procedure

The form which was distributed to the pre-service teachers after teaching them the first law of thermodynamics was applied to them during class hours by giving them 20-25 minutes to complete it. Analysis of the questions in the form was done by entering data to the files opened for each question separately. Moreover, in order to support the findings, semi-constructed interviews were conducted with 20% (five pre-service physics teachers) of the pre-service physics teachers. Interviews conducted with pre-service physics teachers were done by the reserachers in an empty classroom, and the aim was to obtain data of different quality and depth. Pre-service teachers to be interviewed were determined through the data obtained from energy concepts form and among pre-service teachers with different views. When the views of pre-service teachers are taken into consideration, a total of five pre-service teachers were selected among those with correct (one pre-service teacher), incorrect (two pre-service teachers), and incomplete (two pre-service teachers) knowledge about the first law of thermodynamics. Since the scope of the study focuses on determining as to how the first law of thermodynamics is conceptually comprehended, having the views of pre-service teachers with differing views is necessary. Interviews with pre-service teachers were realized a week after the application was completed in an empty classroom, and one interview took 25-30 minutes. Moreover, willingness of the pre-service teacher to give an interview was also taken into consideration in selecting the participants. Data obtained from these interviews were recorded with a voice recorder and them they were transcribed into files in electronic media.

d) Data Analysis

Data obtained in the study were analyzed by content analysis method. Content analysis refers to the interpretation of data by arranging them in a coherent way by putting similar data together according to certain themes and concepts (Yıldırım & Şimşek, 2013). Moreover, content analysis is a technique in which words in a certain text are categorized and systematically summarized via certain codifications (Büyüköztürk, Çakmak, Akgün, Karadeniz & Demirel, 2009). In the study, analysis process started after data collection process. After the completion of data collection process, qualitative data were re-read, and a code list was prepared for each question with inductive analyses. It is thought that pre-service teachers' answers reflect the real situation because of this. In addition, objectivity was sustained in forming and evaluating the data. Then, qualitative data were entered to the code list, which was prepared in accordance with inductive analysis (Miles & Huberman, 1994). During analysis, some additions to the code lists and some alterations in some of the codifications were done; some codifications which were thought to have a relationship were put together. Then, codifications were grouped among each other under certain themes. At the same time, percentages and frequencies of codes under these themes were calculated. All data obtained and transformed to forms were given to another expert, who has a PhD degree in physics education and teaches thermodynamics, in order to see whether the data were under the correct themes and codings in terms of internal validity. Data entries were revised again at different times by the researcher and the expert separately and the consistency between results of the revision were compared with each other. Comparison was done by looking at the similarities (agreement) and differences (disagreement) in the data entries realized by the researcher and the expert. Then, after applying the reliability calculation formula suggested by Miles and Huberman (1994) ($R_{reliability}$ = (Agreement / (Agreement + Disagreement)) x 100), it was determined that consistency between the researcher and the expert is 82%. The fact that the consistency is higher than 70% shows that reliability of research findings is established (Miles & Huberman, 1994). Moreover, the difference was minimized by re-working on the answers given by the researcher and the expert and arriving at a consensus. In Table 2, an example related to the data analysis of the question "If you were to draw energy as a picture or to express it with an image, how would you do it. Explain." was given.

Table 2. *Example Related to Data Analysis*

Themes / Frequency (%)	Codes / Frequency (%)	Explanations
Movement 9 (36%)	Moving particles 3 (12%)	• Energy is a moving particle that has very little matter in it. • Several moving particles move as a knot with a bigger energy as they keep colliding with one another
	Moving car 2 (8%)	• A car has kinetic energy because of its movement.
	Running dog 2 (8%)	• Energy is the movement of an object with a certain mass and velocity from one place to another.
	Moving person 2 (8%)	• Energy is a conservable entity (we can call it an entity). It travels like a constrantly moving person, but it never gets lost and it has a highly developed sense of direction.

During the analysis, special attention was paid to whether especially direct quotations reflect the related code and theme. Moreover, obtained data were supported by semi-constructed interviews conducted in an empty classroom with pre-service teachers. In order to improve internal reliability and validity, views of pre-service teachers were also given. When the interviews were transcribed, pre-service teachers were called PT#1, PT#2, PT#3, PT#4, and PT#5 in accordance with the order they were interviewed. In the interviews, in order to more thoroughly evaluate pre-service teachers' answers to the questions in energy concept form, questions in the form were asked to the pre-service teachers one more time. In line with the answers, additional questions within the boundaries of the research were asked. These additional questions were determined in paralel to the questions about the first law of thermodynamics in the form. At the same time, most of the questions asked in the semi-constructed interviews were designed by the researcher, and in the formation of some literature was consulted (Kırtak, 2010). In order to increase the internal realibility and validity of findings, views of pre-service teachers were taken and the questions asked to them were evaluated by the same experts, and it was decided that questions should be part of the application. Pre-service teachers were given ample time to answer the questions so that they do not get scared or anxious thereby providing internal validity of questions. Moreover, in constructing and evaluating the data, objectivity was sustained, and direct quotations were used. Certain parts of one of the semi-constructed interviews can be found below (R: Researcher):

Researcher: Can we say that our world is an insulated system? What do you think?

Student4: When a house is insulated, all heat is confined within. If the world were not insulated it would take all the heat of the Sun. By the way insulated means protector. In conclusion I think the world is an insulated system.

R: Do you think so because not all heat of the Sun can penetrate the earth? (This question was asked to the pre-service teachers as an additional question).

S4: Yes. Actually, there is a protective belt around the earth which functions as a shield for the harmful rays that could come from without. The fact that not only heat but also harmful rays cannot penetrate the earth and the fact that no effect goes out means that the earth is an insulated system.

R: So, what do you think of the reason of using double-glazed windows? (This question was asked to the pre-service teachers as an additional question).

S4: It prevents the air from going out. I mean, double-glazed windows prevent heat transfer. Moreover, when the windows are closed, the treshold to hear the voices outside is decreased by the glazed windows.

In the external validity of the study, each step of data collection and analysis was indicated in detail. Lastly, obtained data were preserved so that they could be examined by another researcher, and the aim of the study as explained in detail so that the research process could be compared to other studies.

FINDINGS

In the study, data obtained from the form with open-ended questions which also include drawings and explanations about the problem question "How is the conceptual comprehension of pre-service physics teachers who take thermodynamics course?" and from the semi-constructed interviews done to support the data. In this study, it was determined that pre-service teachers have correct and imperfect knowledge about energy and that they have misconceptions. Data and pre-service teachers' explanations and views are given in below in detail.

First question asked to pre-service teachers in the study was "How would you illustrate energy?" Answers of pre-service teachers were gathered under following themes: transformational energy (40%), movement (36%), impact dispersing from the source (16%), wave (16%), and entity (8%). It was seen that pre-service teachers mostly depict energy as an object that has potential energy, electric energy, and vibration energy, all of which are under the transformational energy theme. Codes and expressions obtained from the answers of pre-service teachers were given in Table 3 in detail.

Table 3. *Pre-service Teachers' Views On The Expression Of Energy*

Themes / Frequency (%)	Codes / Frequency (%)	Explanations
Transformational Energy 10 (40%)	An object that has potential energy 4 (16%)	• The object has potential energy, and when it is let down, its potential energy turns into kinetic energy. • Energy is equal to the sum of both potential and kinetic energy. Energy and energy transformation of an object with a height of h and a mass of m, moving at the velocity v is calculated. • I visualize a child sliding. In the beginning, the child has mgh potential energy, and then he moves on by turning his/her energy to $1/2mv^2$ Kinetic energy.
	Electric energy 2 (8%)	• Electric energy moves over resistance. Some of this energy turns into thermal energy over resistance.
	Vibration movement 2 (8%)	• A hanging mass constantly moves to and fro when it has the velocity v. In a scenario where air friction is disregarded, maximum kinetic energy is transformed to potential energy. This transformation keeps occurring. • Energy is the ability to do things. In the representation given in the figure, potential energy turns into Kinetic energy because the spring gives velocity to the object. We see suh energy transformations in many areas of daily life.
	Windmill 1 (4%)	• It is the method of getting energy from wind.
	Total energy graphic representation 1 (4%)	• However energy is transformed, the fact that total energy is conserved within a syste can be expressed through mathematical representations.
Movement 9 (%36)	Moving particles 3 (12%)	• Energy is a moving particle with very little matter in it. • Several moving particles move as a knot with a bigger energy as they keep colliding with one another
	Moving car 2 (8%)	• A car has kinetic energy because of its movement.
	Running Dog 2 (8%)	• Energy is the movement of an object with a certain mass and velocity from one place to another.
	Moving person 2 (%8)	• Energy is a conservable entity (we can call it an entity). It travels like a constrantly moving person, but it never gets lost and it has a highly developed sense of direction.
An Effect that Disperses from a Source 4 (%16)	Lightning 1 (4%)	• I can say that energy disperses from a source such as lightning.
	Light 1 (4%)	• Impact never vanishes nor can it come into being out of nothing. I can only say that energy disperses from a source just like light.
	Scintillant globes 1 (4%)	• Energy disperses around just like a scintillant globe.
	The Sun 1 (4%)	• The Sun is our principle source of energy.
Wave 4 (%16)	Waves 4 (16%)	• It comes out from a source, it does not have a certain direction, and it is not stable. It can expand and change shape. • It can be thought of as a case created by the waves. For example, if kinetic energy occurs in a moving object, energy waves can be thought to come into being during the object's movement.

Table 3. *Continued..*

Entity 2 (%8)	Human being 1 (4%)	• When somebody says "representation of energy," I visualize a muscular and vibrant child. The reason for this is, he/she must have spent a lot of energy to build those muscles. All that energy he/she spent did not go to waste but instead made him/her a strong person. This physical power is reflected in his/her vibrant smile, I mean in his/her self-confidence.
	Thinking man 1 (4%)	• Life is a constant energy cycle, and it moves within its transformation. There is energy in everything everywhere. In the simplest term, the pressure created by my hand and pen, and the friction between the pen and the paper, the movements of my muscles, blood circulation while I write these sentences all happen with energy.

When the same question was asked during the semi-constructed interviews in order to support the data of the study, pre-service teachers answered it as follows:

PT#2: "I think of energy as a moving particle. These particles come together and they get stronger and create a very big impact."
PT#3: "Energy is an impact that disperses from the source."
PT#4: "Energy is everywhere. I do not think of it merely as mechanical. You can get energy from an electric circuit as well."

Pre-service teachers depict energy as an impact that disperses from the source, as electric energy, and as a moving particle. However, it was seen that most of pre-service teachers think of energy as a moving object or a transformational energy form, and that they try to depict it through objects which they think have the impact and energy that disperses from the source. In other words, it is obvious that pre-service teachers try to depict energy via solid situations. Moreover, when pre-service students were asked "What can be done with energy" they gave answers such as the following: "Anything can be done. We can maintain the existence of something. We can observe the transformation and impact of energy," "We spend energy even when we talk, write, and think," "Plants, for example, live by the sun's energy. We move due to certain energies and we maintain our lives with oxygen," "Anything can be done. We can ride down the slide in a theme park because of energy," "Various energy types come to my mind such as wind power, hydroelectric energy. When I think of the types of energy one by one, [I can say that] technology advances due to energy." Another finding of the study is that pre-service teachers think anything can be done with energy, that technology advances and lives are maintained due to energy.

Second question they were asked was "Can we claim that our world is an insulated system? Why? Explain." While the answers of those who expressed that the world is insulated were grouped under the theme closed system (60%), the answers of those who did not think so were grouped under the theme open system (40%) within the interaction code. Pre-service teachers' views concerning this question can be found in Table 4.

Tablo 4. *Pre-Service Teachers' View On Whether Or Not The Earth Is An Insulated System*

Themes / Frequency (%)	Codes / Frequency (%)	Explanation / Frequency (%)
Closed system 15 (60%)	Confined energy 13 (52%)	• The earth is an insulated system. One cannot talk abou energy entry or exit. • Because there is no energy loss, I mean because energy never ends, we can call it an insulated system. • Non-conducting quality of the earth is more predominant. Moreover, as human body and the air contact with each other, our charges become balanced, and there is no loss of energy on earth. • Because there are atmospheric spheres, it can be claimed that the earth is an insulated system. • If it weren't an insulated system, one should be able to hear all sounds made by stars and planets. We don't hear it thanks to insulation. There is no energy entry or exit on earth. • Because the earth is an insulated system, harmful rays cannot reach the earth. There is no energy entry
	Transformational energy 2 (8%)	• Because there is a certain amount of energy within the earth and it constantly transforms. For example, if a vase falls from a table and breaks, potential energy turns to audio and thermal energy. • Because energy cannot be destroyed and cannot be created out of nothing. Energy transformation occurs only on earth.
Open system 10 (40%)	Interaction 10 (40%)	• Whole universe is in harmony. Our earth is in the universe. • We cannot say it is insulated, I mean, we can influence the Moon with gravitational force. Likewise, the movements of the Moon affect the earth (e.g. lunar tide). The whole universe is in harmony. We cannot isolate ourselves; our Earth is part of that system. • There are many energy resources on earth and they are influenced by energy resources that exist within the system. • If it were an insulated system, our clothes, even our hair affects the system during, say, Coulomb law experiment, it would result in miscalculations. • Since sun rays, meteors, and matters enter [the atmosphere of] the earth, it is not insulated.

Supportive expressions taken from the semi-constructed interviews are as follows:

Researcher: Can we say that our world is an insulated system? What do you think?
Student4: When a house is insulated, all heat is confined within. If the world were not insulated it would take all the heat of the Sun. By the way insulated means protector. In conclusion I think the world is an insulated system.
R: Do you think so because not all heat of the Sun can penetrate the earth?
S4: Yes. Actually, there is a protective belt around the earth which functions as a shield for the harmful rays that could come from without. The fact that not only heat but also harmful rays cannot penetrate the earth and the fact that no effect goes out means that the earth is an insulated system.
R: So, what do you think of the reason of using double-glazed windows?
S4: It prevents the air from going out. I mean, double-glazed windows prevent heat transfer. Moreover, when the windows are closed, the treshold to hear the voices outside is decreased by the glazed windows.
R: Then, do you used the word "insulated" in the same sense in both cases?
S4: Yes, in both cases, I used it to mean blocking an effect that comes from without and not letting an effect from going out.
R: So, what do you think is the basis of life on earth?

S4: The first basis of life on earth is water because it is the major component of our bodies. Then it is the Sun. Also the basis of energy on earth is gravitational energy. Life goes on with the energy between the earth and the universe.
R: You mention the universe; is there an energy transfer between the earth and the universe?
S4: Of course there is, but it is very little, scarcely any.
R: So, you say that the Sun is the basis of life on earth and that the earth is an insulated system. In this case, how do the sun rays reach the earth if it is insulated?
S4: the earth blocks harmful rays and the sounds in the universe, it just gets few sunlight and heat, but it is very limited, hardly any. Thus, I can still claim that the earth is insulated. By the way, another basis for life on earth is the human body. Our cells have energy. That's how there is atp synthesis and energy is got.
R: What does the expression "Total energy in the universe is constant" mean to you? Can you explain it?
S4: I don't think the total energy in the universe is constant. Since the earth is part of the universe, let me think about the earth, energy is spent on earth, and this energy is transformed, and here there is energy loss. An example to this would be getting electric power from water in hydroelectric power plants, because there you cannot get 100% efficiency from water.
R: If the total energy on earth is not constant, then what happens to that lost energy?
S4: I don't know about that. We just disregard it in solving the problems anyway. In fact, it is just assumed that the total energy on earth is constant.
R: What do you know about the conservation of energy?
S4: In order for energy to be conserved, there should be an insulated and frictionless environment. Actually this is impossible in reality because friction is everywhere but we disregard this. Hence, the earth is assumed to be insulated. Therefore, we can talk about conservation of energy on earth.
Content of the interview with another pre-service teacher is as follows:
R: Can we say that our world is an insulated system? What do you think?
S2: We are not in an insulated environment even now. The earth is affected by various things such as gravity, the moon and the sun. That is to say the earth cannot be insulated.
R: Can you give an example of an insulated system?
S2: The earth is in the universe and cannot be an insulated system. The earth is affected by the sun and the gravitational pull of the planets. However, I can call the universe an insulated system.
R: What do you think the double-glazed windows are for?
S2: Double-glazed windows are used as a means of heat insulation in houses. We would like our houses to be cooler during the summer; we would like to decrease the effect of the thermal situation outside. I mean, they are used to prevent hot air from going outside. Double-glazed windows prevent energy transfer.
R: What do you think is the basis of life on earth?
S2: Energy. Even the earth was created after a big bang. Moreover, energy is not only available on earth but also in the universe. Energies in the universe affect the earth. Even our breathing is due to energy. In fact, if I should name a certain source of energy, I could say water and oxygen.
R: You also said that the universe has an effect on the energy sources on earth, right?
S2: Yes. Absolutely.
R: So, what does the expression "Total energy in the universe is constant" mean to you?
S2: Energy cannot be created out of nothing, and it cannot disappear. There is a constant transformation. Energy of the earth is constant. Logically, if the energy in the universe is constant, then it is so on earth, too, because the universe and the earth are connected. Thus, the earth's trade with the outside is constant.
R: Can you explain this with the conservation of energy?

S2: Due to the conservation of energy, we breathe, use it, and exhale. Energy on earth is constantly transformed. Energies transform into something else but never disappear. In other words, an object has a potential energy and its potential energy transforms into Kinetic energy when released. Thus, because the existing energy is transformed, total energy is conserved.

It was revealed by the views and explanations of pre-service teachers that many of the pre-service teachers think of the earth as an insulated place and thus it is a transformational energy. Therefore, it was determined that most pre-service teachers have imperfect or incorrect knowledge of the first law of thermodynamics as they disregard the continuous effect of sunrays on earth. Moreover, it was also determined that most pre-service teachers use the word “insulated” to mean “blocking the energy flow,” and that they know the meaning of the word “insulated” in the second question. While it was determined that pre-service teachers see energy, water, oxygen, human body, and gravitational force as the basis of life, it was interesting to see that those who claim that the world is insulated also think of the sun and the gravitational force as the basis of life. In addition to these, it was also revealed that most of the pre-service teachers think that the energy of the earth is constant since the energy of the universe is so, and that they explain the conservation of energy with the energy of the universe being constant. However, it was determined that one pre-service teacher thinks that the total energy of the universe is not constant due to energy loss. In this respect, it can be claimed that pre-service teachers have imperfect knowledge about conservation of energy. As far as conservation of energy is concerned, it was seen that most pre-service teachers give correct explanations as they did in the previous question; however, it was thought that they have imperfect knowledge as they explain it as a contained energy circle that happens only within the earth. Additionally, it was also revealed that one pre-service teacher claims that energy is not conserved and that there should be an insulated environment for its conservation. Generally speaking, it was determined that pre-service teachers cannot fully associate the earth with the universe, and that they have imperfect knowledge on such concepts as energy and conservation of energy.

Third question asked to pre-service teachers was “Can energy be transferred without transformation? Explain by giving examples.” The answers of those who said that it could be transferred were grouped under the theme “contact” (48%) and the answers of those who said that it could not be transformed were grouped under the theme “transformational” (52%). Because most of the pre-service teachers thought that there should definitely be some sort of transformation, they claimed that energy cannot be tranferred without transformation. Details about the question are given below (Table 5):

In the semi-constructed interviews, it was revealed that 20% of students who had thought that energy could not be transformed also changed their opinions. Their explanations are as follows: “Electronic systems came to my mind. Thus, it [energy] cannot be transferred without transformation. Energy transference is energy transition between objects. Or I change my mind, it can be transferred. I remember the saying ‘Cold air entered [the room] when you opened the door, close it’ and here there is transference of energy without transformation. Or, someone who feels cold can get heat standing across the stove;” “It can be transferred. For instance in the Coulomb law experiment, when the balls touch they are charged with electricity and energy is transferred without transformation. I can transfer my own energy to you by heat transfer;” and “It can. If I hit the table, for example, energy is transferred without transformation.” As such, it was determined that most pre-service teachers thought that energy can be transferred without transformation. It can be claimed that those who expressed that energy cannot be transferred without transformation also have imperfect and incorrect knowledge about energy transference.

Table 5. *Pre-service Teachers' Views On Whether Or Not Energy Can Be Transmitted Without Transformation*

Themes / Frequency (%)	Codes / Frequency (%)	Explanations
Contact 12 (48%)	Transfer with Transmission 6 (24%)	• Heat is energy. It may not transform during transmission. For example, when boiling water, heat coming from the stove is transmitted without transformation. • It can be. Thermal energy from hot water to cold water is transferred without transformation. • It can be transferred. An example for this would be the heat exchange of two matters with different temperatures. • We can give heat as an example. Let's think of two masses with different temperatures. There would be heat exchange between masses. As heat is also a form of energy, it is transferred without transformation. • It can be transferred. For example the radiator.
	Transmission through action-reaction 6 (24%)	• It can be transferred. For example; if a car with Kinetic energy hits an unmoving car at the velocity v_o, with this energy transfer the unmoving car has Kinetic energy and can move. • It can be transferred. For example, colliding balls. When balls hit, Kinetic energy of one ball is transferred to the other without being transformed. • It can be transferred. For example, when I punch a wall, it is transferred due to the action-reaction principle. • It can be transferred. Heat can be transferred within a system. Energy that came into life through movement can provide movement to a different system. • It can be transferred. For example, when two cars with a certain velocity collide, they would move again due to the collision. • There is always an exchange in energy. I mean, in order to transfer energy you have to get it.
Transformational energy 13 (52%)	Transformation 13 (52%)	• Energy cannot be transferred without transformation. There is always transformation. • It cannot be transferred. To put it simply, if we want to get energy from the win, we use windmills. We turn it into energy and enrgy cannot be transferred without transformation, because the received and sent energy should be equal to one another. • Energy cannot be transferred without transformation. For example, we cannot get electricity and transmit it to our houses from the solar power, thermal energy or wind power without transforming their energy. • Energy cannot be transferred without transformation. There is potential energy in an unmoving object. The object moves and potential energy turns into Kinetic energy. For example, generation electricity from wind. Wind turns the baffles, so with the transformation of wind power, electric energy is obtained. • It cannot be transferred. It is transformed. E.g. dams. • It cannot be transferred. For example, in wind turbines, there is transformation when you get electric power from the water vapor.

Fourth question asked to pre-service teachers was "How would you explain the melting of ice cubes that rub against one another?" Pre-service teachers explained the melting of ice cubes that rub against one another under the following themes: friction (80%), pressure (8%), heat (8%), and temperature (4%). Most pre-service teachers indicated that ice melts because of the heat that stems from the friction of ice cubes (Table 6).

Table 6. *Pre-Service Teachers' Views On The Melting Of İce Cubes That Rub Against One Another*

Themes / Frequency (%)	Codes / Frequency (%)	Explanations
Friction 20 (80%)	Heat formation 10 (40%)	• Due to friction, there occurs heat. This heat will be transferred to the ice cubes and cause ice cubes to melt. • Since heat will come into being with friction, ice cubes melt with the movement of molecules. • Due to friction, there occurs warming, and heat comes into being due to the temperature which is transformed from hot environment to the cold one, and ice cubes melt. • As frictional force can happen on any surface, it happens in these ice cubes as well, and thermal energy occurs. Two cubes melt due to the heat after the balance with this energy. • Due to the energy that comes into being because of friction, some of the ice between the rubbed surface will melt and some will erode, and the mass of the ice will decrease. • They lose energy by rubbing against one another. Heat comes into being due to friction, and this causes them to melt. • If two objects with the same temperature rub against one another, heat comes into being due to friction. Electrification may also happen due to this friction. Thus, the object loses heat and starts melting.
	Movement 5 (20%)	• Friction enables movecules and particles to move. Thus, ice starts melting. • In friction, ice heats up due to movement and their temperature changes. Then they start melting.
	Heat exchange 5 (20%)	• There is energy exchange between rubbing ice cubes, because energy transforms. At the friction point energy comes into being and the ice melts. • With friction they exchange heat.
Pressure 2 (8%)	Pressure effect 2 (8%)	• Pressure accelerates melting and decreases melting point. • In my opinion, the main factor is pressure. It is not likely for mechanic energy to become thermal energy by friction.
Heat 2 (8%)	Heat exchange 2 (8%)	• There is direct heat transference. Environmen's energy is transferred to ice, ice transmutes. Heat transfer is from the one with high energy to the one with low energy. • It results from heat exchange between the two.
Temperature 1 (4%)	Increase in temperature 1 (4%)	• When ice cubes rub against one another, molecules start to move due to increase in temperature. Moving molecules gain energy, and ice cubes melt.

In the interviews, pre-service teachers uttered the following sentences which support their explanations: "With friction, there is energy transference, temperature increases and so does energy. Temperature is not energy but I had misstated it in the form, it should have been 'heat increases.'With friction, heat comes into being and melting happens." "With friction, heat energy comes into being. Heat is energy but temperature is a quantity," and "Due to friction, energy is spent, heat comes into being, and that energy melts the ice cubes." Other pre-service teachers indicated that "Due to friction, heat exchange takes place, and melting happens," and "Heat is an energy and with heat transfer comes heat exchange. Thus, ice cubes melt." In the interviews, it was seen that pre-service teachers realized and corrected their mistakes. Moreover, most of the pre-service teachers have the correct knowledge but some of them have incorrect or imperfect reasons because they have incorrect or imperfect knowledge.

Last question asked to pre-service teachers was "How is the energy transformation during the power generation at a dam?" Answers of pre-service teachers were gathered under the themes electric (80%), thermal (8%), Kinetic (4%), and mechanical (4%). Themes determined by the researcher were formed based on the energy type indicated by the pre-service teachers. As a result of the study, it was determined most of the pre-service teachers think that during power generation at a dam Kinetic energy transforms into electric energy and potential energy transforms into Kinetic energy. Detailed explanations about the question were given in Table 7.

Table 7. *Pre-Service Teachers' Views On Energy Transformations That Take Place During Generation Of Energy at a Dam*

Themes / Frequency (%)	Codes / Frequency (%)	Explanations
Electric 20 (80%)	*Potential → Kinetic → Electric* 7 (28%)	• Water accumulates in dams and this water has lots of potential energy. I mean, potential energy turns into kinetic energy, and kinetic energy turns into electric energy. Thus, light and energies we use in daily life come into being.
	Kinetic → Electric 7 (28%)	• Kinetic energy, due to the movement of water, and water energy, by hitting the turbines, turns into electric energy with the help of hydroelectric plants.
	Mechanical → Electric 3 (12%)	• Due to the flow of water, mechanical energy turns into electric energy.
	Kinetic → Mechanical → Electric 2 (8%)	• There isa need for a source for generating electricity at a dam. Water that comes and accumulated at the dam has kinetic energy. Then, this energy that is used turns into mechanical energy, and finally electric energy is produced.
	Kinetic → Potential → Electric 1 (4%)	• Water has kinetic energy due to its velocity. Kinetic energy of water turns into potential energy after that water reaches a certain height and mileage. Electric energy is got from this potential energy.
Heat 8 (%)	*Potential → Kinetic → Thermal* 2 (8%)	• Energy at dams turns into thermal energy. Potential energy turns into kinetic energy, and kinetic energy turns into thermal energy and thus into the kind of energy we use daily.
Kinetic 2 (8%)	*Potential → Kinetic* 2 (8%)	• Potential energy turns into kinetic energy.
Mechanical 1 (4%)	*Kinetic → Mechanical* 1 (4%)	• Kinetic energy turns into mechanical energy.

In the semi-conducted interviews conducted with the participation of 20% of the pre-service teachers, it was determined that they expressed their views under the theme "electric." Data obtained from the views of some pre-service teachers are as follows:

PT1: "Water stops, hits the panels, and potential energy turns into Kinetic energy, then electricity power is generated."
PT3: "Energy transformation takes place with motional energy, in other words, Kinetic energy, and electricity is generated from Kinetic energy."
PT4: "Mechanical energy turns into electric energy. Mechanical energy is the sum of Kinetic and potential energy."
PT5: "Mechanical energy turns into electric energy. Water that has Kinetic and potential energy hits the wall very fast and thus transformation takes place, and electric power is generated."

By looking at the views and explanations of pre-service teachers, it was determined that they have incorrect or imperfect knowledge about energy transformation because most of them provided correct answers yet incorrect or imperfect reasons in their explanations. Moreover, it can also be claimed that they could not associate energy transformations with daily things nor could they express them properly.

Lastly, pre-service teachers were asked "Do the concepts you have learned at thermodynamics course help you understand daily life events? Explain" during the interviews. Most of the pre-service teachers indicated that those concepts helped them understand daily life events, while one pre-service teacher expressed that he/she could not associate these concepts with daily life as he/she merely focused on things that would be likely in the exam of the course. Views of pre-service teachers are as follows:

PT1: "Yes, definitely. The expression 'Cold air enters [the room] when you open the door, close it' was wrong. I had said when ice cubes rub onto one another temperature increases, but I have learned that it is wrong. I got definite knowledge about energy transformation. I have a better command of energy as a concept now. I can relate the laws of thermodynamics to daily life."
PT2: "Yes, definitely. They say body heat, but it is in fact body temperature. I learned my mistake in this course."
PT3: **"**I haven't yet related what I have learned in class to daily life. Since I have only studied with the exam in my mind, I can only recall the formulas at the moment."

It was determined that pre-service teachers think that "Thermodynamics" course helped them understand and interpret daily life topics. Moreover, it was revealed through their views that they realized the misconceptions they had had before taking this course and that they reached correct knowledge with the learning they had in this couse.

DISCUSSION, CONCLUSION and SUGGESTIONS

In this study, conceptual comprehension of pre-service physics teachers of a state university about the first law of thermodynamics, which is part of the junior year "Thermodynamics" course, was determined by the energy concept form, which consists of open-ended questions and students'conceptual understanding, drawings and explanations, and semi-constructed interviews conducted to support the data.

As a result of the study, it was determined that pre-service physics teachers depict energy as an object with potential energy, as electric power, and as vibration energy. In addition to these, it was also determined that pre-service teachers explain enrgy as a moving object, an impact that diffuses from a certain source, as wave, and as an entity. Thus, it is evident that pre-service teachers try to explain energy through concrete things. In literature, energy is known to be depicted as a house, cloud, light, electric circuit, windmill, propeller, computer, car, and the sun (Pastırmacı, 2011; Yürümezoğlu, Ayaz & Çökelez, 2009). In the study, it is believed that teaching should be assisted with experiments, videos, games, and animations in order for students to concretize the concept of energy (Hırça, Çalık & Seven, 2011). Another finding is that pre-service teachers mistakenly thought that insulated as a word means preventing energy transference. Pre-service teachers also think that the earth is insulated and thus there is a confined transformational energy within it. As a result of the study, it was revealed that permanent effect of sunrays on earth is disregarded and hence pre-service teachers have imperfect or incorrect knowledge about the first law of thermodynamics. As for the expression "total energy in the universe is constant," it was determined that pre-service teachers think that the energy of the earth is constant as the energy of the universe is so and that they explain the constancy of energy in the universe by the conservation of energy. Moreover, on a similar vein with the study of Gülçiçek and Yağbasan (2004), this study, too, points at the misconception "the total energy in the universe is not constant due to energy loss." When whether or not the pre-service teachers knew the concept of conservation of energy was examined, it was seen that they depicted conservation of energy as energy transformation and the conservation of total energy, but that they also explained conservation as an energy cycle confined to the earth only. Although it is known that energy transformations and transference take place in the universe since it is a system and it is also known that energy transference does not occur in the universe because it is completely insulated and energy amount is constant (Tekbıyık, 2010), by looking at the results, it is thought that pre-service teachers confuse the characteristics of the earth with those of the universe or that they have difficulty associating the earth with the universe. Then, when they were asked what the basis of life on earth is, it was determined that pre-service teachers used such expressions as energy, the sun, water, oxygen, human body, and gravitational force. Thus, it was revealed that some pre-service teachers confused the characteristics of the earth with the characteristics of the universe by making incorrect explanations and thinking that the earth is in fact not insulated. In addition, it was also determined that pre-service thinkers indicated that energy cannot be transferred without transformation since they believe that tere should definitely be a transformation in energy. This view is also in accordance with Tekbıyık's (2010) study, and it puts forth that pre-service teahers cannot properly differentiate energy transformation and conservation of energy. It is believed that energy transformation and conservation of energy as concepts should be taught in more detail and by relating them to daily life (Çoban, Aktamış & Ergin, 2007). Pre-service teachers who expressed that energy could be transferred without transformation think that this transference takes place through transmission and cause-effect (Tekbıyık, 2010). While there is continuous collision in transfer through cause-effect, there is heat exchange due to temperature difference in transfer through transmission. At the end of the study, it was determined that pre-service teachers cannot properly distinguish related concepts from one another. Same result pops in similar studies, and it was seen that students can easily misuse concepts related to energy interchangeably and that it creates a conceptual problem (Yürümezoğlu, Ayaz & Çökelez, 2009; Amettler & Pinto, 2002). It is believed that this issue stems from the fact that these concepts are not handled in detail during teaching and that this may cause conceptual misunderstandings. Another finding of the study is that pre-service physics teachers believe that pressure, increased temperature and heat transfer are effective in the realization of melting and the formation of heat. As Töman and Çimer (2012) also contend, although pre-service teachers have correct knowledge about energy transformation, they have incorrect or imperfect reasonings when they try to explain things, and it is believed to be stemming from rote learning and from lack of a meaningful learning. Thus, it can be said that they cannot explain daily phenomena. Accordingly, when pre-service teachers' explanations – Kinetic energy turns into electric energy, and potential energy turns into Kinetic energy which then turns into electric energy – were examined, it was seen that most of them gave the correct answer but that their reasons were different from one another. As a result, it was concluded that pre-service teachers could not properly relate their theoretical knowledge on energy transformation to daily phenomena. It is believed that this problem can be solved by explaining energy transformation over and over through different examples (Töman & Çimer, 2012). In general, it is believed that topics within the first law of thermodynamics, which is the basis of events in nature, should be taught, beginning with primary school, in relation to daily life (Kırtak, 2010).

Finally, in the study it was determined that concepts pre-service teachers learn at thermodynamics course is helpful in understanding daily phenomena, but that some pre-service teachers indicate they cannot relate the topics to the daily things. It is thought to be due to the fact that thermodynamics class is basically taught through the heavy use of mathematical expressions; and it is also believed that pre-service teachers can learn the concepts in a meaningful way only when they are taught by relating to daily life. Moreover, it was determined that pre-service teachers have realized their misstatements which result from daily language such as "When I open the door, cold comes from outside, and the house gets cold, close the door." It was also determined that they believe they have reached correct knowledge. Studies show that pre-service teachers' misconceptions usually stem from spoken language and that these misconceptions affect their later learning negatively (Palmer, 1999; Yılmaz, Tekkaya, Geban & Özden, 1999).

After the completion of the study, it can be said that instructors who teach thermodynamics classes should relate the concepts to daily life, explain them through different examples. Finally, it can be suggested that while teaching such an abstact concept as the first law of thermodynamics, such activities as different animations, experiments, and field trips or new teaching methods should be effectively employed (Kaper, & Goedhart, 2002; Kırtak, 2010).

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