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The Effect of Common Knowledge Construction Model on Academic Achievement and Conceptual Understandings of High School Students on Heat and Temperature

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Abstract

The aim of the study is to determine the effectiveness of The Common Knowledge Constructing Model (CKCM) on academic achievement and conceptual understandings of the 9th grade students on heat and temperature topic. Participants were 60 students (30 experimental and 30 control group) attending in the 9th grade of a high school in Gürpınar district of Van in the academic year of 2016-2017. Within quasi-experimental research design; The Heat and Temperature Conceptual Understanding Test (HTCUT), and the Heat and Temperature Achievement Test (HTAT) were used as data collection tools. While the qualitative data obtained with the HTCUT were analyzed with a graded scoring key, the quantitative data obtained with the HTCUT and the HTAT were analyzed with Wilcoxon Signed Rank Test and Mann Whitney U-Test. As the result of the study, it was found that the CKCM was effective in increasing academic achievement and conceptual understandings of the students. In addition, it was effective in replacing students' alternative concepts with scientific concepts on heat and temperature topic. To explore the influence of the CKCM on students' academic achievement and conceptual understanding more clearly, it is suggested to perform research on the use of the model in different subjects of physics course.

Keywords

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Introduction

The main aims of the Secondary School Physics Curriculum are to improve scientific literacy and to ensure the progress of students in the psychomotor and affective areas as well as in cognitive area. The objectives of the physics curriculum are gaining scientific process skills, being aware of nature of science, justifying claims based on the evidence and constructing the knowledge socially (Ministry of National Education [MoNE], 2013). In this context, it is important for students to improve opinions on nature of science and construct their knowledge socially. Thus, it can be argued that there is a need for a teaching model or approach which emphasizes the nature of science and construction of knowledge socially. It could be stated that one of the models that focus on teaching these two features is the Common Knowledge Constructing Model (CKCM). In this context, it is thought that the use of CKCM

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in the teaching of physics can contribute to the realize of the purpose of the physics curriculum objectives (Bakırcı, 2014; Bakırcı, Çalık, & Çepni, 2017; Kıryak, 2013; Wood, 2012).

The basic philosophy of CKCM, a teaching and learning model developed by Ebenezer and Connor (1998), is based on Marton's learning variation theory and Piaget's conceptual change studies. (Ebenezer, Chacko, Kaya, Koya, & Ebenezer, 2010). The CKCM composed of four basic phases: The Exploring and Categorizing, Constructing and Negotiating, Translating and Extending, and Reflecting and Assessing. In the exploring and categorizing phase, students focus on the subject; uncover their beliefs and ideas about the subject; and teacher determines the students' readiness level. Also, the misconceptions of students about the subject and the awareness of students are identified about nature of science. In the constructing and negotiating phase, teacher-student(s) and peer discussions were conducted to acquire new information by taking into consideration student pre-knowledge about the subject in the guidance of the teacher. These discussions help students to organize the information about the topic. Thus, students become aware of the fact that knowledge can be constructed through social dimensions such as negotiation, discussion and sharing as well as scientific methods such as experiment, observation and proving. In the translating and extending phase, students transfer the new information they learn to different situations and adapt it to new problems and associate them with daily life. At this phase, students are provided the conceptualization of socio-scientific problems and scientific thinking. Besides, the nature of science is also emphasized. In the reflecting and assessing phase, it is checked whether the students' alternative conceptions are replaced with scientific concepts, and whether they effectively learn the issue (Bakırcı, 2014; Ebenezer & Connor, 1998; Ebenezer et al., 2010; Kıryak & Çalık, 2017).

There are a limited number of studies investigating the effectiveness of the CKCM on different levels and different subjects. It is seen that these studies are related to middle school science and chemistry courses (Bakırcı & Çepni, 2016; Kıryak & Çalık, 2017). In these studies, it was concluded that the CKCM provides constructive discussions in learning environment, makes lessons fun and provides permanent learning (Akgün, Duruk & Gülmez-Güngörmez, 2016); increases academic achievement and improves positive attitude towards science (Bakırcı, Çepni, & Yıldız, 2015; Bakırcı, Artun, & Şenel, 2016); has positive effects on the 8th grade gifted students' attitudes towards chemistry (Demircioğlu & Vural, 2016); influences the 6th grade students' critical thinking skills (Bakırcı & Çepni, 2016); increases the 7th grade students' conceptual understandings and removes the alternative conceptions students have about the water pollution (Çalık & Cobern, 2017; Kıryak, 2013); and influences the 6th grade students' thoughts on nature of science (Bakırcı et al., 2017). Apart from the results of these studies, according to teachers CKCM is more effective for science education (Ebenezer, Chacko, & Immanuel, 2004); CKCM improves the 5th grade students' science literacy (Biernacka, 2006); the CKCM helps the 7th grade students to remove misconceptions on excretory system subject (Ebenezer et al., 2010); the CKCM provides conceptual changes on acid-base subject and influences science achievements of secondary school students (Wood, 2012). When studies on the CKCM are examined, it can be said that the common points of these results are that it increases students' academic achievement, provides conceptual changes, improves positive attitudes towards lessons and increases conceptual understanding. Also it is understood from the studies that the CKCM are effective on science and chemistry education. In this context, it is thought that the use of CKCM is important in terms of teaching an abstract issue such as heat and temperature through concretization

Kıryak & Çalık (2017) also emphasize that the CKCM is an effective teaching model for academic achievement and conceptual change. It can be said that the centralized exams held in Turkey focus on academic achievement and conceptual understanding. High school students are placed in universities based on the scores that they get in Higher Education Institutions Examination. In this central exam, the importance of students' academic achievements and cognitive comprehensions direct educators to use the teaching models centering upon these concepts. In this exam, it is predicted that heat and temperature subjects will take place and students will develop their academic achievements and cognitive comprehensions in the education processes based on the CKCM. When viewed from this perspective, the present study could be considered important as it tries to explore the effects of the CKCM-based teaching of heat and temperature topics on students' academic achievement and conceptual understanding.

The heat and temperature are the topics both in chemistry and physics. Although students study heat and temperature in two different courses, high school students face with difficulties in understanding the topics (De Berg, 2008). Several teaching models and approaches are used in the teaching of the heat and temperature topics, but the misconceptions of students have been continued (Aydoğan & Köksal, 2017; Doige & Tay, 2012; Erkaçan, Moğol, & Ünsal, 2012). The literature suggests that a new approach or a teaching model should be tested in the teaching of heat and temperature. In the evaluation phase of the CKCM, which consists of the syntheses of several learning theories, it is emphasized that supplementary measurement and evaluation techniques are used (Ebenezer & Connor, 1998). On the other hand, it was seen that there has been a transition to mixed learning theory in science teaching programs from the single learning theory and the evaluation approach was focused on a process (Ayas et al., 2015). In conclusion, it is understood that the CKCM is composed of synthesis of many learning theories and science curricula are based on many learning theories. In the light of this information, it can be said that the nature of science curriculum and the theoretical background of the CKCM overlaps to a large extent. Therefore, it is considered that the program will better serve to its aims if the CKCM based teaching is included in the curriculum.

It is known that students have difficulties on learning in most of the physics subjects. Especially on the heat and temperature subjects, it is a fact that students cannot reach to enough learning level. In many studies, it has been determined that students have alternative concepts on the heat and temperature topics (Alwan, 2011; Baser & Geban, 2007; Carlton, 2000; Gurcay & Gulbaş, 2015; Kesidou & Duit, 1993; Maskill & Pedrosa, 1997; Kaptan & Korkmaz, 2001; Taber, 2000). The results of these studies revealed that students have more than a hundred alternative concepts. The most common alternative concepts are "some materials absorb more heat than others.", "temperature depends on substance quantity.", "temperature depends on substance type.", "liquids are colder than solids on the same environment." and "heat and temperature are the same concepts." (Alwan, 2011; Doige & Tay, 2012; Eryılmaz & Sürmeli, 2002; Yavuz & Büyükekşi, 2011). The alternative concept is to assert that the students are confident with the reasons for a wrong definition that they have created in their minds for a concept (Doige & Tay, 2012; De Berg, 2008; Eryılmaz & Sürmeli, 2002). Therefore, it is very difficult to eliminate the alternative concepts or to replace the wrong definition with the scientific definition. Therefore, field educators use different approaches, models, and techniques in the teaching of subject in which alternative concepts exist. Nevertheless, it is observed that students have difficulty in understanding the topic of heat and temperature, and alternative concepts are continuing (Gurcay & Gulbas, 2015; Tanahoung, Chitaree, & Soankwan, 2010; Turgut & Gürbüz, 2011). Therefore, it is believed that the use of CKCM is important in teaching heat and temperature topics since the CKCM is a new teaching model, effective on removing alternative concepts (Biernacka, 2006), teaching complex and abstract subjects (Bakırcı, 2014; Wood, 2012), and being helpful to students in improving the conceptual understandings (Bakırcı et al., 2016; Kıryak, 2013; İyibil, 2011).

Misconceptions and abstract concepts are the greatest challenges that prevent students from meaningful and permanent learning (Hitt & Townsend, 2015). Heat and temperature are abstract concepts and include different mental processes and therefore they may be associated with alternative concepts that students have (Ateş & Stevens, 2003; Aytekin, 2010; Ültay & Can, 2015). In the formation of alternative concepts in students, it is also effective that the concepts of heat and temperature are constantly encountered in everyday life. This is because experiences related to a concept in daily life help formation of alternative concepts in students (Alwan, 2011; Doige & Tay, 2012). Due to these reasons, high school students have difficulties in learning heat and temperature topics (Ültay & Can, 2015; Yeşilyurt, 2006). As heat and temperature topics are abstract, students experiencing difficulty in structuring these topics and these topics are also taught to students at an early age which makes it difficult to grasp (Kurnaz & Çalık, 2008). This leads students to create alternative concepts in their minds. Teaching models and developed teaching materials are used in identification and clarification of alternative concepts (Bakırcı & Çalık, 2013; Özmen, Demircioğlu & Demircioğlu, 2009). The CKCM focuses on identification of students' alternative concepts, clarification of the concept and places an emphasis on abstract concepts (Bakırcı, 2014; Çalık & Cobern, 2017). It particularly employs different teaching strategies in the third phase of the model (conceptual change texts and concept cartoons etc.) and aims to address clarification and elimination of the concepts which are identified in the first phase of the model. Thus, it could be argued that use of CKCM is important when teaching heat and temperature topics.

Teaching materials have an important place in the conceptualization of abstract concepts in science teaching and identification and elimination of alternative concepts (Aydoğan & Köksal, 2009; Bakırcı & Çalık, 2013; Karslı & Çalık, 2012; Nottis & McFarland, 2001). Therefore, different teaching materials were developed and implemented in this study. It can be said that the teaching materials, worksheet, analogies, conceptual changes texts and concept cartoon are particularly influential in conceptual changes of students. Worksheet is known to play an important role in gaining students the concepts of sharing, friendship, and honesty (Demircioğlu & Atasoy, 2006) and eliminating alternative concepts (Hand & Treagust, 1991). Analogies help students effectively structure the abstract concepts in their minds (Şahin, 2010) and eliminate the alternative concepts (Blake, 2004; Chiu & Lin, 2005; Çalık, 2006). In addition, the conceptual change texts have several advantages: They are an effective technique in eliminating students' alternative concepts (Chambers & Andre, 1997; Özmen et al., 2009) and they also help teachers to correct conceptual misconceptions in crowded classes more quickly (Chambers & Andre, 1997), identify and address the misleading thoughts and beliefs of students (Çalık, 2006). They are also effective tools for meaningful learning (Çetingül & Geban, 2011). In addition, concept cartoons have contributions such as revealing the alternative concepts that students have, giving students an opportunity to discuss the reasoning of alternative concepts in the class, increasing interest and motivation of students and providing the students learning with fun (Balım, İnel, & Evrekli, 2008; Erdoğan & Cerrah-Özsevgeç, 2012). In this study, different teaching materials on heat and temperature were developed and used within the context of the CKCM. Therefore, the aim of this study is to investigate the impact of the CKCM on academic achievements and conceptual understandings of ninth grade students. Within the scope of this study, the following research questions were tried to be responded:

- ✓ What is the effect of the CKCM on the 9th grade students' academic achievement in the heat and temperature topic?
- ✓ What is the effect of the CKCM on the 9th grade students' conceptual understanding in the heat and temperature topic?
- ✓ Is there a statistically significant difference between the control group and the experimental group students' academic achievement and conceptual understandings?

In this study, it was assumed that the demographic characteristics of the students in the experimental and control groups were close to each other, students responded correctly and reliably to the measuring instruments, and the sample was appropriate to study the sample. On the other hand, this study was limited with 60 students studying in the 9th grade of a high school in the Gürpınar district of Van in academic year of 2016-2017 and heat and temperature concepts.

Method

Research Design

This research employs quasi-experimental design. The variables such as that students' random distribution to their classes; the formation of experimental and control groups by using another method other than random selection; and ensuring internal validity played an important role in choice of research design (Çepni, 2011; Shadish, Cook, & Champbell, 2002).

Sample

The study was conducted with 60 9th grade students (30 students in the experiment and 30 students in control group) studying at a high school in Gürpınar district of Van during 2016-2017 academic year. The experimental group consisted of 21 female and 9 male students; the control group consisted of 17 girls and 13 boys. Convenient sampling strategy was used in recruitment of students. This was because researchers were working at the school in which data were collected and this eased access to participants as well as the process (Yıldırım & Şimşek, 2006).

Data Collection Tools

The Heat and Temperature Conceptual Understanding Test (HTCUT) and the Heat and Temperature Achievement Test (HTAT) were used as data collection tools.

The HTCUT is based on alternative concepts of the heat and temperature subjects. Therefore, the literature was initially reviewed to identify alternative concepts that students have in terms of heat and temperature. Then, considering these alternative concepts, HTCUT consisting of five questions with two phases was prepared. The two-phase tests help researchers develop an in-depth understanding knowledge about students' level of comprehension of alternative concepts (Treagust & Chandrasegaran, 2007). The Cronbach Alpha reliability of HTCUT was found to be 0.73. The content validity of the test was conducted using specification table. HTCUT were used both as a pretest and posttest.

The learning outcomes with regards to heat and temperature topics and students' academic achievement in CKCM was taken into consideration whilst preparing HTAT. The achievement test was prepared according to CKCM's assessment techniques. Thus, the HTAT was formed using complementary assessment tools such as concept map, diagnostic branched tree, structured grid, and concept cartoon. The HTAT is a test of multiple choice questions. The questions in the HTAT are revised according complementary measurement and evaluation techniques. The expert opinion was taken for content validity. The test was implemented to 50 10th grade students. In this test, the Kuder Richardson-20 (KR-20) reliability formula was used because students were given ten points for the correct answer and zero for the wrong answer. The KR-20 reliability coefficient of the test was found to be 0.74. This value indicates that the instrument is reliable (Büyüköztürk, 2011).

Development of Teaching Materials and Implementation of Pilot Study

In this study, different teaching materials have been developed and implemented because the subject of heat and temperature is abstract and has alternative concepts. Before developing teaching materials, alternative concepts of heat and temperature were identified. Within these concepts, alternative concepts that are very common at the ninth-grade level have been identified. These alternative concepts are; "Temperature depends on the nature of the material", "the temperature of large objects is higher and smaller objects are colder "," heat and temperature are the same concepts "," the temperature depends on the amount of the object/material "and "the objects with high heat also have high temperature" (Aydoğan, Güneş, & Gülçiçek, 2003; Doige & Tay, 2012). Taking these alternative concepts into consideration, researchers developed worksheet, analogy, and conceptual change text and concept cartoon. The developed teaching materials have been examined by instructors of science, chemistry and physics. These lecturers were experienced on CKCM; The first one supervised two doctoral theses on CKCM; the second lecturer did a PhD on the use of CKCM in science education and the last one has many publications on CKCM. The teaching materials were revised according to the feedback provided by these experts. Then, a pilot study was taken to explore to what extent the teaching materials were effective.

A pilot study was conducted to test applicability of teaching materials (e.g, worksheet, analogies, and conceptual change texts) used in the learning environments of CKCM and to identify ineffective aspects of teaching materials. The participants of the pilot study were 32 high school students in Gürpınar province of Van. Pilot study was carried out by one of the researchers who had taken a graduate course related to CKCM. The pilot study lasted two weeks and was meticulously observed by the researchers. Lastly, the problems were identified, and the materials were revised as outlined below:

Grammatical, spelling mistakes and wrong expressions were identified in teaching materials (worksheets, analogies, conceptual change texts and concept cartoons). Moreover, some scenarios are used in the materials were rather long for students to understand. Some sentences had language and expression problems and the guidelines in teaching materials were not always clear for students.

Structural and functional problems in teaching materials were discussed with experts and their feedback were taken. Some revisions made to produce more student-friendly materials. Since some of the explanations in teaching materials were not suitable for the level of students, these explanations were re-written. Ambiguous visuals in materials were also replaced. After these revisions, the teaching materials were used in the actual practice. The teaching materials used in this study are presented in the appendix section. The teaching materials are not included in method section due to the regulations of journal.

Teaching Intervention

The implementation lasted three weeks both for experiment and control group. While lessons were based on present 5E learning model in the control group, they were based on CKCM in the experiment group. The “Heat, Temperature and Internal Energy”, “Units of Temperature”, “Specific Heat and Heat Capacity”, “Thermal Equilibrium” and “Global Warming” subjects which are placed under the Heat and Temperature Chapter have been taught during the implementation. The implementation process is explained with detail in Table 1.

Table 1. The Implementation Process

	Control Group	Experiment Group
Pretest	HTCUT and HTAT were used as pretest before the implementation process. Students were given 20 minutes for each test.	HTCUT and HTAT were used as pretests before the implementation process. Students were given 20 minutes for each test.
Implementation	The courses are conducted according to the 5E learning model. In the lessons, related activities were taken from the 9th grade Physics course book proposed by the Ministry of National Education. *In engage phase*; students' motivation and interest were promoted by asking questions related to the Heat, Temperature and Internal energy subjects. These subjects were discussed on warm water obtained by mixing hot and cold water. *In explore phase*; the units of heat and temperature were introduced. It was discussed how different temperature units and thermometers appeared. The transformations between temperature units were taught. "Heating Up the Water and Alcohol" activity was held to explore specific heat and heat capacity. This activity allowed students to learn the concepts of inherent heat and heat capacity. *In explain phase*; the results gained from the second phase were discussed and the feedbacks were given to students by the teacher. Also, the thermal equilibrium was discussed. *In elaborate phase*; students were asked to relate the heat and temperature subjects they learned to global warming. Examples for the real life usage of heat and temperature subjects were given. *In evaluate phase*; the open-ended assessment questions in the course book were resolved to reveal whether the students learned the subjects.	The courses were conducted according to CKCM and the teaching materials were developed by the researchers. *In the exploring and categorizing phase*; the question "What are the concepts of heat, temperature and internal energy?" were asked in order to reveal the preliminary knowledge of the students. The students' opinions on this question were revealed and classified by brainstorming. And then, the Word Association Test for the heat and temperature subjects was distributed. In addition, students were notified about the temporary, social and cultural natures of science with the "Thermometer" activity. *In the constructing and negotiating phase*; the analogy developed on heat and temperature subjects were implemented to students by giving them 10 minutes. After that the discussions related to the activity were held. The transformations between temperature units were done. The "Specific Heat", "Heat Capacity" and "Thermal Equilibrium" experiments which were designed according Predict-Explain-Observe-Explain (PEOE) were done. The results were presented and negotiated by the students. The experimental and objective natures of science were given indirectly. *In the translating and extending phase*; The "Conceptual Change Text" was distributed in order to get rid of alternative concepts. Students presented their research results about global warming. By doing this, students were attracted attention to the socio-scientific subjects. Also, the nature of science was emphasized with mentioning the lives of the scientists who had studied about the heat and temperature subjects. *In the reflecting and assessing phase*; the evaluation technics like "Diagnostic branched tree" and "Structured grid" were used in order to reveal whether the students learned the subjects. Besides, the "Word Association Test" was reused at the end of the implementation.
Posttest	HTCUT and HTAT were reused as posttest after the implementation process. Students were given 20 minutes for each test.	HTCUT and HTAT were reused as posttest after the implementation process. Students were given 20 minutes for each test.

Data Analysis

Grading rubrics were used to mark multiple-choice tests. It can be said that in this type of assessment instruments, the multiple-choice part is measures the knowledge level whereas the second part of the assessment tool, explanation part, is at a higher level and measures conceptualization. While chance factor may play to find the correct answer in the first part of the two-phase multiple-choice test, there is no chance factor in the second half. In this assessment, one can understand if student had truly learned the topic or not by checking the responses in the second part; therefore, the scores of second section in grading rubric is higher than the first part (Abraham, Grzybowski, Renner, & Marek, 1992; Bakırcı & Çalık, 2013).

HTCUT has been prepared as a two-phase multiple choice test. Therefore, the key test was used in the evaluation of it. HTCUT evaluation was performed independently by two physics teachers and a science educator according to the evaluation criteria presented in Table 2. The consistency ratio among the evaluators were high, but incases of disagreement, a criterion was formulated for evaluation (Abraham et al., 1992). The consistency ratio between the evaluators was found to be 0.79. The highest score that can be obtained from HTCUT is twenty and the lowest score is zero. In the analysis of the HTCUT and HTAT, Mann Whitney U-test for independent samples and Wilcoxon Signed Rank Test for paired samples were used.

Table 2. The Evaluation Criteria of HTCUT

Evaluation Criteria	Explaining	Scores
Correct Answer-Correct Reason (CA-CR)	The multiple-choice part is correct, and the reasoning part is sufficient.	4
Correct Answer-Partly Correct Reason (CA-PCR)	The multiple-choice part is correct, and the reasoning part is insufficient.	3
Wrong Answer-Correct Reason (WA-CR)	The multiple-choice part is wrong, but the reasoning part is sufficient.	2
Correct Answer-Wrong Reason (CA-WR)	The multiple-choice part is correct, but the reasoning part has alternative concept.	1
Wrong Answer-Wrong Reason (WA-WR)	The multiple-choice part is wrong, and the reasoning part has alternative concept.	0

For each correct answer given by the students in HTAT, 10 points were given, while for the wrong answer, zero points were given. The HTAT score of each student was calculated. These scores were uploaded to the SPSS 21.0™ package program. It was found that the data obtained with HTAT did not show homogeneous distribution. In this case, nonparametric test was used in the analysis (Büyüköztürk, 2011). The Wilcoxon Signed Rank Test was used to compare the experimental and control groups within themselves, while the Mann Whitney U-Test was used in the comparison between the groups.

Results

The results of the Mann Whitney U-test concerning the HTCUT pretest and posttest scores of the experimental and control group are presented in the Table 3.

Table 3. The Results of the Mann Whitney U-Test Concerning the HTCUT Pretest and Posttest Scores of the Experimental and Control Group

Test	Group	N	Mean Rank	Sum of Ranks	U	P
Pretest	Experiment	30	30.42	912.50	447.50	0.969
	Control	30	30.58	917.50		
Posttest	Experiment	30	38.08	1142.50	222.50	0.001
	Control	30	22.92	687.50		

Examining the data in Table 3, it is seen that there is no statistically significant difference between the HTCUT pretest scores of the groups [U=447.50, p>0.005]. Also, it is observed that the mean rank and sum of ranks of the pretest scores are close to each other. It is determined that the mean rank and sum of ranks of the HTCUT posttest scores of the experimental group are higher than control group. So that, it is concluded that there is a significant difference between the HTCUT posttest scores in favor of experimental group [U=222.50, p<0.05].

The results of the Mann Whitney U-test concerning the HTAT pretest and posttest scores of the experimental and control group are presented in the Table 4.

Table 4. The Results of the Mann Whitney U-Test Concerning the HTAT Pretest and Posttest Scores of the Experimental and Control Group

Test	Group	N	Mean Rank	Sum of Ranks	U	P
Pretest	Experimental	30	31.37	941.00	424.00	0.698
	Control	30	29.63	889.00		
Posttest	Experimental	30	37.55	1126.50	238.50	0.002
	Control	30	23.45	703.50		

Examining the data in Table 4, it is seen that the mean rank and sum ranks of the HTAT pretest scores of the groups are close to each other. So that, it was determined that there is no statistically significant difference between the HTAT pretest scores of students in the experimental and control group [U=424.00, p>0.05]. Accordingly, it was concluded that the academic levels of the students in the both groups were equal prior to the study. When the mean rank and sum ranks of the posttest are examined, it is seen that students in the experimental group had higher scores. Thus, it can be concluded that there is a significant difference between the HTAT posttest scores in favor of experimental group [U=238.50, p<0.05].

The results of the Wilcoxon Signed Rank Test concerning the HTCUT pretest and posttest scores of the experimental and control group are presented in the Table 5.

Table 5. The Results of the Wilcoxon Signed Rank Test Concerning the HTCUT Pretest and Posttest Scores of the Experimental and Control Group

Group	Test		N	Mean Rank	Sum of Ranks	Z	P
	Posttest	Negative Ranks	0	0.00	0.00		
Experimental	Pretest	Positive Ranks	30	15.50	465.50	-4.786	0.000
		Ties	0	-	-		
	Posttest	Negative Ranks	4	4.75	19.00		
Control	Pretest	Positive Ranks	22	15.09	332.00	-3.983	0.000
		Ties	4	-	-		

When the data in Table 5 is examined, it can be observed that there is a significant difference between the HTCUT pretest and posttest scores of students in the experimental group [Z=-4.786, p<0.05]. When the mean rank and sum of ranks scores are examined, it is seen that the significant difference is in favor of posttest. Similarly, it can be observed that there is a significant difference between the HTCUT pretest and posttest scores of students in the control group [Z=-3.983, p<0.05]. Examining the mean rank and sum of ranks, it is seen that the significant difference is in favor of posttest.

The results of the Wilcoxon Signed Rank Test concerning the HTAT pretest and posttest scores of the experimental and control group are presented in the Table 6.

Table 6. The Results of the Wilcoxon Signed Rank Test Concerning the HTAT Pretest and Posttest Scores of the Experimental and Control Group

Group	Test		N	Mean Rank	Sum of Ranks	Z	P
Experimental	Posttest Pretest	Negative Ranks	0	0.00	0,00	-4.788	0.000
		Positive Ranks	30	15.50	465.50		
		Ties	0	-	-		
Control	Posttest Pretest	Negative Ranks	2	3.50	7.00	-4.468	0.000
		Positive Ranks	26	15.35	399.00		
		Ties	2	-	-		

When the data in Table 6 is examined, it is seen that there is a significant difference between the HTAT pretest and posttest scores of students in the control group [Z=-4.788, p<0.05]. As the mean rank and sum of ranks being examined, it is seen that the significant difference is in favor of posttest scores. It is also seen that there is a significant difference between the HTAT pretest and posttest scores of students in the experimental group [Z=-4.468, p<0.05]. When the mean rank and sum of ranks are examined, it is seen that the significant difference is in favor of posttest scores.

The frequency and percentages of the answers given to HTCUT by students in the experimental and control group are presented in Table 7.

Table 7. The Frequency and Percentages of the Answers Given to HTCUT by Students

	Answers	Pretest				Posttest			
		Experimental		Control		Experimental		Control	
		f	%	f	%	f	%	f	%
1st Question	CA-CR	1	3.33	2	6.67	15	50.00	10	33.33
	CA-PCR	2	6.67	1	3.33	5	16.67	8	27.00
	WA-CR	0	0.00	0	0.00	0	0.00	0	0.00
	CA-WR	6	20.00	4	13.33	4	13.33	5	16.67
	WA-WR	21	70.00	23	76.67	6	20.00	7	23.33
2nd Question	CA-CR	1	3.33	2	6.67	16	53.33	12	40.00
	CA-PCR	3	10.00	1	3.33	5	16.67	7	23.33
	WA-CR	0	0.00	0	0.00	1	3.33	0	0.00
	CA-WR	5	16.70	3	10.00	2	6.67	3	10.00
	WA-WR	21	70.00	24	80.00	6	20.00	7	23.00
3rd Question	CA-CR	1	3.33	2	6.67	14	46.67	13	43.33
	CA-PCR	2	6.67	1	3.33	6	20.00	8	26.67
	WA-CR	0	0.00	0	0.00	1	3.33	1	3.33
	CA-WR	5	16.67	4	13.33	4	13.33	2	6.67
	WA-WR	22	73.33	23	76.67	5	16.67	6	20.00
4th Question	CA-CR	0	0.00	1	3.33	18	60.00	15	50.00
	CA-PCR	3	10.00	2	6.67	6	20.00	8	26.67
	WA-CR	1	3.33	2	6.67	1	3.33	0	0.00
	CA-WR	6	20.00	6	20.00	2	6.67	2	6.67
	WA-WR	20	66.67	19	63.33	3	10.00	5	16.67
5th Question	CA-CR	0	0.00	1	3.33	12	40.00	10	33.33
	CA-PCR	1	3.33	2	6.67	8	26.67	6	20.00
	WA-CR	1	3.33	0	0.00	0	0.00	2	6.67
	CA-WR	8	26.67	6	20.00	6	20.00	8	26.67
	WA-WR	20	66.67	21	70.00	4	13.33	4	13.33

When the Table 7 is examined, it is observed that most of the answers given to pretest are in the last two categories (CA-WR, WA-WR) while answers given to posttest are in the first two categories (CA-CR, CA-PCR). Therefore, this situation has been taken into account when describing data in the Table 7.

The first question of the HTCUT was related to comparing the temperatures of the two different sized objects made of same material after waiting long enough in the same environment. As it can be seen in the Table 7, in the pretest, 90% of the students' answers in experimental group and 90% of the students' answers in control group are in the CA-WR and WA-WR categories. These ratios declined to 33.33% and 40% in the posttest, respectively. However, in the posttest, 66.67% of the students' answers in experimental group and 60.33% of the students' answers in control group are in the CA-CR and CA-PCR categories.

The second question of the HTCUT was related to comparing the heat amount of the two different sized objects made of same material after reaching thermal equilibrium. As it can be seen in the Table 7, in the pretest, 86.67% of the students' answers in experimental group and 90% of the students' answers in control group are in the CA-WR and WA-WR categories. These ratios declined to 26.67% and 33% in the posttest, respectively. However, in the posttest, 70% of the students' answers in experimental group and 63.33% of the students' answers in control group are in the CA-CR and CA-PCR categories.

The third question of the HTCUT was related to comparing the temperature of the two different materials after waiting long enough in the same environment. As it can be seen in the Table 7, in the pretest, 90% of the students' answers in experimental group and 90% of the students' answers in control group are in the CA-WR and WA-WR categories. These ratios declined to 30% and 26.67% in the posttest, respectively. However, in the posttest, 66.67% of the students' answers in experimental group and 70% of the students' answers in control group are in the CA-CR and CA-PCR categories.

The fourth question of the HTCUT was related to comparing the temperature of the solid and liquid materials after waiting long enough in the same environment. As it can be seen in the Table 7, in the pretest, 86.67% of the students' answers in experimental group and 83.33% of the students' answers in control group are in the CA-WR and WA-WR categories. These ratios declined to 16.67% and 23.34% in the posttest, respectively. However, in the posttest, 80% of the students' answers in experimental group and 76.67% of the students' answers in control group are in the CA-CR and CA-PCR categories.

The fifth question of the HTCUT was related to comparing the heat amount of the candle flame and a big lake. As it can be seen in the Table 7, in the pretest, 93.34% of the students' answers in experimental group and 90% of the students' answers in control group are in the CA-WR and WA-WR categories. These ratios declined to 33.33% and 40% in the posttest, respectively. However, in the posttest, 66.67% of the students' answers in experimental group and 53.33% of the students' answers in control group are in the CA-CR and CA-PCR categories.

Discussion and Conclusion

When the findings obtained in this study concerning academic achievement and conceptual understanding are examined, it is seen that there is no statistically significant difference was found between pretest scores of experiment and control groups (See Table 3 & 4). Also, the students' responses obtained in the second stage of the HTCUT pretest were collected in the CA-WR and WA-WR categories (See Table 7). Thus, it can be concluded that both experimental and control group students had similar background knowledge and they were at the same achievement level prior to the study. The students were heterogeneously distributed into classes based on the scores they got from Higher School Entrance exams. Therefore, their prior knowledge on heat and temperature were close to each other.

It was found that there was a significant difference between HTCUT and HTAT pretest and posttest scores of the experimental and control group students in favor of posttest (See Table 5 & 6). This reveals that the teaching methods in both the control and the experimental group have an impact on the students' conceptual understanding and academic achievement. For the experimental group; it is believed that the improvement in the students' conceptual understanding and academic achievement is due to CKCM's process-oriented assessment technique, and the effective discussions during the second phase. Moreover, the HTCUT including concept map, structured grid, and concept cartoons may also have contributed this achievement (Bakırcı et al., 2016). Likewise, Iyibil (2011) conducted a study with 7th grade students and developed a teaching material based on CKCM on the energy topic. The result of this research indicated that teaching materials developed according to CKCM increased academic achievement of students. The increase in academic achievement was the result of complementary assessment and evaluation techniques used during the assessment phase.

In order to investigate which teaching approach had more impact on students' academic achievement and conceptual understanding, the posttests of the HTCUT and HTAT were analyzed with the Mann Whitney U-test. When the test results are examined, it was seen that there was a significant difference between experimental and control groups in favor of experimental group (Table 3 & 4). Thus, it can be concluded that the CKCM applied to experimental group has more impact on students' achievement and conceptual understanding. This indicated CKCM's effectiveness in structuring and negotiating phase. At this stage, discussion technique was used to construct the knowledge of the students by the guidance of the teacher. In this process, student-student and student-teacher interaction took place. Teacher and student cooperation helped students shape their knowledge. In this process, students shared knowledge, researched and negotiated. It showed that scientific activities contribute to the development of conceptual understanding and academic achievement of students (Biernacka, 2006; Brown & Ryoo, 2008; Ebenezer & Connor, 1998; Kıryak & Çalık, 2017; Wood, 2012). On the other hand, in the transfer and expansion phase of CKCM, socio-scientific issues were influential on the academic and conceptual understanding of the students. The teaching of socio-scientific issues has an important role in CKCM's learning environments. The success of the experiment group can be explained by the possibility of discussing socio-scientific aspects in the teaching model. The results of this study is parallel with the findings of the studies in the literature. It has been shown that learning environments based on socio-scientific issues have positive influence on students' learning of science concepts (Klosterman & Sadler, 2010), makes learning interesting (Albe, 2008), affects students' epistemological development positively (Zeidler, Sadler, Simmons, & Howes, 2005) and develops positive attitudes towards science classes (Lee & Erdoğan, 2007).

The success of the experimental group can be explained by the fact that the CKCM is evaluated at least at all stages and that the third step of the model is the effective establishment of knowledge in relation to daily life. In addition to this, it is considered that alternative concepts related to the subject are determined in the first stage of CKCM, and the elimination of these alternative concepts is also thought to be effective at later stages. Similarly, conceptual change applied to the experimental group can be explained by the use of conceptual change texts and concept cartoons. Since it was asserted that the most effective teaching approach that changes the conceptual understanding is the concept change texts (Bakırcı & Çalık, 2013; Kurnaz & Çalık, 2008; Er Nas, 2013), the conceptual change texts and concept cartoons used in the experimental group may have affected students' success. Also, remarkable and fun concept cartoons utilized in this study may have caused such a result (Keogh & Naylor, 1999; Erdoğan & Cerrah-Özsevgeç, 2012). However, the fact that the conceptual change text was prepared in the form of narrative conceptual change text, which is the type that will attract secondary school students and enable them to read in a fascinating way, could be considered as factors that increase the conceptual understanding (Baser & Geban, 2007; Kurnaz & Çalık, 2008; Okur, 2009; Turgut & Gürbüz, 2011). Indeed, many studies on CKCM have shown that this model is effective on students' academic achievement and conceptual understanding (Bakırcı et al., 2015; Bakırcı et al., 2016; Ebenezer et al., 2010; İyibil, 2011; Kıryak, 2013; Özdemir & Hamzaoğlu 2016; Wood; 2012).

As it can be seen in the Table 7, students in the experimental and control group had commonly known alternative concepts in the pretests (Alwan, 2011; Aydoğan et al., 2003; Doige &Tay, 2012; De Berg, 2008; Gürcay & Gülbas, 2015). The percentage of the CA-WR and WA-WR categories in the pretests are higher than that in the posttests (See Table 7). This decline shows that 9th grade students had alternative concepts on heat and temperature topics at the beginning of the study (Alwan, 2011; Gürcay & Gülbas, 2015). This decline may be due to the questions in HTCUT that were prepared taking into consideration the alternative conceptions on the heat and temperature topic in the literature. On the other hand, there is a distinct increase in the CA-CR and CA-PCA categories in the posttests (See Table 7). It has been observed that more than half of the students had correct reasoning for the questions in the HTCUT at the end of the study. Thus, this can be concluded that both implementations used in the experimental and control group are effective in improving students' conceptual understanding (Baser & Geban, 2007; Gönen & Kocakaya, 2010). The increase in the experimental group students' conceptual understanding is thought to be due to the combined use of different teaching techniques in the first stage of CKCM. These instructional techniques play an important role in the determination of students' prior knowledge in the subject, the level of readiness and the determination of alternative concepts (Bakırcı et al., 2017; Biernacka, 2006; Ebenezer et al., 2010; Ebenezer et al., 2004). In addition, the activities used in the other phases were decided and prepared after observing situations in the first phase. In the experimental group, the use of worksheet, word association test and brain storming technique at the first stage of the model; the use of experimentation and analogy in the second phase; and the use of the conceptual change text in the third stage are thought to be effective in the students' conceptual understanding (Bakırcı, 2014; Kıryak, 2013; Wood, 2012). The increase in the control group students' conceptual understanding could be said to result from the discussions made following the experiments.

In terms of comparing the implementation in the experimental and control group; it can be interpreted that the CKCM-based physics teaching enacted in the experimental group is more effective in conceptual learning than traditional physics teaching applied in the control group. When comparing the CA-CR and CA-PCR categories in the posttests, it was realized that the percentage of the students in the experimental group is higher than control group (See Table 7). It is understood that the students in the experimental group were more successful in answering the questions in HTCUT with both in correct answer and in correct reasoning. This situation can be explained by the fact that CKCM consisted of synthesis of many learning theories (Bakırcı & Çepni, 2012; Kıryak, 2013); CKCM includes student centered activities and ensures that questions in these activities are at least comprehension level, and inquiry-based approach and critical thinking skills questions take place in teaching materials. At the same time, it was thought that discussions on nuclear energy and hydroelectric power plants, which were the current socio-scientific subject were effective in understanding the relationship between science-technology-society and the environment in the third stage of CKCM. Discussions made in the context of socio-social issues were influential on students' ability to make judgments and decisions. This situation contributes to students' conceptual understanding on heat and temperature topic (Biernacka, 2006; Brown & Ryoo, 2008; Özdemir & Hamzaoglu, 2016; Wood, 2012). Open-ended questions come into prominence in the evaluation phases of the teaching materials used in the second and third stages of this learning model. Open-ended questions are used to measure students' competence in creative thinking, critical thinking, problem solving, decision making, analysis, synthesis and evaluation skills

(Andrew, 2000, MEB, 2013). Thus, it can be said that the open-ended questions in the teaching materials that were used in the two different stages of CKCM contributed positively to the conceptual understanding of the experimental group students.

Recommendations

CKCM has been found to have an effect on the conceptual meaning of the 9^{th} grade students on heat and temperature subjects. It is believed that the use of CKCM in other physics subjects will have an effect on the conceptual meaning of the students.

There are many studies showing that CKCM is effective in science teaching and this study shows that CKCM is effective in physics teaching (Bakırcı et al., 2017; Biernacka, 2006; Ebenezer et al., 2004). In this context, physics teachers should be encouraged with in-service teacher trainings to use CKCM in-class.

In this study, it is considered that the teaching materials developed about heat and temperature will facilitate the conceptual meaning of the students who are used by physics teachers.

References

Abraham, M. R., Grzybowski, E. B., Renner, J. W., & Marek, E. A. (1992). Understandings and misunderstandings of eighth graders of five chemistry concepts found in textbooks. *Journal of Research in Science Teaching*, *29*(2), 105-120.

Albe, V. (2008). When scientific knowledge, daily life experience, epistemological and social considerations intersect: Students argumentation in group discussions on a socio-scientific issue. *Research in Science Education*, *38*, 67-90.

Alwan, A. A. (2011). Misconception of heat and temperature among physics students. *Procedia Social and Behavioral Sciences, 12*, 600-614.

Akgün, A., Duruk, Ü., & Gülmez-Güngörmez, H. (2016). Sixth grade students' views on common knowledge construction model. *Amasya Education Journal*, *5*(1), 184-202.

Andrew, S. F. (2000). Critical thinking in south dakota public schools grades 3, 4 and 5 the influence of teachers. *Behaviors, Perceptions and Attitudes*, *61*, 888-899.

Ates, S., & Stevens, J. T. (2003). Teaching line graphs to tenth grade students having different cognitive developmental levels by using two different instructional modules. *Research in Science & Technological Education*, *21*(1), 55-66.

Ayas, A., Çepni, S., Akdeniz, A. R., Özmen, H., Yiğit, N., & Ayvacı, H. Ş. (2015). *Teaching science and technology from theory to practice*. Ankara: Pegem academy.

Aydoğan, S., Güneş, B., & Gülçiçek, Ç. (2003). The misconceptions about heat and temperature. *Gazi University Gazi Education Faculty Journal*, *23*(2), 111-124.

Aydoğan, Ş., & Köksal, E. A. (2017). Content analysis of the misconception studies in elementary science education. *Journal of Theory and Practice in Education*, *13*(2), 232-260.

Aytekin, Ü. (2010). *A study on the knowledge of secondary school students about the heat and temperature and utilizing from this knowledge in their daily lives* (Unpublished master's thesis). Gazi University, Institute of Educational Sciences, Ankara.

Bakırcı, H., & Çalık, M. (2013). Effect of guide materials developed in adaptation and natural selection subject on remedying grade 8 students' alternative conceptions. *Education and Science*, *38*(168), 215-229.

Bakırcı, H., & Çepni, S. (2016). The influence of the common knowledge construction model on middle school sixth grade students' critical thinking skills: A case of light and sound unit. *Inönü University Journal of the Faculty of Education*, *17*(3), 185-202.

Bakırcı, H., & Çepni, S. (June, 2012). *A new model for science and technology education: Common knowledge construction model*. Paper presented at the X. National Science and Mathematics Education Congress, Niğde University, Niğde.

Bakırcı, H. (2014). *The study on evaluation of designing, implementing, and investigating the effects of teaching material based on common knowledge construction model: light and voice unit sample* (Unpublished doctoral dissertation). Karadeniz Technical University, Institute of Educational Sciences, Trabzon.

Bakırcı, H., Artun, H., & Şenel, S. (2016). The effect of common knowledge construction model-based science teaching on the seventh-grade students' conceptual understanding-let's learn celestial bodies. *Yuzuncu Yıl University Journal of Education Faculty, 13*(1), 514-543.

Bakırcı, H., Çalık, M., & Çepni, S. (2017). The effect of the common knowledge construction model-oriented education on sixth grade students' views on the nature of science. *Journal of Baltic Science Education*, *16*(1), 43-55.

Bakırcı, H., Çepni, S., & Yıldız, M. (2015). The effect of the common knowledge construction model on sixth grade students' academic achievement: Light and sound unit). *Dicle University Ziya Gökalp Education Faculty Journal*, *26*, 182-204.

Balım, A. G., İnel, D., & Evrekli, E. (2008). The effects the using of concept cartoons in science education on students' achievement and enquiry learning skill perceptions. *Elementary Education Online*, 7(1), 188-202.

Baser, M., & Geban, Ö. (2007). Effectiveness of conceptual change instruction on understanding of heat and temperature concepts. *Research in Science & Technological Education*, *25*, 115-133.

Biernacka, B. (2006). *Developing scientific literacy of grade five students: A teacher researcher collaborative effort* (Unpublished doctoral dissertation). University of Manitoba.

Blake, A. (2004). Helping young children to see what is relevant and why: supporting cognitive change in earth science using analogy. *International Journal of Science Education*, *26*(5), 1855-1873.

Brown, B., & Ryoo, K. (2008). Teaching science as a language: A content-first approach to science teaching. *Journal of Research in Science Teaching*, *45*, 525-664.

Büyüköztürk, Ş. (2011). *Data analysis handbook for social sciences* (14th ed.). Ankara: Pegem Akademi Publishing.

Carlton, K. (2000). Teaching about heat and temperature. *Physics Education*, *35*(2), 101-105.

Chambers, S. K., & 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.

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

Çalık, M. (2006). *Material development and implementation in high school 1 solvers according to constructivist learning theory* (Unpublished doctoral dissertation). Karadeniz Technical University, Institute of Educational Sciences, Trabzon.

Çalık, M., & Cobern, W. W. (2017). A cross-cultural study of CKCM efficacy in an undergraduate chemistry classroom. *Chemistry Education Research and Practice*, *18*(4), 691-709.

Çepni, S. (2011). *Introduction to research and project studies*. Trabzon: Celepler Matbaacılık.

Çetingül, İ., & Geban, Ö. (2011). Using conceptual change texts with analogies for misconceptions in acids and bases. *Hacettepe University Journal Education*, *41*, 112-123.

De Berg, K. C. (2008). The concepts of heat and temperature: The problem of determining the content for the construction of an historical case study which is sensitive to nature of science issues and teaching-learning issues. *Science & Education*, *17*(1), 75-114.

Demircioğlu, H., & Atasoy, Ş. (2006). Development of work sheets in accordance with constructivist learning theory: A model proposal. *The Journal of Buca Faculty of Education*, *19*, 71-79.

Demircioğlu, H., & Vural, S. (2016). The effect of the common knowledge construction model on the 8th grade gifted students' attitudes toward chemistry course [Special Issue-1]. *Hasan Ali Yücel Faculty of Education Journal, 13*(1), 49-60.

Doige, C. A., & Tay, T. (2012). A typology of undergraduate textbook definitions of heat across science disciplines. *International Journal of Science Education*, *34*, 677-700.

Ebenezer, J. V., & Connor, S. (1998). *Learning to teach science: A model for the 21 century*. Upper Saddle River, NJ: Prentice-Hall, Simon and Schuster/A Viacom Company.

Ebenezer, J., Chacko S., & Immanuel, N. (2004). Common knowledge construction model for teaching and learning science: Application in the Indian context. Retrieved from http://www.hbcse.tifr.res.in/episteme/episteme1/themes/jazlin_Ebnezer_finalpaper.pdf

Ebenezer, J., Chacko, S., Kaya, O. N., Koya, S. K., & Ebenezer, D. L. (2010). The effects of common knowledge construction model sequence of lessons on science achievement and relational conceptual change. *Journal of Research in Science Teaching*, *47*(1), 25-46.

Er Nas, S. (2013). *Evaluating effectiveness of the guide material about transferring concepts to daily life in elaborate stage in matter and heat unit* (Unpublished doctoral dissertation). Karadeniz Technical University Institute of Educational Sciences, Trabzon.

Erdoğan, A., & Cerrah Özsevgeç, L. (2012). The effects of concept cartoons on eliminating students' misconceptions: greenhouse effect and global warming). *Turkish Journal of Education, 1*(2), 1-13.

Erkaçan, İ., Moğol, S., & Ünsal, Y. (2012). The effect of the multiple intelligences theory on grade 9 students' academic achievement and retention of learning about heat, temperature, expansion and compressibility. *Journal of Turkish Science Education*, *9*(2), 65-78.

Eryılmaz, A., & Sürmeli, E. (September, 2002). Measuring the misconceptions of students about temperature and temperature by three-step questions. *V. National Science and Mathematics Education Congress.* Middle East Technical University, Ankara.

Gönen, S., & Kocakaya, S. (2010). A cross-age study: A cross-age study on the understanding of heat and temperature. *Eurasian Journal of Physics and Chemistry Education*, *2*(1), 1-15.

Gurcay, D., & Gulbas, E. (2015). Development of three-tier heat, temperature and internal energy diagnostic test. *Research in Science & Technological Education*, *33*(2), 197-217.

Hand, B., & Treagust, D. F. (1991). Student achievement and science curriculum development using a constructivist framework. *School Science and Mathematics*, *91*(4), 172-176.

Hitt, A. M., & Townsend, J. S. (2015). The heat is on! using particle models to change students' conceptions of heat and temperature. *Science Activities: Classroom Projects and Curriculum Ideas*, *52*(2), 45-52.

İyibil, Ü. (2011). A new approach for teaching 'energy' concept: The common knowledge construction model [Special Issue]. *Western Anatolia Journal of Educational Sciences*, 1-8.

Kaptan, F., & Korkmaz, H. (2001). Primary school pre-service teachers' misconceptions about heat and temperature in science teaching. *Hacettepe University Journal of Education, 2*(1), 59-65.

Karslı, F., & Çalık, M. (2012). Can freshman science student teachers' alternative conceptions of 'electrochemical cells' be fully diminished? *Asian Journal of Chemistry*, *24*(2), 485-491.

Keogh, B., & Naylor, S. (1999). Concept cartoons, teaching and learning in science an evaluation. *International Journal of Science Education*, *21*(4), 431-446.

Kesidou, S., & Duit, R. (1993). Students' conceptions of the second law of thermodynamics an interpretive study. *Journal of Research in Science Teaching, 30*(1), 85-106.

Kıryak, Z. (2013). *The effect of common knowledge construction model on grade 7 students' conceptual understanding of 'water pollution' subject* (Unpublished master's thesis). Karadeniz Technical University, Institute of Educational Sciences, Trabzon.

Kıryak, Z., & Çalık, M. (2017). Improving grade 7 students' conceptual understanding of water pollution via common knowledge construction model. *International Journal of Science and Mathematics Education*, 1-22.

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socio-scientific issues-based instruction. *International Journal of Science Education, 32*(8), 1017-1043.

Kurnaz, M. A., & Çalık, M. (2008). Using different conceptual change methods embedded within the 5E's model: a sample teaching for heat and temperature. *Journal of Physics Teacher Education Online*, *5*(1), 3-10.

Lee, M. K., & Erdogan, I. (2007). The effect of science-technology-society teaching on students' attitudes toward science and certain aspects of creativity. *International Journal of Science Education*, *29*(11), 1315-1327.

Maskill, R., & Pedrosa, H. (1997). Pupils' questions, alternative frameworks and the design of science teaching. *International Journal of Science Education, 31*(6), 657-677.

Ministry of National Education. (2013). Secondary school (9th, 10th, 11th and 12th grades) physics curriculum. Ankara: State Books Publishing House.

Nottis, K. E. K., & McFarland, J. (2001). A comparative analysis of pre-service teacher analogies generated for process and structure concepts. *Electronic Journal of Science Education*, *5*(4), 1-15.

Okur, M. (2009). *A comparison of different conceptual change method: A sample for sound propagation topic* (Unpublished master's thesis). Karadeniz Technical University, Institute of Educational Sciences Trabzon.

Özdemir, E. B., & Hamzaoğlu, E. (2016). Impact of common knowledge construction model on the academic achievement and attitude towards science in science education. *World Journal of Environmental Research*, *6*(1), 25-35.

Özmen, H., Demircioğlu, H., & Demircioğlu, G. (2009). The effects of conceptual change texts accompanied with animations on overcoming 11th grade students' alternative conceptions of chemical bonding. *Computers and Education*, *52*, 681-695.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi experimental designs for generalized causal inference*. New York: Houghton Mifflin.

Şahin, Ç. (2010). *Design, implementation and evaluation of the guided materials based on the enriched 5e instructional model for the elementary 8th grade 'force and motion' unit* (Unpublished doctoral dissertation). Karadeniz Technical University, Institute of Educational Sciences, Trabzon.

Taber, K. S. (2000). Finding the optimum level of simplification: The case of teaching about heat and temperature. *Physics Education*, *35*(5), 320-325.

Tanahoung, C., Chitaree, R., & Soankwan, (2010). Probing thai freshmen Science students' conceptions of heat and temperature using open-ended question: A case study. *Eurasian Journal of Physics and Chemistry Education*, *2*(2), 82-94.

Treagust, D. F., & Chandrasegaran, A. L. (2007). The Taiwan national science concept learning study in an international perspective. *Journal of Science Education*, *29*(4), 391-403.

Turgut, Ü., & Gürbüz, F. (2011). Effects of teaching with 5E model on Students' behaviors and their conceptual changes about the subject of heat and temperature. *International Online Journal of Educational Sciences*, *3*(2), 679-706.

Ültay, E., & Can, M. (2015). Determination of preschool student teachers' conceptual knowledge about heat and temperature. *Karadeniz Journal of Social Sciences*, *7*(2), 1-23.

Wood, L. C. (2012). *Conceptual change and science achievement related to a lesson sequence on acids and bases among African American alternative high school students: A teacher's practical arguments and the voice of the other* (Unpublished doctoral dissertation). Wayne State University.

Yavuz, S., & Büyükekşi, C. (2011). Usage of concept cartoons in teaching of heat-temperature topic. *Karaelmas Science and Engineering Journal*, *1*(2), 25-30.

Yeşilyurt, M. (2006). High school students' views about heat and temperature concepts. *International Journal of Environmental and Science Education*, *1*(1), 1-24.

Yıldırım, A., & Şimşek, H. (2006). *Qualitative research methods in the social sciences*. Ankara: Seçkin Publishing.

Zeidler, L. D., Sadler, D. T., Simmons, L. M., & Howes, V. E. (2005). Beyond STS: A research-based framework for scocio-scientific issues education. *Wiley Inter Science*, 357-377.