JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898

THE EFFECT OF CONCEPTUAL CHANGE TEXTS ENRICHED WITH METACONCEPTUAL PROCESSES ON PRE-SERVICE SCIENCE TEACHERS' CONCEPTUAL UNDERSTANDING OF HEAT AND TEMPERATURE

Nejla Yürük,
Pınar Eroğlu

Abstract. *The purpose of this research was to compare the effect of conceptual change texts enriched with metaconceptual processes with the effect of refutational and expository texts on pre-service science teachers' conceptual understanding of heat and temperature. The durability of the effect of the texts on pre-service science teachers' conceptual understanding was also examined. A pre-test- post-test experimental research design was employed. One hundred and five pre-service teachers who were enrolled in an Elementary Science Teacher Education Program of a public university located in Turkey participated in this research. They were randomly assigned to three treatment groups each of which read a different type of texts. Heat and Temperature Concept Test (HTCT) was administered as a pre-test, post-test and delayed test to assess the participants' conceptual understanding of heat and temperature concepts. The results show that the conceptual understanding of pre-service teachers who read conceptual change text enriched with metaconceptual processes was significantly better than that of the other groups and this significantly positive effect did not diminish eight weeks after reading the texts.*

Key words: *conceptual change text, metaconceptual processes, heat and temperature, pre-service science teachers.*

Nejla Yürük
Gazi University,
Ankara, Turkey
Pınar Eroğlu
Ministry of National Education,
Ankara, Turkey

Introduction

In the last decade scientific literacy has become a major goal for science education internationally. Among its various components, a scientifically literate person is expected to accurately apply appropriate science concepts, principles, laws, and theories in interacting with the universe (Tomas & Ritchie, 2015). However, over the past 30 years research in science education has well shown that students of all ages have conceptions which are mostly inconsistent with scientific thinking (Taber, 2014)). In the literature various terms, such as *alternative conceptions* (Dove, 1998), *misconceptions* (Posner, Strike, Hewson, & Gertzog, 1982), *children's science* (Bell, 1993), *preconceptions* (Novak, 1987), *mini-theories* (Claxton, 1993), *initial explanatory frameworks* (Vosniadou, 2002), *alternative frameworks* (Barnett & Morran, 2002; Gilbert & Watts, 1983), and *children's ideas* (Driver, Guesne, & Tiberghien, 1985) have been used for students' ideas that are inconsistent with scientific conceptions. Within this paper, "alternative conception" was used as a neutral term for labeling students' conceptions.

Studies carried out about students' alternative conceptions have changed researchers' understandings of what learning science is and how it occurs. This changed understanding led to the development of a learning model which is called Conceptual Change Model (Posner et al., 1982). In the Conceptual Change Model (CCM) Posner et al. (1982) explained the conditions that need to be fulfilled for an individual to experience conceptual change, and the components of individual's conceptual ecology. There are four conditions that need to be satisfied before conceptual change can take place: (a) the learner must be dissatisfied with the existing conception, (b) the learner must find the new conception to be intelligible; (c) the learner must regard the new conception to be plausible, and (d) the learner must find the new conception to be fruitful, and the new conception must lead to new insights (Posner et al., 1982). Conceptual ecology "provides the context in which the conceptual change occurs and has meaning" (Hewson & Thorley, 1989, p.

ISSN 1648–3898

541). Learners' conceptual ecology, including epistemological commitments, metaphysical beliefs, anomalies, analogies, metaphors, and other knowledge, serves as a base for determining what counts as a valid explanation of a phenomena. Although Conceptual Change Model has inspired a great deal of research that focused on inventing or testing the effect of numerous teaching ideas developed to support the change in individuals' conceptions (Beeth, 1998; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Duckworth, 1997, Hennessey, 1999), it is considered as a "cold" description of the change in individuals ideas because it focused on cognitive structures alone and did not account for affective, motivational, or contextual factors (Pintrich, Marx, & Boyle, 1993).

By the mid-1990s many researchers from the field of educational psychology began to take a closer look at the conceptual change process. They mainly focused on the nature of the development of alternative conceptions. They drew attention to the role of learners' ontological (Chi et al., 1994) and epistemological presuppositions (Vosniadou, 1994), and their "self-explanatory" everyday experiences (diSessa, 1993) in the development of alternative conceptions. These theoretical approaches suggest that learners should juxtapose their existing conceptions against new conception, recognize, integrate and evaluate their existing and new conceptions, associated commitments, everyday experiences and contextual factors to change their alternative conceptions with scientific ones.

The intentional conceptual change perspective is a relatively recent model of how students restructure their conceptual understandings. It utilizes the concept of intentional learning, which can be simply defined as "cognitive processes that have learning as a goal rather than an incidental outcome" (Bereiter & Scardamalia, 1989, p.363), to explain the self-regulated dimension of conceptual change. Sinatra and Pintrich (2003) who advocated for a "warmer" perspective of conceptual change, namely intentional conceptual change perspective, postulated that conceptual change depends not only on cognitive factors but also on metacognitive, motivational, and affective processes. They described intentional conceptual change as "the goal-directed and conscious initiation and regulation of cognitive, metacognitive, and motivational process to bring about a change in knowledge" (Sinatra & Pintrich, 2003, p.6). This perspective highlighted the role of metacognition by suggesting that learners must be aware of the need for change, be able to know what to change, and be able to regulate their change process using cognitive and metacognitive strategies (Luques, 2003).

Due to its multifaceted nature, metacognition has been used as an umbrella terms which covers various types of knowledge and processes regarding one's cognition (Veenman et al., 2006). Metacognition, thinking about thinking, is broadly defined as "one's knowledge and control of own cognitive system" (Brown, 1987, p. 66). Hennessey (2003) described it as one's "inner awareness" about one's learning process, what one knows (content knowledge), or one's current cognitive state. As these definitions suggest, metacognition is a complex and broad construct. It covers a wide range of mental processes which are not limited to those specific to concept learning.

In recent years, an increasing number of researchers preferred to use the term "metaconceptual" to refer to the metacognitive processes that are acting on the content of students' conceptions (Vosniadou, 2003; Yürük, Beeth & Andersen, 2009). Yürük (2005) proposed a taxonomy that classified different types of metaconceptual processes. According to this taxonomy, there are three main types of metaconceptual processes: (1) metaconceptual awareness, (2) metaconceptual monitoring, and (3) metaconceptual evaluation. Within metaconceptual awareness, there are two types of awareness: first-order metaconceptual awareness and second-order metaconceptual awareness. First-order metaconceptual awareness refers to learners' recognition of stored or dynamically generated representations or ideas about the physical world and elements of their conceptual ecology. Second–order metaconceptual awareness involves one's awareness of ideas and elements of conceptual ecology that they had in the past. Metaconceptual monitoring involves online processes that generate information about an ongoing cognitive process or cognitive state regarding learning a new concept. Metaconceptual monitoring processes are subcategorized into: monitoring understanding of an idea, monitoring information coming from other people or sources, monitoring the consistency between existing idea and new information, monitoring existing idea, and new experience and monitoring changes in ideas. Metaconceptual evaluation is a process in which learners make judgmental decisions about competing ideas and provide justifications for them. As learners engage in metaconceptual evaluation they make comments about the plausibility and usefulness of ideas, choose one idea among several alternatives and provide justifications for the validity of the chosen idea.

Since students' alternative conceptions resist to change after formal instruction, various instructional methods have been developed based on the theoretical accounts on conceptual change process. One type of the instructional materials that aim to change students' alternative conceptions with scientifically acceptable conceptions is refutational or conceptual change texts. Conceptual change texts are texts that warn students about possible alternative conceptions and present scientific explanations while pointing out the inconsistency between alternative and scientific conceptions. Many studies have shown that refutational or conceptual change texts help students change their alternative conceptions in a variety of science topics (Çetin, Ertepinar & Geban, 2015; Hynd & Alverman, 1986; Yenilmez & Tekkaya, 2006). Although researchers pointed out the critical role of metacognitive processes in promoting the effect of conceptual change texts on students' conceptual understanding (Palmer, 2003) studies that aim to investigate the effect of conceptual change texts that facilitate learners' metacognitive processes have not been found in the literature. The purpose of this research was to compare the effect of conceptual change texts enriched with metaconceptual processes with the effect of refutational and expository texts on students' conceptual understanding of heat and temperature. Moreover, the durability of the effect of the conceptual change texts enriched with metaconceptual processes was also investigated in this research.

Methodology of Research

General Background of Research

A pre-test post-test experimental research design was employed to compare the effect of three different types of texts on pre-service science teachers` understanding of heat and temperature concepts and to investigate the durability of this effect. One week before the reading interventions, Heat and Temperature Concept Test (HTCT) was administered as a pre-test to pre-service teachers who were enrolled in three classes of the Science Education Programme of a university located in Turkey. 105 pre-service teachers who participated in this research were randomly assigned to three treatment groups each of which read a different type of texts. One week after reading the texts Heat and Temperature Concepts Test was administered again to all groups as a post-test. In order to investigate the durability of the effect of the texts on pre-service teachers` conceptual understanding the same test was employed eight weeks after the administration of the post-test. The research design is summarized in Table 1.

Table 1. Research design.

Groups	Pre-Test	Treatment	Post-Test	Delayed-Test
Control Group	HTCT	Expository Texts	HTCT	HTCT
Experimental Group1	HTCT	Refutational Texts	HTCT	HTCT
Experimental Group 2	HTCT	Conceptual Change Texts Enriched with Metaconceptual Processes	HTCT	HTCT

Participants of the Research

The participants of this research consisted of 105 pre-service science teachers who were enrolled in three classes of the Elementary Science Teacher Education Programme of a public university located in Ankara, Turkey. Students who graduate from this program teach science to middle school students (grade 6-8). The participants were in the third year of their education. During their enrollment in the program they took two undergraduate level courses regarding heat and temperature concepts, including an introductory chemistry course and a physics course. Participants were randomly assigned to three treatment groups so as there were 35 pre-service teachers in each group. The group who received expository texts consisted of 9 male and 26 female pre-service teachers; in the group who read refutational text there were 14 male and 21 female pre-service teachers, and in the group who read conceptual change texts enriched with metaconceptual processes there were 12 male and 23 female pre-service teachers. Throughout the time between post-test and delayed-test the pre-service teachers did not take any course related to heat and temperature concepts.

ISSN 1648–3898

Instruments

In order to assess pre-service teachers` conceptual understanding of heat and temperature concepts a multiple choice concept test was administered to three groups a week before, a week after and 9 weeks after the texts were read. The Heat and Temperature Concept Test (HTCT) consisted of 30 multiple choice items each of which involved one correct answer and four distracters that specifically address students` alternative conceptions. Before developing the test items, a list of students` probable alternative conceptions was prepared after reviewing the literature regarding this phenomenon. Eight items used in the test were developed by Başer (1996), 5 items were taken from the test developed by Yeo and Zadnik (2001) and 7 items in the test were developed by the researchers. In order to ensure the content validity of the test, a table of specifications was generated by listing the alternative conceptions and test items that are intended to assess the listed alternative conceptions. For the assurance of face and content validity the items of the test were checked by a professor of science education and a professor of chemistry. Necessary modifications were made based on the experts` comments before administering the test to a group a 35 third year pre-service science teachers who were enrolled in the science education program of a different university. The reliability analysis generated based on the data collected from this group resulted in a Cronbach Alpha as .69. As a result of this pilot study the content of an item which reduced the reliability of the test was altered by minimizing the ambiguity in that item. The Cronbach Alpha calculated by using the data gathered through the administration of the test to the participants of the study was found as .75. An example to questions used in the HTCT can be found in the Appendix.

The Nature of Texts Used In This Research

Three types of texts were used in this study: (1) conceptual change texts enriched with metaconceptual processes, (2) refutational texts and (3) expository texts. After they were developed by the researchers the texts were checked by a professor of science education and a professor of chemistry education to ensure that the scientific ideas presented in the texts are valid and they are designed in a way that is intended by the researchers. In order to check whether the developed texts are understandable to readers, a group of students (n=33) were requested to read the texts. These students graduated from high school and took private science courses to prepare for university entrance examination. They were asked to identify the pieces that are complex and not meaningful. The texts were revised based on the comments of the experts and students. The characteristics of each type of texts are presented below.

Conceptual Change Texts Enriched with Metaconceptual Processes (CCTMP). This type of texts differs from regular conceptual change texts or refutational texts in the elements that aim to activate students' metaconceptual processes which were classified by Yürük (2005) and Yürük, Beeth and Andersen (2009). These texts do not only compare and contrast students probable alternative conceptions with scientifically accepted conceptions of heat and temperature but they also provide an opportunity for the students to: (a) reflect on their existing conceptions, the associated ontological presuppositions, past experiences, and contexts in which concepts are used; (b) make reference to their past ideas; (c) monitor their understanding of the new conception, ideas coming from different sources, the consistency between existing ideas and information coming from other sources and the change in ideas; and (d) evaluate the relative ability of competing conceptions to explain a physical phenomenon.

In addition to the elements which activate metaconceptual processes, CCTMP involves six conceptual change texts which present students' probable alternative conceptions and scientifically accepted ideas about heat and temperature. Conceptual change texts were written on the basis of the conditions in the conceptual change model proposed by Posner et al. (1982). Scientific ideas were portrayed in a way to make them understandable and plausible to students. Examples from daily life and analogies were presented when applicable. Students' probable ontological and epistemological presuppositions which stand as the cause of students alternative ideas about heat and temperature concepts (Chi et al., 1994) were provided in this part of the texts. For example, students were warned that people's perceptions through their sense organs do not always reflect the reality, therefore, the metal part of a chair that we feel colder does not mean that the temperature of the metal part is lower than the temperature of the wooden part of the chair. Definitions and scientific explanations that need to be emphasized were made bold throughout the texts. Students were reminded that students' understanding of the natural phenomenon might sometimes be different from the scientifically accepted ideas.

Different metaconceptual processes were facilitated by different elements throughout the texts. In order to activate students' awareness of their existing ideas three key concepts, such as heat, temperature and energy were provided and students were asked to describe the relationship among these concepts. Students' awareness of their experiences regarding heat and temperature concepts was activated through examples from daily life given in the form of conceptual cartoons. A major source of students' alternative conceptions regarding heat is their classification of heat concept into an inappropriate ontological category (Chi et al., 1994). Students assign ontological attributes possessed by material substances rather than processes to heat concept. In order to make students aware of their ontological assumptions regarding heat, examples from history of science, namely caloric theory, were presented and students were asked if their ideas about heat were similar to those in caloric theory or not. Throughout the CCTMP different situations from daily life were provided and students were asked to compare and contrast different cases in terms of heat and temperature. For example, students were asked to compare the amount of temperature and heat of a big and a small wood table if they think the tables possess any. One type of metaconceptual awareness is students' awareness of what they do not know. While reading CCTMP students are intended to notice their weaknesses and gaps in their conceptual structure as they answer several questions interspersed throughout the texts.

Students engage in second order metaconceptual awareness when they make reference to the ideas they had in the past. In CCTMP students' use of this type of awareness was activated through asking their initial ideas they had before reading the scientific ideas.

Metaconceptual monitoring involves students' "online and in the moment" processes that produce information about an ongoing cognitive activity, thinking process, or present cognitive state with respect to the newly presented information. In order to enable students to monitor their understanding of new ideas they were asked if they understood the scientific explanations or not and they were encouraged to read the text again if they did not understand it. Students' monitoring of the consistency between their existing ideas and the ideas presented in the texts was initiated by asking students if their ideas were different from those in the texts. Another form of metaconceptual monitoring involves students' monitoring of the changes in their ideas. Students were stimulated to notice the changes in their ideas through requesting them to compare their initial and current ideas regarding variety of situations about heat and temperature at several points of the texts.

As students metaconceptually evaluate competing ideas they make judgmental decisions about validity, plausibility and usefulness of different ideas. When students were provided with different ideas about heat and temperature concepts in the form of conceptual cartoons they were asked to choose one idea over the others and justify why they thought that idea was valid. Additionally, they were requested to compare and contrast different ideas (e.g., caloric theory vs. kinetic theory) presented in the texts in terms of plausibility and usefulness. Some excerpts from CCTMP are provided in Appendix.

Refutational Texts. Refutational texts (RT) used in this study do not involve elements which aim to facilitate metaconceptual processes. Rather refutational texts involve students' probable alternative conceptions and scientific explanations about heat and temperature concepts. The texts were designed with the aim of satisfying the conditions proposed in the conceptual change model (Posner et al., 1982). Refutational texts were written after CCTMP were developed. Refutational texts and CCTMP share the same content in terms of the scientific content, analogies and examples. There were three pieces of refutational texts in three content areas of heat and temperature concepts: Heat and temperature, specific heat and thermal insulation. Refutational texts were not interactive in the way that CCTMP were. They did not direct any questions to the readers. Similar to the CCTMP, refutational texts involved students' probable alternative conceptions, the reasons why students had those alternative conceptions and students' probable ontological and epistemological assumptions that lead to alternative conceptions. The scientific ideas were contrasted with alternative conceptions and necessary arguments were provided to convince students. Important explanations that needed to be emphasized were made bold like in CCTMP.

Expository Texts. Expository texts (ET) used in this study were designed after CCTMP and refutational texts. In terms of the scientific content, expository texts entailed the same scientific content, examples and analogies. Expository texts were very similar to the texts that can be found in many textbooks. However, the content of the texts focused on the concepts related to heat and temperature rather than the mathematical calculations. Expository texts did not involve students' probable alternative conceptions or any arguments that refute students' alternative ideas. Like refutational text expository texts were not interactive but they presented scientific content in a meaningful and reasonable way.

ISSN 1648–3898

Reading the Texts. The texts were read by pre-service teachers in two large classrooms of the university at the same time. Since pre-service teachers were randomly assigned to three groups, the researchers had a list of students who were supposed to read a specific type of text. The texts were distributed to the students according to this list. Students were asked to sit as apart from each other as possible to eliminate the interaction among them. A silent environment was provided for the pre-service teachers to minimize distractions during reading the texts. Pre-service teachers were told that they may spend as much time as they wish to read the texts and do all the activities in the texts so that they did not read the texts under time pressure. Pre-service teachers were requested not to ask any questions regarding the content of the texts to the researchers or their classmates during or after reading the texts. No discussion regarding the content of the texts or any alternative conceptions about heat and temperature was held before or after reading the texts because the aim of the study was only to assess the effectiveness of reading the texts rather than the effect of discussion of any concepts in the texts.

Data Analysis

In order to compare conceptual understanding of pre-service teachers about heat and temperature concepts prior to the reading of the texts One-way ANOVA with α=0.05 was generated. Since no significant difference was found in students' pre-test scores One-Way ANOVA was employed to investigate the differences in students' post-test and delayed test scores.

Results of Research

The means and standard deviations calculated for pre-test, post-test and delayed-test scores of groups who read different types of texts are presented in Table 2.

Table 2. Means and standard deviations of students' scores on pre-, post- and delayed-tests.

		Pre-Test		Post-Test		Delayed-Test	
Groups	**N**	$\overline{X}$	**SD**	$\overline{X}$	**SD**	$\overline{X}$	**SD**
ET*	35	14,800	4,085	16,942	3,788	14,485	4,347
RT**	35	14,800	4,071	19,828	3,459	15,857	3,671
CCTMP***	35	15,400	4,420	23,342	3,446	19,457	4,153
Total	105	15,000	4,164	20,038	4,404	16,600	4,545

**Expository Texts; **Refutational Texts, ***Conceptual Change Texts Enriched With Metaconceptual Processes*

As seen in Table 2, prior to reading the texts, there was a very slight mean difference between the groups in terms of their pre-test scores. The mean of the scores achieved by students who read CCTMP was the highest both in the post-test and delayed test. Every group showed an increase from pre-test to post-test. However, the increase from pre-test to post-test was the highest for the group who read CCTMP. As Table 2 shows, although there was a decrease from post-test to delayed test in each group, the mean of delayed test scores for the group who read CCTMP was still the highest among all groups.

In order to compare pre-service teachers' conceptual understanding that they had prior to reading the texts One-way ANOVA was generated. The results of ANOVA are summarized in Table 3.

Tablo 3. Results of ANOVA on pre-test scores.

Source	Sum of Squares	df	Mean Squares	F	p
Within Groups	8.400	2	4.200	.239	.788*
Between Groups	1795.600	102	17.604		
Total	1804.000	104			

**p>.05*

As Table 3 shows, a non-significant F value ($F_{(2, 102)}$=.239; p> .05) was found as a result of ANOVA generated for pre-test scores. This result indicates that prior to reading the texts, there was no significant mean difference among groups in terms of their conceptual understanding of heat and temperature. Pre-service teachers' conceptual understanding of heat and temperature after reading the texts was compared by using One-way ANOVA. The results of ANOVA generated by using post-test scores are presented in Table 4.

Table 4. Results of ANOVA on post-test scores.

Source	Sum of Squares	df	Mean Squares	F	p
Within Groups	719.105	2	359.552	28.238	.000001*
Between Groups	1298.743	102	12.733		
Total	2017.848	104			

**p< .05*

Table 4 shows that there was a significant mean difference among groups in terms of their post-test scores ($F_{(2, 102)}$)= 28.238; p<.05). The significant F value generated for post-test scores indicates that there was a significant mean difference among groups who read different types of texts in terms of their conceptual understanding of heat and temperature assessed after reading the texts. Scheffe test was performed to identify the groups which had significant mean difference on post-test scores. The result of Scheffe test revealed significant mean differences among all groups in terms of their post-test scores. Conceptual understanding of pre-service teachers after reading the CCTMP (X_{CCTMP}=23,34) was significantly better than the conceptual understanding of the pre-service teachers who read refutational texts (X_{RT}= 19.83) and expository texts (X_{ET}= 16.94). After reading the texts, conceptual understanding of pre-service teachers who read refutational texts was significantly better than those who read expository texts. Eta square was calculated as 0.356 indicating a large effect size according to Cohen (1988). The value for eta square indicates that about %36 of the variance on post-test scores was explained by the use different texts.

In order to examine the durability of the significant differences which existed after reading the texts, means of the group's scores on delayed test were compared by using ANOVA. The results of ANOVA generated by using students' delayed-test scores which were assessed 8 weeks after reading the texts are presented in Table 5.

Table 5. Results of ANOVA on delayed-test scores.

Source	Sum of Squares	df	Mean Squares	F	p
Within Groups	461.486	2	230.743	13.945	.000001*
Between Groups	1687.714	102	16.546		
Total	2149.200	104			

**p< .05*

As seen in Table 5, ANOVA generated by using delayed test scores resulted in a significant F value ($F_{(2,102)}$= 13.945; p< .05). The results revealed a significant mean difference among groups in terms of their delayed test scores. The results of Scheffe test showed that there was a significant mean difference between the groups who read CCTMP (X_{CCTMP}=19,457) and RT (X_{RT}=15,857) in terms of their delayed test scores. A significant mean difference was also found between groups who read CCTMP and ET (X_{ET}= 14,485). No significant mean difference was found between the groups who read RT and ET. This result suggests that 8 weeks after reading the texts, the positive effect of the refutational texts compared to the effect of expository texts on pre-service teachers' conceptual understanding that was observed a week after reading the texts was diminished. However, the positive effect of the CCTMP compared to the effect of other types of texts did not diminish after 8 weeks because there was found a significant difference between groups who read CCTMP and other types of texts in terms of their delayed test scores.

ISSN 1648–3898

Discussion

The results of this research showed that the conceptual understanding of pre-service teachers who read CCTMP was significantly better than that of the other groups and pre-service teachers' conceptual understanding who read refutational text was significantly better than those who read expository texts. The difference in the groups' conceptual understanding regarding heat and temperature can be attributed to the differences in the nature and structure of different types of texts because in this research pre-service science teachers were randomly assigned to the groups and there was found no significant mean difference among groups prior to reading the texts in terms of their conceptual understanding. The results regarding the effect of refutational text over expository texts was not an unexpected result and it was consistent with the result of the previous studies. Studies that have been conducted to examine the effect of refutational or conceptual change text have showed positive effect of these type of texts on changing students' alternative conceptions with scientifically accepted conceptions and promoting their conceptual understanding (Guzzetti et al., 1992; Hynd et al., 1994; Chambers & Andre, 1997; Yürük, 2000; Dilber, 2006; Sevim, 2007; Yürük, 2007a; Sendur & Toprak, 2013). Compared to the group who read traditional expository texts, preservice teachers who read refutational texts had the opportunity to recognize the alternative ideas about heat and temperature that they potentially might have and the reasons and the assumptions of students who had those alternative ideas. They also had the opportunity to compare and contrast alternative conceptions with the scientifically accepted conceptions and construct the scientifically accepted conceptions in a meaningful and plausible way.

With respect to the positive effect of CCTMP over the refutational and expository texts, CCTMP was more interactive in a way that it involved several prompts which aimed to activate various types of metaconceptual processes. Preservice teachers were asked to choose the most meaningful and plausible idea among different ideas provided by imaginary characters who had scientifically accepted conceptions and alternative conceptions. In doing so, preservice teachers had the opportunity to reflect on their existing alternative conceptions, the reasons and ontological and epistemological assumptions behind their ideas. They were also able to evaluate competing ideas in terms of their intelligibility and plausibility. In these texts as the preservice teachers read the texts they were able to write their ideas regarding concepts and various situations about heat and temperature in the form of giving response to several questions. Therefore, as they read the texts, they were able to make references to their past ideas by going back and forth to their previous responses. By doing so, they had the opportunity to compare and contrast their past ideas with the ideas provided in the text. The readers were facilitated to monitor their comprehensions of the texts by asking them whether or not they understood the parts they read at several points. They were encouraged to reread the parts that they did not understand. Readers were also encouraged to monitor the changes in their ideas as they were prompted to answer questions regarding to what has changed in their ideas about some specific concepts. They were prompted to provide reasons to why their ideas were changed. The positive effect of metaconceptual processes on students' conceptual understanding was reported in several studies (Blank, 2000; Wiser & Amin, 2001; Yürük, 2005; Georghiades, 2006; Yürük, 2007b; Yürük, Beeth & Andersen 2009; Yürük, Selvi & Yakışan, 2011; Zohar & Barzilai, 2013). Unlike the present study, metaconceptual processes were not activated with prompts used in texts in these studies. Rather, they were prompted by using several instructional activities, such as journal writing, discussion, poster drawing, prompts used along with computer based models. Therefore, this research contributed to the literature in terms of including metaconceptual processes into a teaching material which can be used as a supplement to instruction.

An important issue in science teaching is learners' regression to their alternative ideas after some time following the instruction (Georghiades, 2001). Therefore, maintaining students' conceptual understanding after a time period after the instruction is a major problem. The results regarding the delayed test pointed out the durability of the effect of CCTMP on pre-service teachers' conceptual understanding about heat and temperature. The positive effect of CCTMP over refutational and expository texts was maintained 8 weeks after reading the texts. There was found no significant mean difference between pre-service teachers who read RT and ET in terms of their delayed test scores although the mean difference just after reading the texts was significant. This result indicated that the test scores of pre-service teachers who read RT became closer to the test scores of pre-service teachers who read ET 8 weeks after reading the texts. However, the test scores of pre-service teachers who read CCTMP did not drop to the level of pre-service teachers who read RT and ET. Pre-service teachers who read CCTMP maintained their relatively better status in terms of their conceptual understanding. This result indicates that activating metaconceptual processes in the texts not only had significantly positive impact following the instructional interventions, but the positive difference in favor of the group who read CCTMP lasted for 8 weeks. The long-term impact of facilitating metaconceptual processes on students' conceptual understanding was also reported in several studies (Blank, 2000; Yürük, Beeth & Andersen, 2009).

The result regarding the durable impact of CCTMP on students' conceptual understanding implies that metaconceptual processes prevent the re-appearance of students' alternative ideas. Vosniadou (2003) pointed out that learning of individuals who are metaconceptually aware of their ideas, presuppositions, and the changes in their ideas is less "fragile." Yürük, Beeth and Andersen (2009) highlighted the importance of monitoring the changes in one's ideas in preventing students' regression to their previous ideas. They explained that individuals who monitor the changes in their ideas are likely to acquire information about the validity of their current and previous ideas and also their justifications for the changes in their ideas. The information about the invalidity of their initial ideas prevents them from using their initial ideas to explain the situation. The finding of this study regarding the durability of the impact of CCTMP suggests that facilitation of metaconceptual processes leads to retaining and using correct ideas for a longer period of time.

Conclusions

The positive effect of conceptual change texts or refutational texts on students' conceptual understanding was well exhibited in previous research. This present research shows that facilitating metaconceptual processes within conceptual change texts has a superior impact on promoting students' conceptual understanding compared to the effect of refutational texts. Although the role of metaconceptual processes in changing students' alternative conceptions was acknowledged by many researchers previously, the effect of amalgamating some elements into conceptual change texts that facilitate students' engagement metaconceptual processes has not been investigated before. This research also contributes to our understanding regarding the more positive effect of CCTMP on the durability of students' conceptual understanding compared to the effect of refutational text and expository text.

Although there is an ample evidence about the positive effect of conceptual change texts or refutational texts on students' conceptual understanding in the literature, this study demonstrated the superior effect of supplementing conceptual change texts with elements that activate variety of metaconceptual processes. The findings also indicated that the effect of activating metaconceptual processes within texts was not a short-term outcome rather it endured for an eight-week period. Although the power of refutational texts in improving students' conceptual understanding was acknowledged in many studies before, this study showed that the effect of refutational texts became significantly equal to the effect of expository texts following a two month time period. The long-term and short-term impact of CCTMP suggests that the promising effect of them should be recognized by publishers and textbook or other text-based material authors. These types of texts can be used in textbooks or as a teaching material to supplement instruction. Teachers should also be aware of these texts so that they supplement their instruction with this type of texts especially in crowded classrooms where it is difficult to implement variety of student-centered teaching activities. They can even write their own texts for changing different alternative conceptions that they observe in their students.

This research was conducted with pre-service teachers with a focus on heat and temperature concepts. New studies with students at different grade levels and with different topics should be conducted to investigate the effect of CCTMP on conceptual understanding and on other variables. In this study pre-service teachers only read the texts. A class or group discussion of the texts within the classroom was not carried out. The effect of discussion of the texts or supplementing the texts with other instructional methods, such as predict-observe-explain can be examined. CCTMP can be published electronically and their content can be enhanced with electronic sources, such as simulations, animations or electronic prompts which can be provided at certain points of the texts. The effect of electronic version of CCTMP should be investigated in further research. Finally, the effect of activating metaconceptual processes within different instructional methods, such as 5E learning cycle model, argumentation, predict-observe-explain on students' conceptual understanding should be examined in future research studies.

Acknowledgements

This research was sponsored by a grant provided from Gazi University Research Fund (BAP- 04/2009-14).

An Earlier version of this research was presented at ESERA conference, 2009, Istanbul, Turkey.

This research was derived from the master thesis conducted by the second author under the supervision of the first author .

ISSN 1648–3898

Appendix

An example to the items used in Heat and Temperature Concepts Test

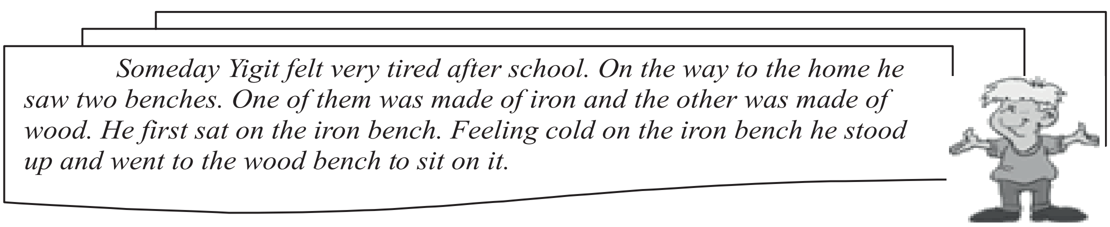
After cooking an egg in boiling water Melis put the egg into a bowl filled up with cold water. Which of the following explanations about the cooling process of the egg is correct?

a) Temperature is transferred from the egg to the water.
b) Coldness flows from the water to the inside of the egg.
c) Hot objects cool down naturally.
d) Energy is transferred from the egg to the water.
e) Energy is transferred from the water to the egg.

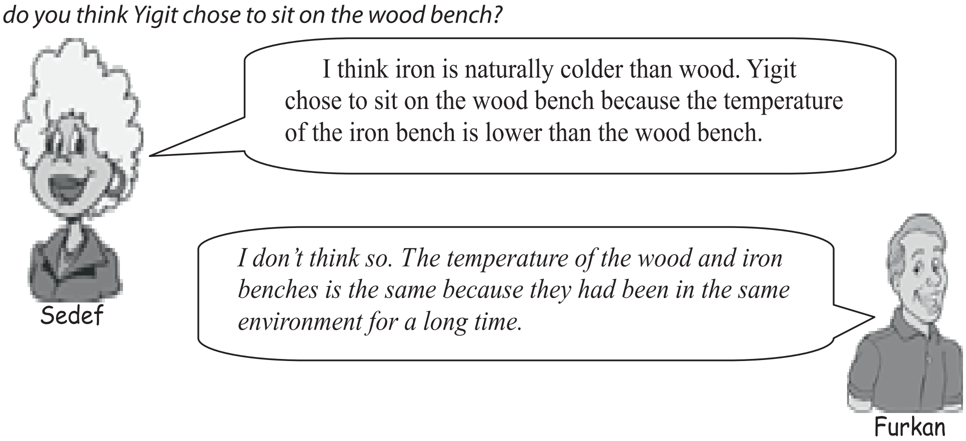
Excerpts from Conceptual Change Texts Enriched With Metaconceptual Processes

Excerpt 1

Please answer the questions about the given case provided below based on what you know about heat and temperature concepts.



Why do you think Yigit chose to sit on the wood bench?



Do you agree with Sedef's idea or Furkan's idea? Explain why? If you do not agree with either Sedef of Furkan you can write your own idea about the given situation.

……
……
……

The concept of heat has been studied for many centuries. The initial explanations offered about heat go back to the 1st century BC. By the beginning of the 19'h century most scientists viewed heat as a physical substance rather than as energy. There were two underlying theories about heat. One of them was caloric theory and the other was kinetic theory. According to caloric theory, heat was seen as a **fluid substance** called caloric. Caloric was assumed to flow from one object to another. This theory viewed heat as a material substance which flowed into or out of the objects and was capable to flying through the space. According to this theory a warmer substance involve more caloric compared to the colder substance. Although caloric theory was widely accepted within the scientific community it is no longer considered to be an adequate or complete description of heat.

Excerpt 2

Similar to the scientists who believed in caloric theory some of us attribute heat some material characteristics and think that heat can flow from one substance to another. Do you hold the same idea about heat?

....

....

....

Kinetic theory describes heat based on the motion of the particles of a substance. Although it is a theory proposed to explain the characteristics of gases it also explains the phase changes of materials with the transfer of heat and heat transfer within the substances. All of the particles of matter are in motion. You previously learned that particles of solid objects vibrate, the particles of liquid and gases vibrate, move around and slide on each other. Particles of objects at different temperature have different speed of motion. Kinetic energy is transferred from one particle to another as they collide to each other. Kinetic energy is transferred from particle with higher kinetic energy to the particle with lower kinetic energy. **Heat is the energy that is transferred between objects due to the difference in their temperature. In other words heat is the energy transferred between substances that are in contact due to the difference in the average kinetic energy in order to reach thermal equilibrium. It is symbolized with Q.** At this point we should differentiate heat from internal energy. Internal energy of a system is the energy contained within the system, including the kinetic and potential energy as a whole. Unlike internal energy heat is not a characteristic of an object. Therefore, we cannot define heat as the energy that an object possesses. As heat is not a characteristic of an object we cannot describe heat as the energy that warm objects have. **Temperature is a measure of the average kinetic energy of the particles of the matter. Although heat is an energy temperature is only a measure of the average kinetic energy of the particles. Therefore, temperature is directly proportional to the kinetic energy of the particles but itself it is not an energy.** Heat is measured by calorimeter temperature is measured by a thermometer. The amount of energy gained by an object when it is heated or the amount of energy released by an object as it gets cooler is calculated by the formula. Q(cal) is the amount of energy gained or lost by the object; m(g) is the mass of the object; c (cal/g°C) is the specific heat which is unique for different objects, Δt(°C) is the change in temperature. When heat is transferred from one object to another, the energy gained is equal to the energy lost $Q_{gained} = Q_{lost}$

ISSN 1648–3898

References

Barnett, M., & Morran, J. (2002). Addressing children's alternative frameworks of the moon's phases and eclipses. *International Journal of Science Education, 24* (8), 859–879.

Başer, M. (1996). *Effect of conceptual change instruction on understanding of heat and temperature concepts and science attitude*. Unpublished MS Thesis, METU, Ankara, Turkey.

Beeth, M. E. (1998). Teaching for conceptual change: Using status as a metacognitive tool. *Science Education, 82* (3), 343-356.

Bell, B. (1993). *Children's science, constructivism and learning in science*. Victoria: Deakin University

Bereiter, C., & Scardamalia, M. (1989). Intentional learning as a goal of instruction. In L.B. Resnick (Eds.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 361-392). Hillsdale, NJ: Lawrence Erlbaum Associates.

Blank, L. M. (2000). A metacognitive learning cycle: a better warranty for student understanding? *Science Education, 84*, 486–506.

Brown, A. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F.E. Weinert & R. H. Kluwe (Eds*.), Metacognition, motivation, and understanding* (pp. 65-116). Hillsdale, NJ: Erlbaum.

Chambers, S. & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching, 34*(2), 107-123.

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

Claxton, G. (1993). Minitheories: A preliminary model for learning science. In P. J. Black & A. M. Lucas (Eds.), *Children's ınformal ıdeas in science* (pp. 45-61). London: Routledge.

Çetin, G., Ertepinar, H., & Geban, Ö. (2015). Effects of conceptual change text based ınstruction on ecology, attitudes toward biology and environment. *Educational Research and Reviews*, *10,* 259-273.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Dilber, R. (2006). *A study of the impact of using analogies and conceptual change texts to overcome misconceptions and their effect on student achievement.* Unpublished Doctoral Dissertation, Atatürk Üniversitesi, Fen Bilimleri Enstitüsü, Erzurum, Turkey.

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

Dove, J.E. 1998. Students' alternative conceptions in earth science. *Research Papers in Education, 13,* 183–201.

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

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas in science.* Milton Keynes, U.K.: Open University Press.

Duckworth, E. (1997). *Teacher to teacher, learning from each other.* New York: Teachers College Press.

Georghiades, P. (2006). The role of metacognitive activities in the contextual use of primary pupils' conceptions of science. *Research in Science Education, 36,* 29–49

Gilbert, J.K., & Watts, D.M. (1983). Concepts, misconceptions and alternative conceptions: changing perspectives in science education. *Studies in Science Education*, *10*, 61-98.

Guzzetti, B., Snyder, T., & Glass, G. (1992). Promoting conceptual change in science: Can texts be used effectively? *Journal of Reading, 35,* 642–649.

Hennessey, M. G. (1999). *Probing the dimensions of metacognition: Implications for conceptual change teaching-learning.* Paper presented at the annual meeting of the National Association for Research in Science Teaching. Boston, MA.

Hennessey, M. G. (2003). Metacognitive aspects of students' reflective discourse: Implications for intentional conceptual change teaching and learning. In G.M. Sinatra & P.R. Pintrich (Eds.), *Intentional conceptual change* (pp. 103-132). Mahwah NJ: Erlbaum.

Hewson, P.W., & Thorley, N.R. (1989). The conditions of conceptual change in the classroom. *International Journal of Science Education, 11(5)*, 541-553.

Hynd, C., & Alvermann, D. (1986a). The role of refutation text in overcoming difficulty with science concepts. *Journal of Reading, 29,* 440–446.

Hynd, C., McWhorter, J., Phares, V., & Suttles, C. (1994). The role of instructional variables in conceptual change in high school physics topics. *Journal of Research in Science Teaching, 31*, 933–946.

Luques, M. L. (2003). The role of domain-specific knowledge in intentional conceptual change. In G. L. Sinatra & P. R. Pintrich (Eds.), *Intentional conceptual change* (pp. 133-170). Mahwah, New Jersey: L. Erlbaum.

Novak, J. (1987). *Proceedings of the second international seminar on misconceptions in science and mathematics.* Ithaca, New York: Cornell University.

Palmer, D. H. (2003). Investigating the relationship between refutational text and conceptual change. *Science Education, 87,* 663-684.

Pintrich, P. R., Marx, R. W. & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 6,* 167-199.

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

Sendur, G., & Toprak, M. (2013). The role of conceptual change texts to improve students' understanding of alkenes. *Chemistry Education Research and Practice, 14,* 431-449.

Sevim, S. (2007). Preparation and application of conceptual change texts on solution and chemical bonding concepts [*Çözeltiler ve kimyasal bağlanma konularına yönelik kavramsal değişim metinleri geliştirilmesi ve uygulanması*]. Unpublished Doctoral

Dissertation. Karadeniz Technical University, Trabzon, Turkey.
Sinatra, G. M., & Pintrich, P. R. (2003). The role of intentions in conceptual change learning. In G.M. Sinatra & P.R. Pintrich (Eds.), *Intentional conceptual change* (pp. 1-18). Mahwah NJ: Erlbaum.
Taber, K. S. (2014**).** *Student thinking and learning in science: Perspectives on the nature and development of learners' ideas***.** New York: Routledge.
Tomas, L., & Ritchie, S. (2015). The challenge of evaluating students' scientific literacy in a writing-to-learn context. *Research in Science Education, 45*, 41-58.
Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition and Learning, 1,* 3–14.
Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4,* 45-69.
Vosniadou, S. (2002). On the nature of naïve physics. In M. Limon & L. Mason (Eds.)*, Reconsidering conceptual change: Issues in theory and practice* (pp. 61-76). Amsterdam: Kluwer.
Vosniadou, S. (2003). Exploring the relationship between conceptual change and intentional learning. In G.M. Sinatra & P.R. Pintrich (Eds.), I*ntentional conceptual change* (pp. 377-406). Mahwah NJ: Erlbaum.
Wiser, M., & Amin, T. (2001). "Is heat hot?" Inducing conceptual change by integrating everyday and scientific perspectives on thermal phenomenon. *Learning and Instruction, 11,* 331-355.
Yenilmez A, & Tekkaya C (2006) Enhancing understanding of photosynthesis and respiration in plant through conceptual change approach. *Journal of Science Education and Technology, 15*, 81–87.
Yeo, S., & Zadnik, M. (2001). Introductory thermal concept evaluation. *The Physics Teacher, 39*, 496-504.
Yürük, N. (2000). *Effectiveness of conceptual change text oriented instruction on understanding electrochemical cell concepts*. Unpublished master thesis, Middle East Technical University, Ankara, Turkey.
Yürük, N. (2005). *An analysis of the nature of students' metaconceptual processes and the effectiveness of metaconceptual teaching practices on students' conceptual understanding of forces and motion*. Unpublished doctoral dissertation, Ohio State University, Columbus.
Yürük N (2007a). The effect of supplementing instruction with conceptual change texts on students conceptions of electrochemical cells. *Journal of Science Education and Technology, 16*, 515–523.
Yürük, N. (2007b). A case study of a student's metaconceptual processes and the changes in her alternative conceptions of force and motion. *Eurasia Journal of Mathematics, Science & Technology Education, 3* (4), 305-327.
Yürük, N., Beeth, M. E., & Andersen, C. (2009). Analyzing the effect of metaconceptual teaching practices on students' understanding of force and motion concepts. *Research in Science Education, 39*, 449-475.
Yürük, N., Selvi, M., & Yakışan, M. (2011). The effect of metaconceptual **t**eaching activities on pre-service biology teachers' conceptual understanding about seed plants. *Educational Sciences: Theory & Practice, 11,* 447-464.
Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. *Studies in Science Education, 49* (2), 121-169.

Received: *October 06, 2016* Accepted: *November 25, 2016*

Nejla Yürük	Ph.D., Associate Professor, Science Education Programme, Gazi University, Ankara Turkey. E-mail: nejlayuruk@gazi.edu.tr Website: http://www.websitem.gazi.edu.tr/site/nejlayuruk
Pınar Eroğlu	Master's Degree, Science Teacher, Ministry of National Education, Ankara, Turkey. E-mail: pakgulbale@gmail.com