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Exploring the impact of common knowledge construction model on students' understandings of heat transfer

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Abstract

The achievement of a proper conceptual change is a challenge for students since there are some constraint-based interactions including different ontological categories with the well-known dichotomy of matter or process. To mitigate this state of affairs, more instructional sequences with pedagogical approaches are needed because many students, regardless of their grade or academic background, incline to see science conceptions with emergent processes as an ontological matter. In this regard, compared to the existing ones, a newly-introduced model called Common Knowledge Construction Model (CKCM) is likely to leverage student learning. The purpose of the study was to investigate the possible impact of CKCM on students' understanding of heat transfer. The study had a pretest-post-test, pre-experimental research design based on qualitative data. The participants of the study comprised a total of 30 sixth grade students selected by convenience sampling model at a state school located in the south-east of Turkey. The data were collected via a semi-structured questionnaire consisting of five open-ended questions, and analyzed using coding method of the qualitative data analysis. The results revealed that majority of the participant students explicated their understandings of heat transfer with less alternative conceptions. The results also showed some improvements in students' understanding of heat transfer via the aforementioned teaching model.

Keywords: Common knowledge construction model; conceptual change; heat transfer; science education

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1. Introduction

It is frequently mentioned in the literature that students have ingrained alternative conceptions about heat. Like many other abstract conceptions, heat is supposed to be difficult to understand due to ontological reasons (Chi, Slotta, & De Leeuw, 1994). As highlighted previously, the definition of heat adopted under these ontological presuppositions also influences the understanding of heat transfer. In contrast to classical conceptual change models (e.g. Posner, Strike, Hewson, & Gertzog, 1982), the Variation Theory (Marton & Booth, 1997) based on relational conceptual change centralizes the contextual effect in learning. According to the theory, stimulated variation results in relational conceptual change in turn. This radical view was initially coined by Marton (1981) and came to the fore within phenomenographic approach. Built on this approach in the learning process, CKCM is based on an epistemological presupposition depending on the view that scientific phenomena are dealt with the expected variations in the learning process, as well as the aforementioned ontological presuppositions. Accordingly, it is aimed to identify the emergent categories within this model, which was organized under the relational conceptual change, in order to construct common knowledge. Through the lesson plans prepared in the light of these emergent categories, it is aimed for students to distinguish the disciplinary context and everyday context, and to harmonize their intellectual tools (Ebenezer, Chacko, Kaya, Koya, & Ebenezer, 2010). Overall, based on these theoretical arguments, the present study also concerned with the practical implementation within the research area. First, CKCM that is based on relational conceptual change is of recent vintage. Therefore, it can be supposed that there is a lack of research examining its possible pedagogical effects. Not surprisingly, even if there are many research reports focused on CKCM and its effects on science achievement of solubility (Ebenezer & Erickson, 1996), energy in solution (Ebenezer & Fraser, 2001), excretion (Ebenezer et al., 2010), energy (İyibil, 2011), celestial bodies (Bakırcı, Artun, & Senel, 2016), light and sound (Bakırcı & Çepni, 2016), nature of science understandings (Bakırcı, Calik, & Cepni, 2017), water pollution (Kiryak & Çalık, 2017), attitudes toward chemistry course (Demircioğlu & Vural, 2016), there is no study on the relationships between CKCM and heat transfer. Second, it is crucial to evaluate students' alternative conceptions of heat and heat transfer in terms of specific conceptual frameworks, and that these evaluation frameworks are based on findings from previous studies. In addition to that, alternative conceptions that emerged in a comprehensive literature review by Chiou & Anderson (2009) were evaluated through an interpretive framework suitable for the K-12 level, hierarchically defining these four phases from naive to informed (Chiou & Anderson, 2009). Third, as mentioned earlier, CKCM is based on phenomenography and located at the heart of the intersection between two competing conceptual change theories. Therefore, it can be said that CKCM lesson sequence can host teaching activities that have been shaped under the assumptions of both theories. Indeed, according to Ebenezer et al. (2010, p. 29) "common knowledge" refers to "constructing reality that resides in the science context of meaning that differs from those employed in everyday thinking or thinking in other contexts". On the other hand, diSessa (2008) suggests in his view of knowledge-in-piece that knowledge is first structured as basic fractions, called phenomenological primitives (p-primes), and then multiple p-primes can be organized in a complex structure. It can be said that the process mentioned in this theory is similar to the process of construction of common knowledge. In the theory of variation, dealing with the person-world relationship in dialectical terms, and in phenomenography, accepting the fact that the world is open to variations, the assumption that knowledge is shaped based on context is addressed by diSessa as multiple p-primes. Therefore, it can be deduced that CKCM, which is based on the phenomenography, is susceptible to diSessa's theoretical framework as well as other theories. Based on the given rationales, we believe that the present study is likely to contribute to the related literature.

1.1. Purpose of the study and research questions

The main purpose of the present study was to examine the instructional efficacy of Common Knowledge Construction Model (CKCM, henceforth) lesson sequence embedded in science course on sixth grade students' conceptual understandings of heat and heat transfer at the conceptual level. Students were required to engaged in only the first two phases of the model and the course was arranged in this respect. Then, the following research questions below guided the research:

1. What are students' conceptions of heat transfer after CKCM lesson sequence supported with activities based on POE Strategy?

2. What evidence do the qualitative findings provide with students' ontological beliefs of heat in terms of given categories commensurate with scientifically accepted heat definition?

2. Theoretical Background

Prior research on conceptual change dates back to the past six decades including Ausubels' works based on meaningful learning in which individuals integrate new knowledge to existing one in her/his cognitive structure and apply to new learning situations (Novak, 1994; Novak, 2010). This cognitive structure is organized to build the link between the subject and the object in a continuum from rote learning to highly meaningful learning at the conceptual level. Existing relevant cognitive structures lead to result in contextually stimulated variations in meanings ascribed to any given concepts and this supposition provides a solid conceptual framework to explain the idiosyncratic nature of relational conceptual change (Ebenezer & Gaskell, 1995; Novak, 2002). In the concept acquisition process, meaning sharing is the key (Novak, 2002). This situation increases the importance of subject-object relationship in variation of meaning. Piaget, the pioneer of the conceptual change theories, built the link between the subject and object based on the person and natural world dichotomy. He defined knowledge, which he transformed conceptually, through the cognitive domain. Nevertheless, the conceptual change theories continue to be closely connected to the relationship established between this dichotomy. Along with the idea that the link within this dichotomy may be due to dialectical relations, the absolute correspondence between the person and the natural world has come into question in the context of the conceptual change theory. Given no such correspondence exists indicates that everyone will reconstruct his or her conceptions relative to each other in such a way as to form a reference point to each other and that preconceptions that have been considered to have a common form, contrary to common belief, may not play such a crucial role in the process of conceptual change (Ivarsson, Schoultz, & Säljö, 2002). The theory of variation, which refers to this situation, focuses on the conceptual frameworks students have rather than the conceptions they have (Marton & Booth, 1997), because learning occurs based on a specific context, and the contexts in which students are involved in the learning process vary substantially. The conceptual change based on variations indicates a relative conceptual change (Ebenezer et al. 2010). Phenomenography is a qualitative research design that examines the ways in which individuals experience, conceptualize, perceive, and interpret the phenomena that exist in the natural world (Marton, 1981; Limberg, 2008). The heat conception discussed within the scope of the present study is based on a complex physical phenomenon and includes processes. Contrary to classical conceptual change approaches, the conceptions that individuals develop based on a phenomenon are based on the qualities that the phenomenon has, and these conceptions are temporary. On the other hand, conceptions are shaped by the individual's prior knowledge and experience. It can be said that conceptions can also point to limited meanings in terms of the fact that each person has a certain mental capacity. The interactions of the conceptions both within themselves and with other conceptions lead to conceptual learning differences among individuals. These differences are shaped by the variations arising from the context-based nature of intellectual activities. The main purpose of effectively teaching a conception is to change the conceptual mental models of individuals with more plausible ones (Ebenezer & Fraser, 2001; Ebenezer et al., 2010). What is important here is not to bother with the use of preconceptions in their own daily contexts. For this reason, instead of a total replacement, these conceptual frameworks are being upgraded.

Nevertheless, it can be seen that the conceptual models covered in the studies in the related literature are predominantly based on a non-relational conceptual change. As such, relational conceptual change emerged with gradually much interest in the last decade. To make relational conceptual change more accessible to students and educational settings, CKCM has provided a useful tool for deeper understandings of scientific phenomena. CKCM is linked intimately to fenomenography and overlap to an extent. In essence, CKCM as a teaching and learning model was developed and coined by

Ebenezer & Connor in 1998 (Biernacka, 2006). Basically, CKCM is fundamentally based on Martons' relational learning, Bruners' view of language as symbolic system of culture, Vygotskys' zone of proximal development and Dolls' postmodern view of perspectives on curriculum (Ebenezer et al., 2010).

A comprehensive literature review carried out by Chiou & Anderson (2009) gave an insight into deeper understanding of students' interpretive frameworks on the term of heat under four distinct, but somewhat hierarchical lines as given below:

- Heat is considered as an internal entity belonging to any of matter. Students have such a deeply-rooted opinion that wood is already hot, and ice is already cold. Thus, the student in this framework does not have a clear and accurate understanding of the movement or transmission of heat (Rosebery, Ogonowski, DiSchino, & Warren, 2010; Schönborn, Haglund, & Xie, 2014).

- Heat is treated as a material or substance (Chi et al. 1994; Kirikkaya & Güllü, 2008). It is interpreted in a way in which a group of hot particles moves from a hot object to a cold object. According to them, the opposite of heat is cold. In this way, cold can also move towards the hot object. In this perspective, heat and temperature are not distinguished, and the temperature is considered as a measure of the temperature trapped within an object.

- Heat is considered as a non-material or non-substantial property, namely as caloric flow. This view points to a caloric flow that diffuses from objects with high temperature to objects with low temperature. The temperature change of an object is measured by calculating the net caloric flow amount that the object receives or gives.

- This is the opinion that is accepted as scientifically correct. Heat is seen as a transfer in thermal energy due to temperature difference. This energy is the total kinetic energy of all particles such as atoms or molecules that make up a substance. Temperature is a measure of this thermal energy. Heat transfer is a thermal energy transition process, and the leading force of mechanisms involving this process is the movement of particles.

Considering its ontological and epistemological ties, it can be said that it is more logical to deal with the alternative conceptions about heat and its transfer within the context of a model that serves a relational conceptual change strategy, since heat is a frequently experienced conception in everyday life. Thus, the students' prior knowledge and alternative conceptions about heat and its transfer are modified within themselves, provided that its everyday context is not changed. Consequently, it can be argued that CKCM provides a better conceptual understanding of the conceptions in terms of constructing and negotiating the meanings as well as components such as the exploration and categorization of students' ideas. It may be possible to construct common knowledge through CKCM, which is formed in the context of everyday life and other contexts, and is a product of its own conceptual frameworks. The guided discovery process also plays an important role in structuring common knowledge that can be regarded as the product of a negotiation process. It can be said that the Predict-Observe-Explain (POE) teaching strategy, which is widely used in this respect, will support the relative conceptual change (Ebenezer et al., 2010).

2.1. Prior research on heat conception

From 1970s onwards, science misconceptions have been undergone in an intensive study and the related literature has covered a wide range of approaches looking for dispelling those conceptions undermining the scientific definitions of students by giving them an inaccurate insight into their conceptual development process (Ebenezer et al., 2010; Burgoon, Heddle, & Duran, 2011; Lee, 2014). These studies have long served to justify the urgent need to focus on these misconceptions belonging to thermal conceptions hinder the learning of such terms including heat energy, heat transfer and temperature (e.g. Kesidou, Duit, & Glynn, 1995; Cotignola, Bordogna, Punte, & Osvaldo, 2002; Chiou & Anderson, 2010; Doige & Day, 2012; Lee, 2014). For instance, Burgoon et al. (2011) examined teachers' misconceptions positing that there are similarities between conceptions of physical science held by both students and teachers. In conclusion, temperature was among the common student misconceptions also seen in teachers. In another study, Doige & Day (2012) in their study resorted to classifying existing definitions in textbooks, concluded that heat could be grouped in the textbooks under the categories of energy in motion, energy transfer and molecular kinetic energy. In addition, Schönborn et al. (2014) aimed at combining the sense of touch via POE Strategy in a guided discovery. Despite the use of a thermal camera, it was observed that students still had difficulty in understanding the caloric flow of heat. The researcher suggested that a simple heat flow model could be useful in knowledge of heat transfer in various contexts. In addition, Lee (2014) concluded that teachers could not explain the heat transfer phenomenon. The question why both students and teachers are unable to survive in this issue deserves more attention. In Marton's theory (1984), students operate their intellectual tools in various contexts in the conceptual change process. In this direction, Ebenezer et al. (2010) call for in-depth analysis of the efficacy of the CKCM directly linked to relational conceptual change. On the other hand, past studies have also identified that the mismatch between students' and scientists' ontological beliefs of heat can be attributed to be the major barrier to learn a coherent and scientifically accurate understanding of this conception. In conclusion, it was revealed that students thought of metals inherently cold and considered temperature as a measure of hotness of the objects. It was observed that in some contexts, students advocate criteria that came from the category of ontological belief of substance when evaluating heat transfer (Chiou & Anderson, 2009). The present study tries to manage to elicit a response for the aforementioned calls accordingly.

2.2. Prior research on CKCM

The research literature on CKCM is rather limited and emerged as a research area in the last decade. Few studies existing in the related literature highlight the models' features and its implementation in various science topics. Comprehensively examining the effectiveness of CKCM lesson sequence, in their pioneering study Ebenezer et al. (2010) used a mixed approach to investigate its possible effect on students' science achievement and conceptual understandings in the unit of excretion. The sample were divided and assigned as intervention and control group. The intervention group was taught the unit through CKCM, the control group with traditional methods. The findings concluded that students in the intervention group showed significant improvement compared to those in control group. In a recent study using an intervention with seventh grade students, Kiryak & Çalik (2017) investigated the effect of CKCM lesson sequence in the specific context of water pollution. The results of the study confirmed the effectiveness of CKCM lesson sequence providing with deeper conceptual understandings. With their non-science major sample, Ebenezer & Fraser (2001) examined the conceptions of energy in solution processes held by chemical engineering students. Through the analysis of students' responses to three tasks about different salts dissolved in water, four emerging categories were explored. Students tended to describe the solution process using their prior chemical conceptions. In addition, even though many of the students used similar chemical conceptions, it was found out that not all the students attribute the same meaning to the conceptions used. Bakırcı, Çepni, & Ayvacı (2015) were interested in teachers' views on CKCM. In conclusion, teachers stated that the first phase of the CKCM was time-consuming and this challenge limited the effectiveness of the model. In addition, teachers offered a layer-phase to be added after the second phase of the model. The rationale was to make easier to reach the common knowledge that is fundamental to the model. In a similar vein, Akgün, Duruk, & Gülmez Güngörmez (2016) examined sixth grade students' views of CKCM through phenomenological approach using qualitative data. Based on the findings, the researchers concluded that students agreed on the view that CKCM is a way of constructing common knowledge. Also, students stated that it improved their achievement on the unit of heat transfer. Bakırcı et al. (2016) also examined the effectiveness of the model on seventh grade students' understandings of celestial bodies. In the study, the researchers mainly focused on the comparison of CKCM and 5E Learning Cycle in teaching the science content. Students in the intervention group were taught through CKCM lesson sequence. In conclusion, both were found as effective on teaching celestial bodies as well as CKCM used in intervention group was more effective than that of control group. Bakırcı et al. (2017) investigated the effect of the CKCM on students' nature of science understandings with their quasi-experimental study and they found that the model is effective for improving students' nature of science understandings in terms of some of the NOS tenets. Another study (Bakırcı & Çepni,

2016) was about the effect of CKCM on six grade students' critical thinking skills in the unit of light and sound. Also, with eight grades gifted students' attitudes toward chemistry course in the specific context of acids and bases (Demircioğlu & Vural, 2016). Similarly, İyibil (2011) examined the effect of CKCM on the conception of energy with seventh grade students and concluded that CKCM is a useful way after the intervention with control group. More recently, Çalik & Cobern (2017) investigated the effect of the model cross-culturally comparing Turkish and American preservice teachers. To sum, the model seems to be effective on both conceptual understandings and conception change process to some extent. The evidence on the perceptual effectiveness of the model (Bakırcı et al. 2015; Akgün et al. 2016) also encouraged us to further examine the effectiveness of the model in school science in the specific context of heat transfer which is scarce in the literature.

3. Method

3.1. Research Design

In the study, pre-experimental research design was utilized to examine the effect of CKCM lesson sequence embedded in a science course on sixth grade students' conceptual understandings of heat and in the specific context of heat transfer. Specifically, one group pre-test post-test arrangement in pre-experimental perspectives was facilitated to meet the research questions previously given. Experimental research aims at determining if the intervention (as an independent variable) had any effect on dependent variable. Among others, pre-experimental research is basic in terms of experimental research due to its lack of any control group. Therefore, this type of design is widely criticized for solely analyzing the intervention effects at the group level. Despite some scholars have brought it into disrepute (Knapp, 2016), we stick by our decision to use it as some other scholars persistently advocating its efficacy in practice settings of human services evaluation research (Thyer, 2002), leadership (Shek & Sun, 2012), statistics (Leavy, 2006), and creative thinking (Sak & Oz, 2010). In particular, we stand for it as it enables us to determine the effect of a new teaching model upon a group of children in a relatively short time period (two weeks) and it includes a pre-test measure baseline scores at the outset of the study. As such, it provides researchers to compare the findings and explore the possible effect of any intervention (Shadish, Cook, & Campbell, 2002).

3.2. Participants

A total of 30 students who were selected via convenience sampling method participated in the study. The participants who consented to participate in the study were enrolled at a state school located in south-east of Turkey.

3.3. The Issue Context: Heat Transfer

The study was based on the specific context of heat transfer. Also, the activities used during instruction were implemented in this context. Mainly, heat transfer roughly refers to the transition of thermal energy until thermal equilibrium is secured. When a temperature difference occurs in any system, heat transfer starts accordingly. In other words, heat transfer can be triggered by both the temperature difference between two objects adjacent to each other and an object hotter or cooler than its surroundings. With the basis of warming or cooling, the analysis at the macroscopic level is accompanied by microscopic one that investigates the particles' (such as atoms, molecules and, ions) movement in an object. At microscopic level, there are three modes of movement called vibration, translation and rotation. Mainly, the particles in an object are in constant motion. This motion results in an increase of kinetic energy. The particles vibrating about a fixed position produce vibrational kinetic energy in solids. Instead, translational kinetic energy is stemmed from the movement of tiny particles called as bangers elastically colliding with adjacent atom or molecules. All this kind of movement takes place in heat conduction. Heat convection accounts for both conduction and fluid flow. The rate how fast the fluid flow determines the rate of convection. Similarly, in heat conduction, but rather differently, heat radiation is transferred as radiant energy with electromagnetic wave motion between objects (Chiou & Anderson, 2009; Hitt & Townsend, 2015). Overall, although heat transfer is generally viewed as a process in which the particles' motion at the microscopic level results in kinetic energy, heat transfer is considered at conceptual level and the attention is directed to the conceptual understanding in the present study.

3.4. Intervention

In the instructional process, the first phase of CKCM as "Exploring and Categorizing" was used at the outset of the instruction of the units. All participants were engaged in an intervention that aimed to improve the understandings of participants regarding heat transfer. Students had the chance of constructing the correct meaning of the conceptions through communication and negotiation with peers and teachers in the course in relation to the second phase of CKCM as "Constructing and Negotiating". The intervention was undertaken in the context of CKCM lesson sequence in which all participants were taught by their regular science teacher. The intervention was conducted over a two-week period. The unit of heat transfer began with the participants exploring their prior knowledge about such conceptions including heat and temperature and their distinction that is difficult to keep straight. After a brief brainstorming, the teacher who is the third author of the present study, lead to a whole-class discussion about the relationship among heat and temperature. Students' thoughts were triggered by various questions to disambiguate heat and temperature. Following the discussion, participants were also encouraged to work in groups to focus on the ways of heat transfer. Then, the participants were required to discuss in small groups and share their prominent thoughts explicitly with their peers. The teacher engaged participants in three different activities based on POE Strategy that explicitly addressed the learning outcomes. Throughout the unit, more attention was given to take into consideration the balance of core content knowledge about heat and heat transfer and its corresponding learning outcomes in the science curriculum. Specifically, only the first two phases of CKCM were used in the study. Accordingly, materials used in the course were rearranged according to the requirements of these two phases. The purpose of the first phase of the model was to explore the participants' prior knowledge of heat transfer regardless of its correctness and categorize them. In the second phase of the model, participants were presented and then encouraged to engage in the activities based on Predict-Observe-Explain (POE) Strategy. Accordingly, three working sheets including the phases of POE were constructed and used by the author during the intervention. Each activity was followed by a whole-class discussion. The working sheets were comprised of the issues called "Heat Conduction", "Heat Convection" and "Heat Radiation", respectively. In the first working sheet, after giving prior information about the activity by the teacher, participants were asked to respond to the first question and write down their initial predictions. Then, participants were provided a video presentation prepared for heat conduction, heat convection and heat radiation in the phase of observation and they were required to write down what they observed. At the final phase, participants were asked to make an explanation both using their predictions and observations.

3.5. Data Collection

In the data collection process, the participants were administered a semi-structured questionnaire developed by the researchers comprising five open-ended questions. The most important reason for using open-ended questions was to minimize the error of measurement and to reveal the students' in-depth understanding of heat including a process (Turgut & Baykul, 2012). To rely on the results, it is well-known that the measuring instrument should have validity to ensure the measuring if corresponds to what we intend to measure. Therefore, these open-ended five questions in a form were initially presented to three science teachers to be judged. These three teachers had at least five years of experience in science teaching at the secondary school level. After all, the first two researchers compared the analyses and resolved any discrepancies by consensus. POE activities based on CKCM are contexts for us to find out how students predict, observe and, explain heat transfer. Pilot-testing of the POE activities was also conducted in another sample before the beginning of the present study with grade 7 students who did not participate in the study. Then, they were revised to make them more understandable and readable to students.

3.6. Data Analysis

The participants' responses were analyzed to identify alternative conceptions of heat and heat transfer. The qualitative analysis involved comparing the responses on heat transfer. The data analysis of the study mainly included two major phases. In the first phase, students' alternative conceptions regarding heat transfer were examined by open-coding and given in frequencies corresponding to related questions. Major categories were identified by content analysis run by the first two authors. The categorization of participants' responses was done by the first two researchers. In the second phase, it was sought to keep track of students' ontological belief categories related to the term of heat. Alternative conceptions emerged from the responses were associated with the ontological beliefs inherent to the term of heat under the interpretative framework of Chiou & Anderson (2009) appropriate for K-12 level. Therefore, the final analysis based on this framework was conducted in an interpretive manner (Charmaz, 2006).

4. Results

The findings presented in tables 1-5 given below in a row indicate quantitative gains in participants' understandings of heat transfer. The findings provide empirical support that CKCM is effective in improving understandings of heat transfer. As can be seen in Table 1, no participant was able to fully express the ways of heat transfer prior to the intervention. Energy, temperature, sun, air, and light were among the examples participants gave to explain the ways of heat transfer. Participants consider the mentioned conceptions as a medium in the transmission of heat. After the intervention, it was found that 16 correct responses were given. This suggests that the frequency of scientifically accepted heat transfer definition increased. It was observed that incomplete knowledge about the ways of heat transfer and the existence of alternative conceptions persisted even after the intervention. Energy and light were again some of the mediums that were mentioned. When compared with the views before the intervention, it was noticed that the frequency of alternative conceptions decreased, and the frequency of incomplete knowledge increased.

The previously mentioned interpretive framework was used to search for the response to the second research question of the study. Considering the participants' responses, it can be said that the view that "heat is transferred in case of increase in number of the people, that is, it is transferred when people bring together" pointed to the "material substance" component of this interpretive framework. Although the participants with this view had consistent views on heat or its transfer, it can be said that they perceived heat transfer as a transition of a group of particles from a hot object to a cold object, that they could not fully distinguish between heat and temperature and that they consider heat as temperature which was trapped in each object (Chiou & Anderson, 2009). On the other hand, it was seen that participants also had views like "heat can be transferred in any way" prior to the intervention.

Table 1. Comparison of participants' understandings of how heat is transferred before and after the intervention respectively

Question	Categories	Students' Descriptions	f	Categories	Students' Descriptions	f
How is heat transferred?	Energy	"Heat is transferred by energy"	2	Incomplete Knowledge	"Heat is transferred by the way of molecules collide with each other and transfer the energy to each other"	7
	Temperature	"Heat is transferred by temperature"	5	Correct Answer	"Heat can travel from one place to another in three ways: conduction, convection and radiation"	16
	Sun	"Heat is transferred by solar power"	2	Energy	"Heat is transferred by energy"	2
	Air	"Heat is transferred by air"	3	Light	"Heat is transferred through a linear way"	1
	Light	"Heat is transferred by light"	2	Incomplete Knowledge	"Heat is transferred by the way of molecules collide with each other and transfer the energy to each other"	7
		"Heat is transferred passing through transparent materials"	2			
	Sound	"Heat is transferred by collisions with objects"	1			
	Other	"Heat could be transferred by any other ways"	1			

The second question on the data collection tool was asked to expand the responses given in the first question. In this question, it was asked whether heat transfer occurred in the same way in different states of matter. The participants did not respond correctly to this question before the intervention. It was seen that the participants tried to justify their alternative conceptions or incomplete knowledge with arguments such as viscosity, conductivity, specific heat, rigidity, fluidity, volatility and diffusion form of matters (Table 2). After the intervention, it was found that 13 correct responses were given. On the other hand, it was found that incomplete knowledge persisted, and the participants tended to justify that the distance between the particles forming the solids, liquids and gases is not the same. This justification was also observed after the intervention. In other words, it could be summarized that students consider the basis of inter-particle distance as the criterion of heat transfer. In addition, the conductivity of the material was found to persist after the intervention, even though reoccurred only once.

Table 2. Comparison of participants' understandings of how heat is transferred in other phases of matter before and after the intervention respectively

Question	Categories	Students' Descriptions	f	Categories	Students' Descriptions	f
Is heat transferred in all states of matter by the same way?	Alternative Conception	"Yes, heat is transferred by the same way in all matters"	2	Alternative Conception	"Yes, heat is transferred by the same way in all matters"	1
		"Yes, because all matters have the same viscosity"	1			
	Incomplete Knowledge	"No, both three phases of matter are different. Therefore, heat is transferred by different ways".	17	Incomplete Knowledge	"No, heat is transferred by different ways in all matters"	7
		"No, because conductivity levels of matters are different"	1			
		"No, because when we heat a solid matter, it becomes warmer slowly. When we heat a liquid, it becomes warmer in a short while. We cannot heat gases.	3		"No, the ways of heat transferring are different because spaces among particles are different	5
		"No, because solid matters are hard, liquids are flowing, and gases are as stream. Therefore, they are transferred by different ways.	1			
	Alternative Conception	"No, because every matter has its own way of dispersion".	2	Correct Answer	""No, heat is transferred by conduction in solids, convection in both liquids and gases, radiation by photons"	13
				Incomplete Knowledge	"No, because different matters have different conductivity"	1

The previously mentioned interpretive framework was used to search for the response to the second research question of the study. Considering the participants' responses, it can be said that the following view, which was in the incomplete knowledge category and was seen 14 times before the intervention, refers to the "intrinsic property" component of this interpretive framework: "Yes, the water in the pot gets warmer and the spoon gets warmer because it is metal. If it was wood instead of metal, it would not get warmer." It could be generalized that participants who had this view did not have consistent knowledge on heat conduction. In this view, it is assumed that, instead of heat transferability, each material has its own heat, for example wood is spontaneously warm, and ice is spontaneously cold. This view corresponds to a naive view on heat, as stated by Chiou & Anderson (2009). On the other hand, this view points to the role of conductivity in explaining the temperature difference. In other words, the temperature difference between the metal and wooden spoon is attributed to the conductivity difference.

The third question refers to the heat transfer in solids as called heat conduction. Responses to this question were considered to reveal participants' views on the heat transfer of solid materials (as can be seen in Table 3). It was seen that the participants could not respond correctly before the intervention as in the previous two questions. It was noticed that the responses before the intervention were mainly gathered on incomplete knowledge. After the intervention, it was found that 19 correct answers were given. On the other hand, it was seen that the incomplete knowledge continued to exist, and the participants tried to justify their argument by asserting that the substance was metal.

Table 3. Comparison of participants' understandings of how heat conduction occurs before and after the intervention respectively

Question	Categories	Students' Descriptions	f	Categories	Students' Descriptions	f
Does the spoon forgotten in a pot with boiling water get warmer? If so, how?	Boiling	"Yes, water in the pot gives heat to the spoon. Consequently, the spoon gets warmer"	13	Correct Answer	'Yes, because particles at the bottom of the spoon get heated by boiling water and they start to vibrate and conduct their energy to each other. By this way, the spoon gets warmer from the bottom to top.	19
	Incomplete Knowledge	"Yes, the water in the pot gets warmer and also spoon gets warmer because it is metal. If it was wood instead of metal, it would not get warmer"	14	Incomplete Knowledge	"Yes, it got warmer"	2
				Alternative Conception	"Yes, it got warmer. Because particles in the water passed into spoon"	2
					"Yes, because water starts to be heated at the bottom of the pot and metal spoon gets warmer due to the fact that it sinks"	1
				Incomplete Knowledge	"Yes, the spoon gets warmer in the boiling water because it is metal"	3

Before the intervention, the participants had this view 14 times, and the participants in this category expressed that conductivity was a unique feature of metals. This view was also observed after the intervention. Surprisingly, it was observed that the participants told about the motion of the heat particles. They also mentioned that these particles passed from the hot water to the spoon that was cold as if a process of diffusion. These particles are considered as tiny imaginary particles of substance, and their density in one region indicates that the mentioned region is warmer. These particles can also be represented as an imaginary fluid at the same time. This finding is noteworthy for the emergence of a feature that was not occurred before the intervention and which was thought to be inappropriate for the ontologically scientific view. In addition, as reported in Chiou & Anderson (2009), these tiny heat particles are heuristically imagined. In other words, students may provide a suitable way to explain their own analogous cognitive representation without worrying about its reality to depict the mechanism of heat conduction. The students with this view should be made aware of the fact that at least through the interaction of the particles the heat from the interaction can be transferred through an effective conceptual change. That is, their agent or medium of heat conduction should be replaced by an agent that is represented as a group of molecules containing basic particles whose movement determines the temperature of the system. The goal of this conceptual change must be an accurate and permanent understanding as heat is a thermal energy change.

The fourth question concerns the heat transfer through radiation. As indicated in Table 4, participants were predominantly shown to give the response “photon” to this question before the intervention. However, this response is incomplete knowledge because the participants knew that the factor that causes the radiation-induced heat transfer is the photons, but they could not explain how it happened. On the other hand, it was seen that the participants suggested alternative conceptions such as temperature, energy, and brightness. After the intervention, it was found that 22 correct answers were given. Moreover, it was found that alternative conceptions and incomplete knowledge were almost completely gone.

Table 4. Comparison of participants’ understandings of how heat radiation occurs before and after the intervention respectively

Question	Categories	Students’ Descriptions	f	Categories	Students’ Descriptions	f
How does the sun heat our homes?	Incomplete Knowledge	“The sun heats our homes by photons”	14	Correct Answer	“Photons coming from the sun to earth surface passes through our windows and heats our homes by radiation”	22
		“The sun heats our homes by its temperature and its energy”	2	Alternative Conception	“Temperature enters into roofs and heats our homes by this way”	1
		“The sun heats our homes by its brightness”	1		“Particles of heat in the sun collide with each other and propagate. Later, they reach to our homes and heat them”	1
		“The sun heats our homes as a huge source of heat”	2			
		“The sun heats our homes over time, primarily photons are reflected and then travel to our homes and finally heats all parts of our homes”	3		“The sun heats all around the world and our homes because it is located too high”	1
	Alternative Conception	“Photons are reflected to our homes across a line. Therefore, our homes get warmer”	2			
		“The sun heats our homes passing through windows”	2		"The sun heats all around the world and our homes because	1

		“The sun provides heat and light. Light turns into heat by moving in vacuum and heats our homes”	1		it is located too high"	
				Incomplete Knowledge	“Light coming from the sun reaches to our world by both heating and enlightening our homes”	1
				Incomplete Knowledge	“The sun enters into our homes and heats them because windows are transparent”	1

The fifth question concerns the heat transfer through convection. Prior to the intervention, it was seen that the participants used alternative conceptions such as boiling, transmission, heat exchange and temperature as justification items. It was seen that the number of correct responses increased from 2 to 12 after the intervention. On the other hand, it was observed that the existence of alternative conceptions like boiling, transmission and radiation continued to exist, although in a small quantity (Table 5). This finding is important because students generally tend to decide the way of heat transfer whether the elements involved are in contact with each other. However, heat convection does not necessarily a direct contact as it comes to fluids (Chiou & Anderson, 2010). In addition, it seems students recognized that the heat transfer is a process instead of an immediate action. So, the intervention could have provided students with informed view that heat is not a substance and heat conduction may be preceded by heat convection in any given context of everyday life (Ebenezer et al., 2010).

Table 5. Comparison of participants’ understandings of how heat convection occurs before and after the intervention respectively

Question	Categories	Students’ Descriptions	f	Categories	Students’ Descriptions	f
How is the water in a pot is heated completely?	Correct Answer	“The water at the bottom of the pot rises up and the water at the top sinks back down to the bottom when heated. Thus, all of the water in the pot is heated by this way”	2	Incomplete Knowledge	“All of the water in the pot is heated by convection”	7
	Boiling	“If we heat the lid of a pot, all of the water would be heated. That is, all the water is heated by boiling”	9	Correct Answer	“The water at the bottom of the pot heats up first, then this heated water rises up through the cooler water at the top of the pot. The cooler water at the top goes down to the bottom. Thus, all of the water is heated by the way of convection”	12

	Heat	"All of the water gets warmer with the effect of the heat we give to the pot"	10	Boiling	"All of the water gets warmer when the water boils"	4
	Conduction	"All of the water is heated by the collisions of atoms or molecules in the water"	3	Conduction	"The pot conducts the heat to the water. So, all of the water gets warmer"	1
	Heat Exchange	"The stove and the pot make heat exchange and all of the water gets warmer by this way"	1	Radiation	"All of the water in the pot gets warmer thanks to the photons of heat coming from the stove"	3
	Temperature	"When the heat combined with the temperature in the pot, all of the water gets warmer"	1			
	No Answer		1			

5. Discussion

As already known, any efforts undertaken within science teaching programs to help students develop in-depth understanding of science conceptions should be directed to achieve meaningful learning (Chiou & Anderson, 2010). However, research has consistently shown that students at K-12 level have not attained the desired understanding of science conceptions, in particular, within heat and heat transfer topics. As such, this research field needs to be further examined by novel studies. The study presented herein examined the effect of CKCM lesson sequence that has been rarely explored empirically. Since CKCM is inherently linked to relational conceptual change, findings are discussed in light of emergent categories. The CKCM lesson sequence may be effective in the development of students' relational conceptual understanding of heat transfer. Exploring and Categorizing as the first phase of the CKCM could be notably effective in revealing prior knowledge. The discussions were directed into a scientific discourse framed by the activities of the second phase, and so the common knowledge was constructed in the class in a social sense. At this phase, POE was used as an instructional tool for discussions to focus on the topic of heat transfer. Students shared their knowledge with their peers and socially engaged in the process of negotiating in the class by this way (Ebenezer & Connor, 1998).

In the present study, similarly, a majority of students were found to harbor naive views of heat and heat transfer at the outset of the study. Nonetheless, much change was evident after the intervention. As is evident, CKCM model resulted in improvements of students' achievement in the context of heat transfer with the help of the first two phases of CKCM instructional model. More clearly, based on the first two phases of the CKCM model, it was seen that conceptual understanding about heat transfer developed and alternative conceptions decreased substantially (Ebenezer et al., 2010). Therefore, the current study lend support to the notion that CKCM lesson sequence based on relational conceptual change has the capacity to enhance students' understanding of heat transfer. In addition, CKCM could have provided students with more coherent understanding on heat transfer with less incomplete knowledge. These results corroborate the findings in previous research (Ebenezer et al., 2010; İyibil, 2010; Bakırcı et al., 2016; Kiryak & Çalik, 2017).

The present findings are significant in, at least, two major respects. First, these sources are the dimensions in the context of the topic being discussed. Heat is a conception involving emergent processes. It is therefore more difficult to understand compared to the conceptions that have direct processes. In essence, the conceptual change takes place in the form of a transition from direct processes to emergent processes. A scientifically correct conceptual change can be achieved by individuals who know the difference between direct and emergent processes (Chi, 2005). It is stated that the heat-related views of students who do not know this difference are not included in the categories to which they should ontologically belong (Chiou & Anderson, 2009). In this study, it was seen that some participants tended to consider heat as a substance rather than a process. This finding is consistent with the related literature (Chi et al., 1994; Chiou & Anderson, 2009; Wong, Chu, & Yap, 2016). Second, POE strategy was applied in the context of CKCM lesson sequence to develop relational conceptual change. As a result of the study, it was found that POE was particularly effective in constructing scientific knowledge and leads to more effective results in the context of relative conceptual change when used with CKCM. Indeed, in a study organized by guided discovery and conducted with POE activities, Schönborn et al. (2014) found that the POE strategy created a cognitive conflict and opened up the transfer of knowledge between contexts. This finding is consistent with the current study. Through the data obtained during the process of implementation of the POE strategy, it was ensured that scientifically accepted and constructed knowledge about heat transfer was structured by the students through class discussions, group work, related videos and inquiry-based activities. During classroom discussions and group work, it was tried to cause dissatisfaction among students about their current conceptual frameworks by letting them recognize the views of their peers with different prior knowledge (Lee, 2014; Kiryak & Çalik, 2017). Into the bargain, the instruction through CKCM align with the discussions about a sequence of activities seems to have triggered students to improve their understanding of heat transfer. This strategy is particularly important in that it involves prediction. Prediction plays an important role for the conceptual change to actively take place and for this process to be carried out through the students' preliminary knowledge. It can be said that this is because it triggers the upper cognitive processes of the students by considering the prior knowledge. This view was supported by the study aimed at revealing sub-models related to heat transfer and studied heat transfer through multi-dimensional representations (Chiou & Anderson, 2010).

On the other hand, there are situations that were encountered during the intervention. For example, the expression of “motion of heat” may cause a vernacular misconception (Brookes & Etkina, 2015). Because it may result in the impression that heat is a moving object. Thus, students with this view tend to perceive hotness and coldness as opposite of each other by distinguishing between them (Chiou & Anderson, 2009). This situation was frequently observed during the intervention. Similarly, it was observed that heat was also perceived as a natural feature of a substance as an internal entity. It can be argued that such students dwelt on the conservation of heat rather than the transfer of heat. On the other hand, it is also important which of the heat definitions in textbooks is used as a base, because there are studies reporting that textbooks also characterize heat as a moving entity (Doige & Day, 2012). For this reason, it can be said that it is generally necessary to avoid the expression of motion of heat (Allen & Coole, 2012). It can be argued that conceptions in the process of conceptual change through the relative conceptual change can be more applicable to students’ daily lives through this aforementioned feature (Lee, 2014). Thus, the distinction of disciplinary context and everyday context is accomplished in a way that the model predicts and is made in accordance with phenomenography which dictates this model (Ebenezer et al., 2010).

6. Conclusion and Suggestions

CKCM gave us the unique opportunity to gain deep insight into how students construct the common knowledge thanks to its phenomenological approach resulted in relational conceptual change. However, the results are prone to be viewed with caution. First, the present study included activities that lasted only two weeks. Considering heat conception is resilient to change and sensitive to ontological category change, it needs more longitudinal studies to conduct. Consequently, we would recommend in future implementations to ask more ontology-oriented questions to prompt students understanding of heat transfer more deeply. In addition, the study needs to be conducted in other contexts using various instructional sequences. Moreover, it can be suggested that the concept of heat, which has a dynamic structure, can be examined at the model level rather than the concept level, to deeply understand students’ views about heat (Chiou & Anderson, 2009; Chiou & Anderson, 2010). Notwithstanding, the present study focused on the understandings at the conceptual level. In addition, CKCM in which variations in meanings are constructed relatively, requires a qualitative analysis on the addition or elimination the ideas students put forward in both two phases of CKCM during instruction. It also requires the replacement of everyday language with scientific labels. However, there is no investigation about these two lines in the present study except for the analysis on how the number of students change in the emerging categories and the difference in the complexity of the students’ understanding of heat transfer at the end of the instruction. As such, the future research can be reoriented into the investigation of changing everyday language with scientific labels to facilitate a more relational conceptual change.

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