FOSTERING MIDDLE SCHOOL STUDENTS' KNOWLEDGE INTEGRATION USING THE WEB-BASED INQUIRY SCIENCE ENVIRONMENT (WISE)

BESTE ULUS

BOĞAZİÇİ UNIVERSITY

2017

FOSTERING MIDDLE SCHOOL STUDENTS' KNOWLEDGE INTEGRATION USING THE WEB-BASED INQUIRY SCIENCE ENVIRONMENT (WISE)

Thesis submitted to the

Institute for Graduate Studies in Social Sciences

in partial fulfillment of the requirements for the degree of

Master of Arts

in

Educational Technology

by

Beste Ulus

Boğaziçi University

2017

Fostering Middle School Students' Knowledge Integration

Using the Web-Based Inquiry Science Environment (WISE)

The thesis of Beste Ulus

has been approved by:

Assoc. Prof. Diler Öner
(Thesis Advisor)

Assist. Prof. Devrim Güven

Assist. Prof. Bahadır Namdar
(External Member)

June 2017

DECLARATION OF ORIGINALITY

I, Beste Ulus, certify that

- I am the sole author of this thesis and that I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources, which have been produced or published by another person or institution;
- this thesis contains no material that has been submitted or accepted for a degree or diploma in any other educational institution;
- this is a true copy of the thesis approved by my advisor and thesis committee at Boğaziçi University, including final revisions required by them.

Signature...

Date ....05.06.2017...........................

ABSTRACT

Fostering Middle School Students' Knowledge Integration

Using the web-based Inquiry Science Environment (WISE)

This mixed methods study investigated the use of a web-based inquiry science environment (WISE) unit to improve Turkish middle school students' knowledge integration (KI), which refers to the ability to link ideas and to distinguish among these ideas in the process of generating arguments based on normative ideas. This study examined whether using this unit improved Turkish seventh-graders' knowledge integration about heat and temperature concepts and investigated the mechanisms of WISE that led to higher KI gains. The unit on heat and temperature was newly designed within the WISE authoring environment that reflected KI principles and processes. Seventh-grade (*n*=75) students from a public middle school in Istanbul participated in this study. To evaluate students' KI levels, a 10-item KI Scale about heat and temperature was developed and used as a data collection instrument for quantitative analysis. Finally, the WISE logs of three students were analyzed qualitatively to examine how the mechanisms of the WISE interaction varied for students who had different levels of KI gains when they started with the same or the similar KI scores. The results indicated that the students significantly improved their KI levels on the heat and temperature topic after studying on the WISE unit. The qualitative findings suggested that revisiting the steps, the quality of revising explanations, and reflecting on the learning process were influential factors to improve KI within the WISE platform.

ÖZET

Ortaokul Öğrencilerinin Bilgi Bütünleştirmelerinin Web Tabanlı Sorgulamaya Dayalı Fen Öğrenme Ortamı (WISE) ile Geliştirilmesi

Bu karma yöntem çalışma, web-tabanlı sorgulamaya dayalı fen öğrenme ortamında (WISE) yedinci sınıf Türk ortaokul öğrencilerinin ısı ve sıcaklık konusunda bilgi bütünleştirmelerini geliştirmeye yönelik hazırlanan bir ünitenin kullanımını incelemiştir. Bilgi bütünleştirme, normatif fikirlere dayalı düşünce geliştirme sürecinde bilimsel fikirler arasında ilişki kurma ve bunları ayırt etme becerisi olarak tanımlanır. WISE ortamında, bilgi bütünleştirme tasarım prensipleri ve aşamalarını yansıtan, ısı ve sıcaklık ile ilgili bir ünite tasarlanmıştır. Bu çalışmada, bu ünitenin, öğrencilerin ısı ve sıcaklık konusundaki bilgi bütünleştirme seviyelerini arttırmada etkili olup olmadığı ve ileri düzey bilgi bütünleştirmeye yol açan WISE mekanizmaları araştırılmıştır. İstanbul'daki bir devlet ortaokulunun yedinci sınıf öğrencileri (*n* = 75) çalışmaya katılmışlardır. Öğrencilerin bilgi bütünleştirmelerini değerlendirmek amacıyla ısı-sıcaklık konusuna dair 10 soruluk Bilgi Bütünleştirme Ölçeği geliştirilerek nicel analiz için veri toplama aracı olarak kullanılmıştır. Son olarak, farklı bilgi bütünleştirme kazanımları olan üç öğrencinin WISE kayıtları WISE kullanımında farklılaşmalarını incelemek için nitel olarak analiz edilmiştir. Nicel sonuçlar, WISE ünitesiyle, öğrencilerin, ısı ve sıcaklık konusundaki bilgi bütünleştirmelerinin anlamlı bir şekilde arttığını göstermektedir. Nitel bulgular ise, öğrencilerin ünite adımlarına geri dönme oranları, açıklamalarını iyileştirme dereceleri ve kendi öğrenmeleri üzerine yansıtma yapabilmeleri gibi üç faktörün WISE platformunda daha iyi bilgi bütünleştirme seviyeleri edinmede etkili olduğunu göstermektedir.

ACKNOWLEDGMENTS

I am grateful to those who made this thesis possible. First and foremost, I would like to express my sincere gratitude to my advisor, Assoc. Prof. Diler Öner. She has made her support available in a number of ways. Without her continuous encouragement, support and expertise, this study would hardly have been completed.

I would like to express my greatest appreciation to each of the other members of my thesis committee, Assist. Prof. Devrim Güven and Assist. Prof. Bahadır Namdar, for their valuable comments, feedback, guidance and suggestions that broadened my horizons in this period. I gratefully acknowledge the help provided by Assoc. Prof. Emine Adadan and Assoc. Prof. Ebru Kaya.

I also thank Taylan Özbek for his permission to conduct this research in the school he is principal and Mustafa Yılmazoğlu and Burak Çalışkan, who volunteered to participate in this study with their students. My beloved friends made an enormous contribution to my research. The meticulous comments of Gülşah Özkan, Behiye P., and Aylin Ö. helped me design the knowledge integration activities, scales and rubrics on the topic. Cemile A., Fatma K., Gizem K., Fatma T. helped me reach a great numbers of students. The support of Kevser E., Çiğdem K., Pınar Ö., and Aydan S. were invaluable. I would like to offer my special thanks to Selda C. and Kathryn Mator for editing and language support. I have greatly benefited from the experience of my friend and colleague Ekrem Kutbay. Lastly, I am grateful to İrem N. and Nurdan K. for assisting me with the data collection period.

Last but not least, I owe a very important debt of gratitude to my beloved family: to my mother, Vesile, to my father Hüseyin, and to my sister Elem. They stood by me all throughout this tough process and had faith in my ability to succeed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

5E: Engage, Explore, Explain, Elaborate, Evaluate

EIMA: Engage, Investigate, Model, Apply

ILDs: Interactive Lecture Demonstrations

KI: Knowledge Integration

MUVE: Multi-User Virtual Environment

NRC: National Research Council

OECD: Organisation for Economic Co-operation and Development

PhET: Physics Education Technology

PISA: Programme for International Students Assessment

POE: Predict, Observe, Explain

SI: Sustainability Investigator

SMILE: Stanford Mobile Inquiry-based Learning Environment

TELS: Technology Enhanced Learning in Science

WISE: Web-based Inquiry Science Environment

CHAPTER 1

INTRODUCTION

Recent developments in the constructivist view of learning have heightened the need for identifying students' previous ideas about scientific phenomena, which plays a key role in accurate science understanding. Students in science classrooms have difficulties in understanding complex scientific concepts. This has been a concern for science education researchers who have extensively studied students' views of the natural world and their understanding of everyday concepts over almost three decades (Carey, 2000; Driver, Asoko, Leach, Mortimer & Scott, 1994; Duit, Treagust & Widodo, 2008; Lorsbach & Tobin, 1992; Matthews, 1993; Vosniadou, Ioannides, Dimitrakopoulou & Papademetriou, 2001). The result of this body of research shows that students have a repertoire of ideas on many concepts such as heat and temperature as a consequence of interacting the world (Duit & Treagust, 2003). Connately, Turkish students in different grade levels have a wide range of intuitive ideas about heat and temperature (Tamkavas, Kıray, Koçak & Koçak, 2016).

Research has, however, consistently shown that these intuitive ideas generally prevent students to construct scientific ideas about the concepts even after schooling since they are mostly abstract, such as heat and temperature (Erickson, 1985; Clough & Driver, 1986; Lewis & Linn, 2003; Harrison, Grayson & Treagust, 1999). Educational researchers suggest that learners can change these conceptions when their existing ideas are conflicted in new situations and when they have opportunity to integrate their ideas with normative ones (Linn, 2006; Linn & Eylon, 2011). In contrast, current school curricula do not provide students much opportunity to explore how to use these normative ideas in everyday problems (Clark & Linn, 2013).

In the past two decades, several researchers have sought effective ways to integrate students' ideas into lessons in an attempt to aid their conceptual understanding. In this respect, technology integration is increasingly recognized as an essential method to support conceptual understanding of students as well as inquiry-based instruction in science education. Many methodologies and technologies were developed and investigated to promote coherent science understanding, which infers that students logically relate and integrate new scientific ideas with their previous ideas. An important methodology of science education is the use of inquiry-based instruction to promote conceptual understanding (Anıl & Batdı, 2015; Clark & Linn, 2013; Harrison et al., 1999; Lee et al., 2011; Patro, 2008; Quan, 2011; Ryoo & Linn, 2015). A knowledge integration approach advances inquiry and coherent understanding by emphasizing the ability to link ideas and to distinguish among these ideas in the process of generating arguments based on normative ideas (Clark & Linn, 2013; Lee et al., 2011; Linn, 2006; Linn & Eylon, 2011; Ryoo & Linn, 2015). The knowledge integration framework explains how students link new ideas and perspectives to their existing ideas about scientific phenomena (Slotta, 2004).

In this sense, a considerable amount of literature has been issued on various technology-supported inquiry-learning environments. These were aimed to help students to comprehend scientific concepts and teachers' implementation of inquiry activities on easy terms. These studies show that these environments help fostering students' understanding of scientific concepts and their inquiry skills, and whilst also changing students' attitudes toward science positively (Buckner & Kim, 2014;

Erlandson, Nelson & Savenye, 2010; Jones, Scanlon & Clough, 2013; Ketelhut, Dede, Clarke & Nelson, 2010; Lee, Linn, Varma & Liu, 2010; Lin, Hsu & Yeh, 2012; Sarabando, Cravino & Soares, 2014; Song, 2014; Williams & Linn, 2002). Apart from these, Linn and her colleagues have developed an online platform to support conceptual understanding and have effectively implemented science inquiry within the knowledge integration perspective. A number of researchers have reported that WISE units have the potential to improve students' domain knowledge in science (Chiu & Linn, 2014; Clark & Linn 2003; Gerard, Ryoo, McElhaney, Liu, Rafferty & Linn, 2016; Lee et al., 2010; Liu, Ryoo, Linn, Sato & Syihla, 2015; Ryoo & Linn, 2015; Svihla & Linn, 2012; Visintainer & Linn, 2015; Vitale, McBride & Linn, 2016; Williams & Linn, 2002; Williams, Linn, Ammon & Gearhart, 2004).

In spite of the availability of such technologies, Turkish students have had limited access to the inquiry-based instruction and technology-enhanced learning environments. Few teachers allocate time for technology-enhanced learning activities and do not include those materials into their lessons, even though the Turkish Ministry of Education has recently put emphasis on constructivist teaching and technology integration. Research reveals that teachers rarely use technology, particularly smart boards and tablet PCs in their classes due to fact that the (electronic) content is insufficient (Ayvacı, Bakırcı & Başak, 2014; Dağhan, Nuhoğlu-Kibar, Akkoyunlu & Atanur-Başkan, 2015; Dursun, Kuzu, Kurt, Güllüpınar & Gültekin, 2013; Özkale & Koç, 2014; Pamuk, Çakır, Ergun, Yılmaz & Ayas, 2013).

Much of the research up to now has studied the effects of WISE on knowledge integration and inquiry skills. However, there has been little discussion about the use of technology-enhanced learning environments to foster students' knowledge integration in Turkey. Furthermore, effective methods to integrate inquiry-based instruction into science education and its relation with computer-aided instruction have not been studied in Turkey (Kızılaslan, Sözbilir & Yaşar, 2012; Kula-Wassink & Sadi, 2016). In the light of these, in Turkey, it appears that there is no study specifically on WISE, which is an adaptable platform for any scientific concept to integrate inquiry-based learning into curriculum by incorporating technology. Thus, there is a need for research on the effects of WISE on students' conceptual understanding, more specifically knowledge integration, within the Turkish settings.

1.1 Significance of the study

Turkish students' level of thinking skills in science is very low according to the reports of international tests. For example, no single Turkish student was able to perform at higher levels in the science proficiency tests in the Programme for International Students Assessment (PISA) (OECD, 2016; Salman, 2016). It can be argued that Turkish students might not be good at conceptualizing information based on their investigations, linking multiple information sources and representations, and developing argumentations. Researchers believe that abstract science concepts, curriculum, instructional programs and methods have been the sources of this problem (Bağcı-Kılıç, 2002; Balım, Deniş, Evrekli & İnel, 2010; Cengiz, Uzoğlu & Daşdemir, 2012; Sözbilir, Şenocak & Dilber, 2006). Turkish students' low scores on international tests further points at the crucial need for studying effective methods and technologies to foster advanced scientific understanding.

This study addresses the problem of low science proficiency and contributes to the literature in the following ways: First, the WISE learning platform was translated to Turkish so that Turkish teachers are now able to prepare inquiry activities, units or projects and deliver them to their students in Turkish. Second, an online heat and temperature knowledge integration unit in Turkish including simulations was designed and developed within WISE platform. Third, a Knowledge Integration Scale on heat and temperature in Turkish was developed so that teachers could evaluate their students' knowledge integration development. Forth, the results of this study supported the literature on knowledge integration and the effectiveness of WISE on accurate science understanding and inquiry skills. Finally, the study findings provided the mechanisms of WISE experience that might lead to different level of knowledge integration improvement.

1.2 Purpose of the study

The purpose of this mixed-methods study is to examine whether a WISE-based unit on heat and temperature improved Turkish seventh-graders' knowledge integration about heat and temperature concepts and to investigate the mechanisms of WISE interaction that led to higher knowledge integration gains among these students.

1.3 Research questions

Therefore, this study raises two major research questions as follows:

1) Do Turkish seventh grade students significantly improve knowledge integration level after participating in the WISE instructional unit about heat and temperature?
2) How does Turkish seventh grade students' interaction with the WISE environment in the heat and temperature unit explain different levels of knowledge integration gains?

1.4 Research hypothesis

Based on the existing research on science education and technology, the hypothesis of this study is that students will significantly improve their knowledge integration levels after participating in the WISE instructional unit about heat and temperature.

CHAPTER 2

LITERATURE REVIEW

This chapter is concerned with the issue of educational theories and methods including knowledge integration framework to achieve conceptual science understanding. Existing research on technology in science education within two paths, conceptual change and knowledge integration, were reviewed. In the following sections, various technology-enhanced learning environments including WISE aiming to improve students' scientific understanding were presented. Then, the purposes of the study were stated, the research questions were posed and finally the hypotheses were declared.

2.1 Social constructivism / Social cognitive theory

In the constructivist view of learning, learning is characterized as an active process that refers to meaning construction through integration of new ideas with learners' previous knowledge (Naylor & Keogh, 1999; Vosniadou et al., 2001). From this perspective, concepts and conceptions of students are key elements in meaningful science learning. There is a body of research that studied how students grasp physical world and how they master in understanding scientific concepts. Students have many problems in learning science concepts such as matter, heat, temperature, density, and force. There is a large volume of reported studies describing the role of alternative conceptions in understanding those concepts (Carlton, 2000; Fulmer, 2013; Hashweh, 1986; Lewis & Linn, 2003; Krummel et al., 2007). It has been noticed that students' alternative conceptions lead to confusion in understanding scientific concepts. For instance, students might fail to differentiate the related concepts such as heat and temperature (Erickson, 1980; Erickson, 1985; Jasien & Oberem, 2002; Lewis & Linn, 2003; Lee & Liu, 2010; Niaz, 2000b; Quan, 2011; Thomaz, Malaquias, Valente & Antunes, 1995).

2.1.1 Concepts in science education

A concept can be described as a unit of mental representation corresponding to an individual word such as a plant, nature, heat, temperature, mass, velocity and so on (Carey, 2000). Carey also indicated that some concepts are related to each other. Some individual concepts are building blocks of complex representational structures (which are also concepts) such as "plants are alive." Likewise, Zirbel (2004) labeled those individual concepts as core concepts, which are base knowledge to build on while understanding the natural world. Similarly, diSessa (1998) indicated that concepts are the center of human understanding and beliefs but they are underestimated.

In order to explain human understanding about a concept, Treagust and Duit (2008) used the term conception as ‘‘the learner's internal representations constructed from external representations of entities constructed by other people such as teachers, textbook authors or software designers'' (p. 298). Roth, Lee and Hwang (2008) correspondingly classify a conception as collective incidences of expressions or a set of techniques of expressing some entity. From the constructivist perspective, children's conceptions are constructed from their reality, which are compatible to their experiences and allow them to make sense of their environment (Lorsbach & Tobin, 1992).

2.1.2 Repertoire of students' ideas in science

Recent research has revealed that students have some specific ideas about content to be learned before instruction (Chen & Bradshaw, 2007; Hashweh, 1986). Students develop these initial ideas in consequence of interacting with the natural world (Hashweh, 1986; Read, 2004) and explain scientific events based on those as "everyday knowledge," not as "school knowledge" (Lewis & Linn, 1994). In other words, students form alternative conceptions to explain scientific events in relation to their physical world experiences. This justification and organization of their own ideas shows their knowledge of science, beliefs about learning and views of scientists (Linn, 2006). Glynn and Duit (1995) made a distinction between ideas of students as mental models and conceptual models. Mental models are personal knowledge that refer to what students have in their minds whereas conceptual models are scientific knowledge that are cognitive representations of scientific phenomena accepted by the science community.

Students can formulate their own ideas about a concept before they are formally taught in schools (Clark & Linn, 2003; Glynn & Duit, 1995; Krummel, Sunal & Sunal, 2007). Limitations of human brain and human perceptions of natural world account for some of these conceptions (Lewis & Linn, 1994). Since students may not imagine or believe these ideas taught in schools, they prefer to describe and explain them with familiar ideas (Asoko, 2002; Strauss, 1981; Vasniadou, 2003). In science education literature, the existing thinking and ideas of students about scientific conceptions have been labeled with various terms such as pre-instructional conceptions, preconceptions, naïve conceptions, informal ideas, intuitive ideas, intuitive conceptions, misconceptions, alternative frameworks, alternative conceptions and commonsense knowledge (Chi & Roscoe, 2002; Driver & Erickson, 1983; Duit, Treagust & Widodo, 2008; Erickson, 1980; Grayson, 1994; Hashweh, 1986; Howe, Devine & Tavares, 2013; Lewis & Linn, 2003; Driver et al., 1994; Treagust & Duit, 2008; Zirbel, 2004). In this study, the term repertoire of ideas which are views held by a learner (Linn, 2006) was considered.

It is not critical how to name these ideas but it is fundamental to know why they are usually resistant to change (Bain, Moon, Mack & Towns, 2014; Chi & Roscoe, 2002; Treagust & Duit, 2008). There are important barriers to develop understanding of scientific principles behind everyday events (Fulmer, 2013; Hashweh, 1986; Lewis & Linn, 2003; Krummel et al., 2007). Many researchers have reached a consensus that students' ideas stem from analogies with associated events, observations, cultural practices, or use of everyday language. Ruhf (2003) summarized that previous experiences and perceptions, cultural values and ideas, and language are possible causes of alternative conceptions.

Carlton (2000) declared that alternative conceptions that students experienced in their childhood remains until they confront challenging situations failing to explain the situation. There are various reasons why alternative conceptions are hard to change. One reason is that people are prone to see the natural world within consistent frames of current conceptions (Lorsbach & Tobin, 1992; Ruhf, 2003). Another statement is that these conceptions are constructed via sensory experiences with the natural phenomena even before linguistic experiences and development (Driver & Erickson, 1983). Finally, Hasweh (1986) indicated that these conceptions are persistent when involving metaphysical and/or causal explanations that help people to understand concepts. He added that explicit cultural beliefs, language and persistent common-sense epistemology in the culture are factors that lead persistency of alternative conceptions. Alternative conceptions are not an obstacle only for students; even conceptions of many science teachers do not correspond with the scientific view. Similarly, their conceptions of scientific phenomena are similar to students' alternative conceptions (Treagust & Duit, 2008).

Alternative conception, which was first introduced by Ausubel (as cited in Treagust & Duit, 2008), is one of the most critical factors that affect students' learning of scientific concepts (Thomaz et al., 1995). Thus, teaching for understanding should be planned in the consideration of students' alternative conceptions (Asoko, 2002; Carey, 2000; Chen & Bradshaw, 2007; Lewis & Linn, 2003; Linn, 1992; Linn & Songer, 1991; Strauss, 1981). Kang and Howren (2004) suggest that starting a lesson by identifying alternative conceptions of students and providing challenging activities are important for understanding of scientific ideas. Glynn and Duit (1995) stated that replacing students' mental models with conceptual models by eliminating their mental models is not rational and believed that meaningful science learning occurs when students stimulate their existing knowledge, link it to instruction and construct new conceptual models. Similarly, an instruction that considers students' alternative conceptions will favor the development of these conceptions through the school science (Driver & Erickson, 1983). Considering the importance of alternative conceptions in science education, students' repertoire of ideas related to heat and temperature were searched through reviewing heat and temperature education literature. In the next section, most observed alternative conceptions on that topic were presented.

2.1.2.1 Repertoire of ideas regarding "heat and temperature"

Students' alternative conceptions regarding heat and temperature which are previously associated in childhood are resistant to change (Clough & Driver, 1985;

Clough & Driver, 1986; Harrison et al., 1999). Students explain scientific events related to heat and temperature based on their intuitive conceptions which are the ideas derived from observation and interaction with the natural world, and making sense of everyday phenomena (Erickson, 1985; Lewis & Linn, 2003).

There are two views on the concept of heat: caloric and kinetic. Teachers mostly rely on caloric view as they plan instruction; yet, it is believed that kinetic view is more helpful to build a coherent understanding about heat and temperature (Wiser, 1986). However, it is a challenging process for students. In a study by Niaz (2000b), it is seen that students resist on the caloric theory of heat even after they had been exposed to the kinetic energy theory of heat in lectures. Likewise, Linn and Muilenburg (1996) showed that middle school students find heat flow ideas are more beneficial than molecular kinetics ideas for understanding concepts related to heat such as thermal equilibrium, heating and cooling and direction of heat flow. Apart from those views, students have their own hypothesized viewpoint of heat different from caloric and kinetic view of heat (Erickson, 1980).

Jasien and Oberem (2002) found that students most commonly have confusion about the meaning of the following concepts: thermal equilibrium, heat transfer and temperature change, and the relationship between specific heat, heat capacity and temperature change. Thus, based on the literature, in the current study, the alternative conceptions of students are categorized into three main groups:

- Heat is seen as a kind of substance, not as a form of energy.
- Confusion between temperature and sensation of an object.
- Inability to differentiate heat and temperature (Erickson, 1985; Jasien & Oberem, 2002; Lee & Liu, 2010; Quan, 2011; Thomaz et al., 1995).

Since alternative conceptions have a great influence in accurate understanding, the inquiry activities of this study were designed targeting these three major alternative conceptions regarding heat and temperature.

2.1.3 Theories and processes of conceptual change

Many researchers have been interested in the ways to foster conceptual change for students and suggested several strategies. The most cited conceptual change model belongs to Posner, Strike, Hewson and Gertzog (1982) in science education research. According to this model, dissatisfaction with existing conceptions, minimal understanding of new conceptions, initially plausible new conceptions for students, and new conceptions suggesting possible and useful research program are necessary conditions for conceptual change.

Since the 1970s, conceptual change has attracted attention in research communities of science education and learning psychology (Duit et al., 2008). Yet, there is still not a consensus on an efficient method, although research on conceptual change enlightens how to teach and learn scientific concepts (Duit et al., 2008). In general terms, conceptual change can be defined as the learning process that changes some existing conceptions with current scientific understandings (Posner et al., 1982; Tanahoung, Chitaree, Soankwan, Sharma & Johnston, 2009; Treagust & Duit, 2009; Vosniadou, 2007). Wiser and Amin (2001) suggest that conceptual change can be induced by integrating the everyday and scientific knowledge thus scientific knowledge justifies the everyday knowledge of students.

Many researchers have categorized the conceptual change into groups based on the summary of literature on knowledge acquisition and conceptual change. There are at least two conceptual change levels: easy and difficult (Harrison et al., 1999;

Niaz, 2000b, as cited in diSessa, 1998). Easy level (weak restructuring or accumulation) refers to adding new facts and forming new relations between existing and new concepts. On the other hand, difficult level (radical restructuring or revolutionary) represents more radical changes of core concepts, conceptual structure and phenomena.

According to this categorization, change in the concept of heat falls into the second level of conceptual change (Quan, 2011) as students have earlier experiences related to the concept of heat. However, Wiser and Amin stated that conceptual change in thermal physics has both evolutionary (accumulation of information) and revolutionary (categorical reorganization) components. Beyond this, Pintrich, Marx, and Boyle (1993) indicated that changes in students' the conceptions are rarely revolutionary. In spite of the rarity of revolutionary conceptual change, Harrison et al. (1999) stated that it is considerably less effective than revolutionary conceptual change considering recent research on conceptual change. Therefore, it is important to design instruction for conceptual change considering the components of concepts.

Treagust and Duit (2008) classified the views of conceptual change into three categories as epistemological, ontological and affective orientations. According to epistemological perspective, conceptual change involves how students' conceptions are transformed and how they currently construct knowledge. The ontological perspective of conceptual change refers to how students consider the nature of the scientific conceptions within the frame of their own reality. Conceptual change in heat, which this study aims to investigate, is one of the examples of ontological conceptual change (Treagust & Duit, 2008). Lastly, affective aspects regarding students' interest and motivation are essential in science education since they are highly important for conceptual change. Multi-perspectives of conceptual change taking into account epistemological, ontological and affective domains should be combined to deal with the complexity of the teaching and learning science (Duit et al., 2008).

2.1.4 Methods to promote conceptual change

Research on conceptual change suggest some methods for promoting conceptual change such as model-based instruction, conceptual change texts, computer-based instruction, concept mapping, and inquiry instruction (Asan, 2007; Hitt & Townsend, 2015; Özkan & Selçuk, 2015; Tanahoung et al., 2009). Hitt and Townsend (2015) found out that students could overcome misconceptions and precisely understand heat and temperature when they were taught with model-based instruction. This instructional approach begins with developing a sketchy model for a target phenomenon (heat and temperature in that study). With further instruction and experiences, they gradually change their models until they have developed a completely accurate model.

Moreover, conceptual change texts have been seen as an important strategy to provide students conceptual change (Tanahoung et al., 2009). Özkan and Selçuk (2015) designed technology enhanced conceptual change texts, which were developed about buoyancy in liquids and buoyancy in gases topic considering Posner’s approach of conceptual change conditions of dissatisfaction, intelligibility, plausibility and fruitfulness. These texts included five parts: identification of misconceptions, indication of these misconceptions as wrong, scientific explanation, reflection and assessment (transferring new situations). In this study, it is found out that technology enhanced conceptual change texts can help to overcome misconceptions of students more successfully than the traditional instruction. A study by Tanahoung et al. (2009) indicate that students' understanding of heat and temperature concepts were increased via Interactive Lecture Demonstrations (ILDs) consisting microcomputer-based laboratory tools and worksheets rather than traditional instruction.

Another strategy is to assure conceptual change is the use of concept mapping which combines new connections and relationships between concepts. Harrison et al. (1999) investigated the effects of concept mapping by asking students to draw concept maps of their understanding of heat and temperature. The study showed that the number of students' conceptions increased, the connection become more sophisticated and detailed and conceptual hierarchies emerged over time. This demonstrated that concept mapping is beneficial for generating new hierarchies and connections between prior and new knowledge. Asan (2007) concluded that concept mapping could be a useful learning tool in science lessons since many concepts are inter-related and built on other concepts. There is ample support to claim that one of the most prominent strategies to sustain conceptual change is the inquiry-based instruction (Anıl & Batdı, 2015; Clark & Linn, 2013; Harrison et al., 1999; Lee et al., 2011; Patro, 2008; Quan, 2011; Ryoo & Linn, 2015), which was discussed below in depth.

2.1.5 Inquiry-based instruction

2.1.5.1 Scientific inquiry

It is possible to find various definitions for inquiry in the literature of science education. Minner, Levy and Century (2010) state that inquiry consists of at least three notable activity categories: scientist work, student learning, and pedagogical approaches employed by teachers. Bell, Smetana and Binns (2005) roughly define inquiry as an active learning process in which students try to seek answers to research questions by analyzing the data. They state that a science activity should include the following steps: scientific questions, gathering data and analyzing these data to constitute inquiry. Linn, Clark and Slotta (2003) comprehensively defined inquiry as “the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, revising views, researching conjectures, searching for information, constructing models, debating with peers, communicating to diverse audiences, and forming coherent arguments” (p. 518). Yet, National Research Council (NRC) (1996) standardized scientific inquiry description as: “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.” (p. 23). In educational context of science, inquiry is defined as “the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (p. 23). NRC (2000) also suggested the five essential features that should be in a classroom inquiry as “(1) engagement of learners with scientifically oriented questions, (2) emphasis on the evidence to generate and evaluate explanations, (3) formulation of explanations from evidence to address inquiry questions, (4) evaluation of their explanations considering alternatives, and (5) justification of their proposed explanations.

Additionally, Leonard and Penick (2009) remark the pillars that make inquiry learning authentic as follows: making initial observations, posing research questions, generating hypotheses, planning the procedure, collecting and analyzing data, sharing ideas and finally reaching a final decision. They also think that a posed research question is a must in real authentic inquiry learning. Furthermore, Colburn

(2000) states that inquiry often requires hypothetical reasoning and students who think concretely have troubles in the understanding of abstract concepts. Apart from these main components of scientific inquiry activities, many researchers agree that inquiry should involve some certain interconnected activities such as observing, identifying questions, investigating sources of already-known information, planning investigations, analyzing and interpreting data, proposing explanations and predictions, and finally exchanging the results (Duschl, Schweingruber & Shouse, 2007; Lee et al., 2010; Lin et al., 2012; NRC, 1996; Quintana, Zhang & Krajcik, 2005; Song, 2014). Although the current literature shows consensus on what inquiry is, it has different types and levels, which was discussed in the next section.

2.1.5.2 Types and levels of scientific inquiry

Not all the science activities consist of the same amount of inquiry. The level of inquiry varies according to the amount of information given to students about research questions, methods and solution. Herron (1971) added "*zero*" level to the work of Schwab (1964) who first introduced the inquiry continuum as the simplest, second and third level. Based on this continuum, there are four types of inquiry levels; confirmation activity, structured inquiry, guided inquiry and open-inquiry (Bell et al., 2005; Bell & Banch, 2008; Eastwell, 2006).

Confirmation activity is a teacher-led presentation focusing on a specific topic or phenomenon with striking observations. In other words, questions and procedures are provided and students just observe the expected and known results of the inquiry activity. Structured inquiry, on the other hand, has only teacher-presented questions and prescribed procedure. Students collect evidence from provided data and information to draw a conclusion but the teacher decides method of investigation. In a guided inquiry activity, students are provided only questions and are free to use any methods for any solutions. Particularly, the teacher poses the question or the problem to be investigated whilst the students design and achieve the procedure for the investigation of evidence that emerged from information collected by students. Finally, open inquiry is a situation in which students pose their own questions about a topic or phenomenon and then design their investigations, collect data and analyze to answer these questions.

In this research study, the inquiry activities in the online WISE unit can be considered as a guided inquiry since the research questions and data related to concepts were provided to students and they tracked an inquiry map to conduct an inquiry. This means that the students were oriented to generate explanations for the provided research questions and to communicate their results in the guidance of this inquiry map. It also corresponds with the remark of Chiu and Linn (2011), which is WISE supports guided inquiry.

2.1.5.3 Inquiry-instruction

Several researchers claim that inquiry-based instruction is one of the most powerful ways to promote students' conceptual understanding of scientific concepts (Anıl & Batdı, 2015; Clark & Linn, 2013; Harrison et al., 1999; Lee et al., 2011; Patro, 2008; Quan, 2011; Ryoo & Linn, 2015). Bell et al. (2005) argued that science instruction can build on the constructed ideas of students that keep the enthusiasm and the natural intellectual skills for exploring the world. They added that curiosity for scientific events stimulate students to explore, observe, connect, and question their ideas. Similarly, Asoko (2002) put forward the claim that the ideas of students are required to become explicit and challenged to stimulate learning according to some teaching strategies. Posner et al. (1982) indicate that challenging students' ideas is likely to promote dissatisfaction with current conception, which is a must and stimulation for learning. Harrison et al. (1999) found that an inquiry based teaching model reconstructed student's alternative conceptions related to heat and temperature concepts towards a more scientific form. Quan (2011) designed a special curriculum called Physics by Inquiry module in which students conducted experiments that they design and then construct physics concepts through their observations. It is found that the Physics by Inquiry module was more advantageous than the algebra-based course on students understanding of calorimeter problems, and thermal equilibrium. Lewis and Linn (2003) also claimed that combining students' intuitive conceptions into classroom resulted in more powerful understanding of elementary thermodynamics giving students the opportunity and encouragement to integrate their ideas.

2.1.5.4 Models of inquiry instruction

Since the inquiry-based learning process supports students to develop inquiry skills, which are important for this century (Kong & Song, 2014), there are various approaches to science inquiry instruction. Researchers have proposed many inquiry models for decades. Leading models of inquiry instruction approaches can be summarized as: Learning Cycle, Predict-Observe-Explain (POE), Engage-Investigate-Model-Apply (EIMA), Engage-Explore-Explain-Elaborate-Evaluate (5E Instructional Model) and finally Knowledge Integration (KI).

2.1.5.4.1 The learning cycle model

The first model used with the intent of inquiry based lesson planning was a three-phase inquiry approach suggested in the early 1970s (Türkmen, 2009). It provides students with the concrete experiences necessary to develop conceptual understanding (Ramsey, 1993). According to learning cycle there are three phases:

1. Students learn with their own actions and reactions as they examine new ideas and new materials (Exploration).
2. Teacher/textbook introduces the terms/concepts (Invention).
3. Students attempt to assimilate and apply the new terms and/or reasoning patterns to additional contexts (Discovery).

This inquiry-learning model has three types: descriptive, empirical-abductive (experience-first) and hypothetical-deductive (ideas-first) (Lawson, Abraham & Renner, 1989). Descriptive learning cycles are driven by observation and description. Empirical-abductive learning cycles include observation of a relationship and test possible explanations. In hypothetical-deductive learning cycles, students are asked to generate and test alternative explanations. Based on those descriptions and the inquiry continuum, learning cycle activities fall on confirmation activity and structured inquiry.

2.1.5.4.2 The predict-observe-explain (POE) model

Another inquiry strategy is Predict-Observe-Explain (POE) that aims to elicit students' ideas and promotes discussion about their ideas. According to this teaching approach, instruction involves the following stages: showing students a situation, asking for prediction, getting reasons for the prediction, performing and observing, and trying to accommodate any discrepancies between prediction and observation

(Gunstone, 1990; Kearney, Treagust, Yeo & Zadnik, 2001; Kearney, 2004; Palmer, 1995). This inquiry teaching strategy promotes inquiry activities that support structured inquiry, which is the second level on the inquiry continuum.

With the interest in technology in education, Kearney et al. (2001) examined POE learning tasks in a computer environment. They found out that multimedia provides students time to discuss and think about their ideas as a means of learner control. Moreover, in the prediction phase, interesting and real-world context makes students confident and comfortable. In another study of computer-based POE tasks, Kearney (2004) asserted some advantages of POE. The results of this study indicate that students are encouraged to articulate and justify their ideas, to reflect on the applicability of partners' ideas and their own ideas and to construct new ideas together.

2.1.5.4.3 The engage-explore-explain-elaborate-evaluate (5E) instructional model

The 5E Instructional Model consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006). The first phase of this model engages students in the learning task. In the exploration phase, activities accommodate students with common and concrete experiences. The phase of explanation provides a common use of terms about the learning task. The fourth phase of the model facilitates transferring the concepts to closely related and new situations. In the last phase, students can adopt the skills they have gained and weigh their knowledge. The description of phases in 5E instructional model shows that activities have some specific objectives and students are required to achieve them. Therefore, it can be inferred that 5E inquiry instruction model reflects structured inquiry.

Research on the 5E inquiry teaching model shows that it is effective on students' understanding of scientific phenomena. A study by Patro (2008) indicated that students had a better understanding of cell respiration after being taught with the 5E method and they were more active in the learning process. Moreover, the results of a meta-analysis on 5E and traditional instructional approaches in Turkey points out that students' academic achievement scores concerning retention and attitude are higher when they are exposed to the 5E instruction (Anıl & Batdı, 2015).

2.1.5.4.4 The engage-investigate-model-apply (EIMA) model

Engage-Investigate-Model-Apply (EIMA) is another strategy to teach inquiry and is adopted from the 5E inquiry model (Schwarz, 2009). EIMA consists of the following instructional stages: occupying students with the topic and uncovering their prior ideas, helping them to investigate the topic or ideas by considering data collection and analysis, helping them to generate models or explanations and to make comparisons and finally expecting them to apply their own models and /or explanation in new situations (Schwarz & Gwekwerere, 2007). EIMA as the 5E instruction also falls on the structured inquiry side of inquiry continuum. Using the EIMA instructional framework, (pre-service) teachers who learned how to design inquiry-based science lessons modified their science teaching orientation toward guided inquiry.

2.1.5.4.5 The knowledge integration (KI) model

Finally, the knowledge integration approach that supports guided inquiry (Chiu & Linn, 2011) is one of the inquiry-based science teaching methods, which is reported as remarkably effective in supporting students to understand scientific concepts over

30 years of research (Chiu & Linn, 2014, Gerard et al., 2016). Knowledge integration blends recent trends in learning in the sense of developmental, constructivist, sociocultural, and cognitive perspectives (Chiu & Linn, 2011). This approach promotes inquiry and coherent understanding by underlining the ability to link ideas and to distinguish among these ideas in the process of generating arguments based on normative ideas (Clark & Linn, 2013; Lee et al., 2011; Ryoo & Linn, 2015). Knowledge integration framework boosts students in linking new ideas and perspectives to their existing ideas about scientific phenomena (Slotta, 2004). Linn (2006) assumes that all the methods above do a good job in helping students to understand scientific concepts but often disregard links between concepts as and real-life. Therefore, she suggested knowledge integration for both understanding challenging science concepts and making links between concepts and ideas since students need to integrate their ideas. For this reason, theoretical framework of this study is the knowledge integration.

2.2 Knowledge integration framework

Knowledge integration framework describes the learning process that students follow as they make sense of science. This is a process of restructuring and reorganizing new and existing ideas (Clark & Linn, 2013; Kali & Linn, 2008). According to this framework, science learning is achieved when students elicit their own ideas, add new normative scientific ideas, develop empirical criteria to distinguish among the ideas, and generate more coherent ideas about science as a result of integrating various scientific views (Liu, Lee & Linn, 2011; Ryoo & Linn, 2015). In short, Clark and Linn (2003) state that knowledge integration involves a dynamic process of linking, connecting, distinguishing, organizing, and structuring ideas about scientific phenomena such as facts, views and theories.

2.2.1 Knowledge integration principles

In the knowledge integration framework, the design of inquiry science activities that take advantage of students' ability to comprehend scientific phenomena across different contexts is required. Therefore, knowledge integration researchers suggest some design principles (see Figure 1). According to these principles, knowledge integration framework has four tenets: making science accessible, making thinking visible, helping students learn from each other, and promoting lifelong learning.

2.2.1.1 Make science accessible

This principle calls for encouragement of students to connect their new ideas to existing ideas and acknowledge the relevance of science topics to their everyday lives (Chiu & Linn, 2011; Chiu & Linn, 2014). It emphasizes building on student ideas, connecting to personally relevant experiences and to focusing attention on salient information. WISE design seeks for the scientific content of a project or unit so that students can restructure, rethink, compare, critique, and develop more coherent ideas (Linn & Slotta, 2000). This principle can be accomplished by considering personally relevant contexts of scientific phenomena in instructional design and integrating them into the instruction.

Major Tenets	Design Guidelines	Inquiry Activities
Making Science Accessible	• Build on student ideas • Build scientific knowledge framework • Connect project to personally relevant questions • Connect to standards-based curriculum • Models the inquiry process	• Investigating a driving question or inquiry task • Eliciting student ideas • Connecting to personally relevant problems
Making Thinking Visible	• Create and use personal representations • Express ideas • Explore new representations • Encounter multiple representations • Representations incorporated into assessments • Learning activities through representations • Activities reflecting the process of inquiry	• Modeling, simulating, animating • Graphing, representing data • Representing arguments • Questioning / explaining • Drawing
Learning From Others	• Different social activity structures • Listen others • Productive interactions to develop understanding • Develop shared criteria for scientific discourse • Opportunity to share findings after generating ideas	• Developing criteria • Discussing with peers on-line • Discussing with peers in the classroom • Reflecting on discussion • Conducting a debate • Critiquing peers
Promoting Autonomous & Lifelong Learning	• Engaging projects through meaningful reflection • Critiquing diverse scientific information • Engaging students in multiple approaches to science inquiry • Opportunities to learn and apply • Context-embedded science ideas	• Writing reflection notes • Conducting a project • Preparing for a debate • Describing an inquiry • Critiquing own performance • Designing an inquiry • Revisiting ideas outside of class

Figure 1. Knowledge integration framework

Source: [Slotta, 2004]

These principles were explained below.

2.2.1.2 Make thinking visible

The second principle refers to the process of modeling and critiquing the connection and organization of ideas in both normative understanding and in students' repertoires (Chiu & Linn, 2011; Chiu & Linn, 2014). There are three possible meanings of making thinking visible (Linn et al., 2003). Researchers firstly refer to models, simulations, and alternative representations of scientific phenomena. The other two possibilities are more related to making the teacher's thinking visible in response to student articulations and to making students' thinking visible for assessment. This principle can be applied as follows: designing interactive simulations, argument-representation tools, linking multiple representations, modeling scientific thinking, representing data collected by students. Furthermore, WISE projects use embedded assessments to make student thinking visible.

2.2.1.3 Help students learn from each other

The third principle suggests aiding the use of others' ideas and beliefs to develop criteria and improve a student's own understanding (Chiu & Linn, 2011; Chiu & Linn, 2014). Encouraging students to compare viewpoints, involving students in debate and supporting negotiation of meaning, can achieve this principle of knowledge integration principles.

2.2.1.4 Promote autonomous lifelong learning

The fourth and final principle refers to helping students to improve their existing knowledge by monitoring and reflecting on their ideas during their studies (Chiu & Linn, 2011; Chiu & Linn, 2014). Establishing a generalized inquiry process using the inquiry map (in WISE) including predictions and explanations, encouraging reflection on alternative ideas and solutions, and by supporting posing new problems are some of the ways to promote autonomous lifelong learning. Asking for reflection on their response and learning process in an instructional activity can succeed in this principle.

2.2.2 Knowledge integration processes/patterns

Several attempts have been made to suggest an instructional pattern that can guide instructional designers by the creators of knowledge integration framework. They identified the pattern in the typical instruction as motivate, inform and assess (Linn & Eylon, 2011). Typical instruction often focuses on adding ideas but not on helping students integrate new and existing ideas (Chiu & Linn, 2011). Therefore instruction scaffolds are needed to support learners in expressing their existing ideas, adding new scientific ideas, distinguishing among ideas, and reflecting on their practice of increasing the coherency of their ideas (Linn, Eylon, Rafferty & Vitale, 2015; Ryoo & Linn, 2015). Knowledge integration process can be also adapted to teacher's professional development.

2.2.2.1 Eliciting ideas

Eliciting ideas acknowledges experiences students bring to learning contexts. It provides the opportunity to students reconsider their ideas developed over years in interpreting and adding new ideas and enables teachers to enhance students' repertoire of ideas and adjust their instruction considering them (Chiu & Linn, 2011; Linn, 2006; Linn et al., 2015). Eliciting the existing ideas of students provides an opportunity for them to compare those ideas to the new ones and make appropriate distinctions.

A particularly effective way for eliciting ideas is asking students to make predictions or to develop ideas about a particular scientific concept in order to deal with their previous views (Ryoo & Linn, 2011). Many research studies have shown that when students make predictions they are more likely to learn the material than when they do not make predictions (Linn & Songer, 1991).

2.2.2.2 Adding ideas

As a knowledge integration pattern, adding new ideas means that students make sense of the new idea and connect them to their existing ideas (Chiu & Linn, 2011). Linn (2006) claims that instruction commonly adds new ideas and students immediately forget these new ideas if they do not integrate them with their existing ideas. Knowledge integration researchers have investigated ways to take advantage of technology for adding new ideas by designing visualizations of scientific phenomena (Linn et al., 2015).

2.2.2.3 Distinguishing among ideas

Adding accurate ideas is not enough to ensure that students understand scientific phenomena. Without distinguishing and connecting these ideas, students may develop a collection of multiple, potentially contradictory and disconnected ideas. When students do not have the opportunity to distinguish among their ideas, they often revert to their original ideas when confronted with a complex dilemma. Students need to distinguish among both their own ideas and the new ideas utilizing information from experiments, observations, or other sources (Linn, 2006; Linn, et al., 2015). Students need to develop criteria for evaluating ideas to distinguish among them (Chiu & Linn, 2011).

The WISE units guide students to develop criteria that allow them to select the most valid ideas from among their repertoire. To help students distinguish among ideas, knowledge integration researchers have designed a variety of guidance tools of the WISE such as *Automated Guidance* (Linn et al., 2015) in collaboration with *c-Rater*, *Reflection Notes* where students answer a question or explain their ideas, *My System* where students work on diagrams, *Idea Basket* where students are prompted to add ideas and *Explanation Builder* where students use ideas from their *Idea Basket* to form a response.

2.2.2.4 Sorting ideas

Making predictions, adding ideas, and distinguishing among ideas are helpful for achieving accurate scientific understanding. Students need to reflect on the evidence that generated their original ideas, the new evidence, and the connections among the ideas they have to form an integrated perspective and to find gaps or discrepancies in their understanding (Chiu & Linn, 2011; Linn, 2006; Linn et al., 2015; Ryoo & Linn, 2011). Correspondingly, White (2000) states that reflection is a requirement for linking ideas concerning recognition of the content, its meaning and its relation with anything except school.

The process of reflecting is an important step towards lifelong learning. Lifelong learners become adept at sorting out their previously held ideas and integrate them with new ones to progress coherent understanding. Recognizing and processing these connections is essential for building a coherent, cumulative understanding of science.

In the following sections, the variety of technology-based learning environments that aims to improve science inquiry learning for conceptual change and knowledge integration was presented. In addition, the results and findings of the research studies related to technology-enhanced inquiry-based learning were discussed concerning knowledge gain and inquiry skills development.

2.3 Technology-enhanced learning environments in science education

In recent years, there has been an increasing interest in technology and its effectiveness in science education. Science education research indicates that technology-enhanced learning environments providing concrete experiences with visual representations of abstract concepts help students to understand these concepts (Ardaç & Akaygün, 2004; Chang & Linn, 2013; Levy, 2013; Ryoo & Linn, 2011; Williams & Linn, 2002; Williams, Linn & Hollowell, 2008; Zhang & Linn, 2011). Numerous studies have attempted to explain how to integrate technology into inquiry-based science learning and how it affects students' understanding of scientific concepts. Proponents of technology-based learning have suggested that technologies support learning as a social practice in an inquiry-based science context (Kim, Hannafin & Bryan, 2007). Essentially, technology allows teaching scientific concepts that are challenging to conduct scientific inquiries as in the real settings such as geological events (Lin et al., 2012), chemical reactions (Ardaç & Akaygün, 2004; Chang & Linn, 2013; Levy, 2013; Zhang & Linn, 2011), biological processes (Quellmalz et al., 2013; Ryoo & Linn, 2011; Williams & Linn, 2002; Williams et al., 2008).

2.3.1 Technology-enhanced learning environments for conceptual change

2.3.1.1 Multi-user virtual environments (MUVEs)

One of the computer-based learning environment genres to support science learning is the Multi-User Virtual Environments (MUVEs). MUVEs refer to computer programs that have an animated character, namely an avatar controlled by a user within a virtual environment. They enable multiple participants to access virtual worlds simultaneously, communicate with each other instantly, and to interact with digital artifacts. MUVEs provide specific affordances to use technology to simplify involving social constructs into the science inquiry learning process (Erlandson et al., 2010). Qian (2009) indicates that MUVEs are feasible platforms to conduct scientific inquiry, gateways to an engaging and social learning, connecting and blending formal and informal science learning.

River City is an example MUVE (Ketelhut et al., 2010), which is developed for middle school students to learn scientific inquiry within a research project. In this online environment, students work together in groups to help the town understand the reason for residents' illness by using technology to designate causes of illnesses, generate hypotheses, conduct experiments to test their generated hypotheses, and advice based on the collected data. Ketelhut et al. (2010) created three versions and aimed to find out which version of the River City MUVE is best for middle school students' science inquiry in the process of problem solving about a disease in a virtual town. Although the results did not present a consistent pattern for the best River City version to foster scientific inquiry, the researchers concluded that the students with low-level science knowledge improved and understood scientific inquiry with embedded visual and auditory clues.

In the study by Erlandson et al. (2010), another MUVE, the SimLandia, consisted of a 3-D virtual town and provided undergraduate students an opportunity to act as research scientists investigating several diseases. There were no significant differences between science learning of students who used voice-based communication and students who used the text-based communication. The researchers predicated the lack of evidence for learning to improper design and suggested refinement of the inquiry environment. They believed that a close examination of the cognitive processes of participants as they interact with the SimLandia environment and curriculum would be achieved through a pilot study employing eye tracking (or other measures of cognitive load).

2.3.1.2 Computer simulations

A computer simulation is a program that includes a system or a process model (de Jong & van Joolingen, 1998). Simulations are designed in an attempt to facilitate teaching and learning through visualization of the concepts and interaction with dynamic models of natural phenomena (de Jong & van Joolingen, 1998; Lin et al., 2012). Science simulations and virtual laboratory products are promising to support middle school student's learning based on the meta-synthesis conducted by Scalise, Timms, Moorjani, Clark and Holtermann (2011). Furthermore, Lin et al. (2012) stated that computer simulations provide authentic contexts to occupy students in simulated real-world situations. Renken and Nunez (2013) believe that computer simulations have the potential to reduce complexity of scientific concepts by clarifying observations through experimentation.

Sarabando et al. (2014) aimed to compare seventh grade students' progress in understanding the concepts of weight and mass by comparing three groups: only computer simulation group, only hands-on activities group, and computer simulation and hands-on activities group. According to the results, there was a statistically significant change in conceptual understanding of weight and mass from the pretest to the posttest for all groups of all the three teachers.

Lin et al. (2012) aimed to examine how students constructed the concepts of geological time and how a computer simulation, namely FossilSim, influenced their inquiry skills (planning, analyzing and modeling). They considered FossilSim as authentic simulation software engaging students in a similar environment where geologists normally conduct their research. The data yielded by this study provided strong evidence that the overall inquiry skills of ninth grade students significantly developed with a medium effect size (Cohen's $d = 0.47$) as a result of using the FossilSim computer simulation. Looking closely, however, while the inquiry skills in the processes of planning and analyzing were significantly improved with medium effect sizes, there was no significant improvement for inquiry skills in the modeling process, which also had a small effect size.

2.3.1.3 Mobile learning

People find mobile devices like smart phones, tablets highly appealing and it is inevitable to integrate these devices into educational context. Buckner and Kim (2014) believe that mobile devices in classrooms have the real power to prepare students to be creative and problem solvers. The study by Song (2014) aimed to investigate how students improved their content knowledge and perception about their science inquiry experiences in a seamless inquiry-based learning environment within their own mobile devices. The students were required to make an investigation about the anatomy of fish by using their own mobile devices that consisted of some applications such as Edmodo, Evernote and Skitch. The results of the perception questionnaire revealed positive outcomes about the students' perception about overall learning experiences supported by their personal mobile devices.

Another environment for mobile learning developed by the research team in Stanford University (Buckner & Kim, 2014) is the Stanford Mobile Inquiry-based Learning Environment (SMILE), which provides an interactive learning environment by occupying learners with processes of critical reasoning and problem solving. SMILE consists of two elements: a mobile-based application for students (Junction Quiz) and an activity management application for the teacher (Junction Quiz controller). In a pilot study, 32 fourth and fifth grade students were asked to rate their satisfaction about this learning environment. The results indicated that 87% of the students were very satisfied, 10% were mostly satisfied, 3% were somewhat satisfied and none of them was not satisfied (Seol, Sharp, & Kim, 2011).

Jones et al. (2013) conducted two case studies to compare the ways to support inquiry learning with mobile devices in informal and semi-formal learning settings. The results of the first case study, which is about personal inquiries in a geography after school club (semi-formal), shows that the portable netbooks and the Sustainability Investigator software (SI) enabled students to conduct their personal inquiries successfully. Furthermore, the mobile devices promoted the inquiry process without adult support, through the SI. The second case study aimed to find out the impact of Web 2.0 and mobile devices on informal learning. It is revealed that such technologies can be useful in informal settings in which learners are autonomous about their learning goals in semi-formal settings where motivation is often high.

In this section, various empirical research studies related to technology-supported inquiry-based learning environments aiming at conceptual change in science education were presented. These environments are Multi-user Virtual Environments (MUVE), computer simulations and mobile learning environments. The data gathered in these research studies suggest that these environments foster students' domain knowledge gain, the development of inquiry skills, and a positive change in the attitudes of students toward science. By contrast, Matuk, Linn and Eylon (2015) believe that their impact on classroom teaching and learning has limited scope and sustainability dissimilar to knowledge integration offers. In the next section, similar learning environments supporting particularly knowledge integration as a complex construct indicating conceptual understanding (Linn, 1995) and that have been studied in this research were presented.

2.3.2 Technology-enhanced learning environments used for fostering knowledge integration

2.3.2.1 Dynamic visualizations

Technology-enhanced visualizations can improve inquiry learning in science education when they are intended to foster knowledge integration. Visualizations can help students get insights into things that are too small, vast, or complex to observe directly (Zhang & Linn, 2011). McElhaney, Chang, Chiu and Linn (2014) define dynamic visualizations as computer-based and animated representations of scientific phenomena in science. The findings of their meta-analysis on dynamic visualization demonstrate that there is a great potential of dynamic visualizations to promote complex science learning as knowledge integration and authentic science practices.

Ryoo and Linn (2011) found that students had a more normative view about the energy transformation, which is an unseen and complicated process, through the dynamic visualization, than static illustrations. They stated that students in dynamic condition explained the process of energy transformation with more detail. In 2013, they compared the typical approach of reading instructional explanations with an inquiry-oriented approach of generating their own explanations. The results of this study depicted that generating explanations during interaction with dynamic visualizations is more effective than reading explanations for middle school students to understand unseen and abstract concepts related to energy transformation and to explain its processes. They added that students who generated their explanation developed accurate ideas without any feedback.

In a similar study by Zhang and Linn (2011), it is found that students who generate representations had more complex ideas and links about chemical reactions than students who interact with visualizations. Zhang and Linn (2013) were interested in how generating drawings and selecting amongst alternatives (simple and complex) influence students' distinguishing between ideas. In generating drawings condition, students were asked to draw valid information from interacted visualization and write an explanation about their product. In the simple selection condition, students needed to use images from visualization while they were required to use images from both visualization and representations of students' common confusions not appearing in visualization. The results indicated that generating drawings and complex selection were more helpful than simple selection for students to understand chemical reactions.

Chang and Linn (2013) investigated how dynamic visualization influences knowledge integration of students and conducted a study to compare three uses of the visualizations about thermal equilibrium as follows: observation, research guidance and critique. In observation condition, participants only watched the visualization. In the research guidance condition, they reviewed experiment guidelines and conducted virtual experiments while they critiqued an experiment in the critique condition. The results of this study demonstrated that virtual experiments consisting dynamic visualizations are more informative along with the critique activity rather than combined with the research guidance activity. Students in the critique condition more systematically and consequentially conducted experiments, and showed improved ability to integrate phenomena that are observable and microscopic. These visualizations become interactive simulations when learners can manipulate parameters as they to conduct scientific inquiry (Quellmalz et al, 2013).

2.3.2.2 Web-based inquiry science environments

Many web-based learning environments featuring Internet have been presented for inquiry learning in science education. For example, Mulholland et al. (2012) developed a web-based software environment, nQuire, to provide a support for (personal) inquiry learning since learners have difficulty in managing inquiry processes. Iordanou and Constantinou (2015) developed a similar web-based learning environment called SOCRATES and examined the way of using evidence in argumentation while eleventh graders engaged in argumentative and reflective activities. The results of this study indicated that students increased the use of (accurate) evidence in their dialogs and making explicit reference to the source of argumentation after they engaged in SOCRATES. Although those environments are effective in supporting learning inquiry, they have some shortcomings. For instance; use of SOCRATES is limited since it is only included in a database on the topic of climate change including five learning units. In addition, Okada (2013) found out that most of the learning environments are not active and current.

Web-based Inquiry Science Environment (WISE) developed at the University of California, Berkeley is one of those web-based science inquiry-learning environments in science education. This free online system is offered for designing, developing, and implementing inquiry activities in science education. WISE provides an online authoring and instructional delivery platform for researchers and teachers (Gerard et al., 2016), which records student responses and supports teachers to monitor student progress (Levy, 2013; Ryoo & Linn, 2015). WISE is the product of longitudinal studies and refinement process and it offers many pedagogical tools such as inquiry map, drawing tools, cognitive hints, and embedded reflection and assessment notes (Chiu & Linn, 2014).

WISE reflects the socio-constructivist ideas of learning, provides learners cognitive tools and procedural guidance for their inquiry learning, and supports a learning community wherein teachers and learners collaborate to solve complex scientific problems (Slotta, 2004). Slotta (2004) considers WISE as an Internet-based platform where middle and high school students work collaboratively on scientific activities for inquiry projects by utilizing evidence and resources from the Web.

The WISE learning environment, its curriculum and assessment procedures are grounded on the knowledge integration principles (Linn et al., 2003). The main purposes for developing this framework were to make sense of students' ideas that they bring to science classes and to find out how to make science learning effective (Slotta, Linn & Lee, 2009). This framework enables designing accessible science content, makes thinking visible for the purposes of assessment, enables collaborative learning, and finally supports lifelong, autonomous learning (Linn et al., 2003).

WISE curriculum materials and tools are also designed by taking advantage of these knowledge integration principles. There are over 40 tested curricula (inquiry units) varying in science subject, grade level and language in the WISE project library. Each inquiry unit emphasizes knowledge integration processes: elicit ideas, adding ideas, developing criteria to distinguish among ideas and sorting ideas. These units are also blended with interactive simulations and models built with modern web technologies such as Java and HTML5 through WISE.

Several research studies show that WISE units have the potential to improve students' domain knowledge in science. Lee et al. (2010) investigated several inquiry units in WISE, which take advantages of technological features especially visualization in order to study knowledge integration, that is, deeper learning of science, by integrating multiple ideas of students. They aimed to find out how typical and technology-enhanced inquiry instruction (on WISE) in 27 different teaching contexts affects student's knowledge integration of complex science topics such as earth, life, biology, and chemistry. The results indicated that technology-enhanced and well-designed inquiry instruction was more helpful than typical inquiry instruction to improve middle and high school students' understanding of complex science units such as cell division and mitosis. The average knowledge integration level of the inquiry group who studied with the WISE units was significantly higher than that of the typical group who studied with conventional units. However, students in three teachers' classes could not improve their understanding because of technical and timing problems.

Another research used WISE to scaffold students to compare plant growth, collect data, outline their results, and analyze their data (Williams & Linn, 2002). The purpose of this two-year study was to investigate how WISE improved students' understanding of plant growth and development. First-year students improved their understanding of the concepts dramatically with an effect size of 2.67. Moreover, pre- and post-test of second-year students significantly differed with an effect size 5.1. The results indicated that students made significant gains of understanding scientific concepts including photosynthesis and plant growth using WISE.

These studies show that WISE is highly effective in promoting students' knowledge integration on scientific concepts and inquiry skills. For this investigation, WISE activities were used to promote knowledge integration of students since scientific inquiry is one of the important requirements of accurate understanding of science topics.

2.3.2.2.1 WISE interaction mechanisms

WISE researchers have been studying its effectiveness on knowledge integration and accurate science understanding. Most of them focused on the design of instruction and impact of this instruction on students' comprehension. For example, Davis (2000) investigated the mechanism behind self-monitoring prompts to foster knowledge integration of students who work on science projects and found that these prompts increase knowledge integration significantly.

In the analysis of WISE impact, Zhang and Linn (2013) offered some design implications for science activities, as they should focus on the explorations in visualizations and guide to distinguish among ideas. Similarly, Zhang and Linn (2011) suggested that visualizations should be designed with supportive instructional activities that can encourage knowledge integration processes and prompt learners to reconsider their initial explanations. Another research by Ryoo and Linn (2014) shows that students consistently engaged in constructive argumentative discourse and construct scientific explanations when they were prompted to generate explanations in the exploration of dynamic visualizations. The integration of visualizations and scaffolds to generate explanations were borne in mind in the design process of the study.

On the other hand, Visintainer and Linn (2015) investigated students' experience for understanding mechanisms of global climate change rather than WISE interaction mechanisms. Lee et al. (2010) analyzed the impact of science subjects and teaching contexts on the knowledge integration after the inquiry units were implemented. They found a significant interaction between impact cluster and teacher experience. It means that students of the teachers with more inquiry experience had better learning outcomes from inquiry instruction (Lee et al 2010).

However, few of them have aroused curiosity for the WISE interaction mechanisms that account for the full range of knowledge integration performance. For example, Chiu and Linn (2012) wondered the interaction of students with visualizations and suggested further research on this. In this study, cases of three participants were selected and their interaction with WISE elaborated in regard to revision count, revision quality and reflection. The main purpose of analyzing these case studies considering these dimensions was to offer some design implications for WISE platform itself.

2.4 Science instruction in Turkey

Turkish students have low level of scientific thinking skills according to reports of international tests (Bağcı-Kılıç, 2002; Cengiz et al., 2012; Ural & Bümen, 2016). Most recently, no single Turkish student could perform at the highest level at the science proficiency tests in the Programme for International Students Assessment

(PISA) (OECD, 2016; Salman, 2016). This demonstrates that they are not able to conceptualize information based on their investigations, to link multiple information sources and representations, and to generate their explanations. Researchers believe that abstract science concepts, curriculum, instructional programs and methods have caused this problem (Bağcı-Kılıç, 2002; Balım et al., 2010; Cengiz et al., 2012; Sözbilir et al., 2006). Inquiry-based teaching is a new area for Turkish science researchers (Kızılaslan, Sözbilir & Yaşar, 2012) as well. The Ministry of Education gives priority to such activities that enable students to conduct inquiry and to improve their inquiry skills (MEB, 2013). However, few teachers allocate time for this kind of learning activities in their lessons (Atila & Sözbilir, 2016; Bağcı-Kılıç, 2002; Sözbilir et al., 2006; Tatlı & Ayas, 2013).

Apart from these, Turkish students have limited access to the technology-enhanced learning environments. Inadequate learning and teaching content, English as medium of instruction and focus on traditional methods can be the major reasons for this limited access. Although the Ministry of Education has recently put emphasis on constructivist teaching and technology integration, teachers have not often include those materials into their lessons. Research reveals that teachers rarely use technology particularly smart boards and tablet PCs in their courses because the (electronic) content is insufficient (Ayvacı et al., 2014; Dağhan et al., 2015; Dursun et al., 2013; Özkale & Koç, 2014; Pamuk et al., 2013).

In addition, many studies in Turkish web-based science education context investigated college level students and pre-service teachers (Erdoğan, Bayram & Deniz, 2008; Hevedanlı, 2015; Usta, 2011). As in the context of secondary education; the effects of these environments on the motivation, self-efficacy, achievement and attitude of learners were particularly investigated (Akkağıt, 2014;

Çetin, 2010; İnam, 2011; Meral, Çolak & Genç, 2012). The common characteristic of these environments is that they are designed for a specific learning unit and they do not embrace other scientific concepts.

Furthermore, between 2001 and 2011, how inquiry-based learning could be effectively integrated into science education, and how it is related to computer-aided instruction have not been studied (Kızılaslan et al., 2012). A content analysis by Kula-Wassink and Sadi (2016) also demonstrates similar results; there is little research on computer-based instruction as a teaching method in science education. In the light of these, there is no study particularly on WISE, which is adaptable for any scientific concept and knowledge integration, which is a framework to integrate inquiry-based learning into science curriculum by incorporating technology.

2.5 Summary

Constructivism has emphasized meaning construction via integration of new ideas with learners' previous knowledge. In this context, concepts and conceptual understanding have been approached as key elements in meaningful science learning. It appears that students hold alternative ideas before science instruction as a consequence of interacting with the world and these ideas have a great influence on accurate science understanding. Therefore, research on science education and technology indicate that students' existing ideas are very important to understand abstract scientific phenomena such as heat and temperature. In this review, education theories and instructional methods that deal with alternative conceptions in science education were examined. In brief, it is suggested that existing ideas of students should be included in inquiry-based instruction, which offers to integrate those ideas with normative scientific ones in authentic learning settings. Knowledge integration design principles and patterns promote inquiry and coherent understanding by emphasizing the ability to link ideas and to distinguish among these ideas in the process of generating arguments based on normative ideas (Clark & Linn, 2013; Lee et al., 2011; Ryoo & Linn, 2015).

Furthermore, various technology-enhanced learning environments including WISE were described, which were investigated to support students understanding of science concepts. The results indicated that they mostly achieved their purpose, although they have some discrepancies such as limited number of activities and courses; and a lack of opportunity to offer making links among ideas. Since WISE provides technological features and supports knowledge integration for an accurate understanding of science, its effect on middle school students' understanding of heat and temperature was investigated in this study. International WISE research has usually investigated the effects of WISE on knowledge integration and inquiry skill improvement of students and its features like dynamic visualization, guidance and embedded assessment; and effective design of inquiry instruction (Chiu & Linn, 2014; Clark & Linn 2003; Gerard et al., 2016; Lee et al., 2010; Liu et al., 2015; Ryoo & Linn, 2015; Svihla & Linn, 2012; Visintainer & Linn, 2015; Vitale et al., 2016; Williams & Linn, 2002; Williams et al., 2004). However, there are few studies on the mechanisms of WISE interaction that reflect the range of knowledge integration improvement.

Turkish students' level of science performance in international tests is low and they have limited access to the technology-enhanced learning environments. Inadequate instructional content, English as medium of instruction in these environments and focus on traditional methods might be the major reasons for limited access. There is no study, to best of our knowledge, exploring the integration of inquiry-based instruction into science education and its relation with computer-aided instruction in Turkey. Therefore, this study seeks to foster seventh-grade Turkish students' knowledge integration level with an online unit on WISE and to provide an insight to understand the difference in knowledge integration levels by investigating students' interaction within WISE unit.

In this study, two main research questions were investigated:

1) Do Turkish seventh grade students significantly improve knowledge integration level after participating in the WISE instructional unit about heat and temperature?
2) How does Turkish seventh grade students' interaction with the WISE environment in the heat and temperature unit explain different levels of knowledge integration gains?

Based on the available literature, it is expected that the students will significantly improve their knowledge integration levels after participating in the WISE instructional unit about heat and temperature.

CHAPTER 3

METHOD

In this chapter, the method of the study was discussed in depth. The research design, the research questions, details about setting and participants, materials used in the study, data collection instruments, data collection procedures and finally data analysis were explained.

3.1 Design

An embedded mixed methods research was used to investigate the effectiveness of WISE-based unit on knowledge integration and the mechanisms of WISE interaction that bring about different levels of knowledge integration gains. Mixed methods is a methodology for conducting research that involves collecting, analyzing and integrating quantitative and qualitative methods in a single study (Creswell & Plano Clark, 2011). In the embedded mixed methods design, both quantitative and qualitative data are collected simultaneously to support one form of data with the other form of data (Creswell & Plano Clark, 2007). This design is differed from other mixed methods with that second form of data has the supportive role to address the research questions (Creswell & Plano Clark, 2007).

This study aimed to support quantitative data that is collected via the Knowledge Integration Scale by incorporating qualitative data, which are students' logs on WISE (Figure 2). The purpose of this design is also associated with a complementarity mixed-method study, which aims to measure joint but also different aspects of a phenomenon and to provide an enriched, elaborated understanding of that phenomenon (Greene, Caracelli & Graham, 1989). The quantitative data assessed whether the online WISE curriculum had an impact on the students' knowledge integration outcomes, while the qualitative data addressed how the differences in students' knowledge integration scores can be linked to how they interacted with the designed activities within the WISE environment. This study method enables researchers to take advantage from both quantitative and qualitative data (Creswell, Plano Clark, Gutmann & Hanson, 2003). Therefore, the main rationale for choosing this design, in the context of this study, is to ensure the interpretability, meaningfulness, and validity of knowledge integration construct and WISE effectiveness by benefiting from the strengths of the both data forms (Greene, Caracelli & Graham, 1989).

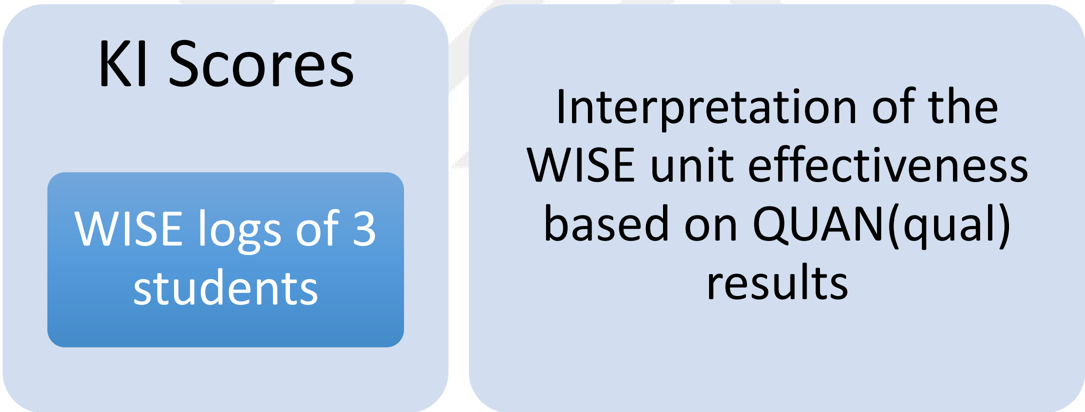


Figure 2. Visual elaboration of embedded mixed methods design

3.2 Setting and participants

The participating middle school is located in a low-income area in Istanbul. The school operates in two shifts; with one group of students (seventh and eighth graders) attend school early in the day and a second group of students (fifth and six graders) later in the day. There are physics, chemistry and bio labs, an IT class, library, a conference room, a canteen and a yard. There are 20 desktop computers with

Windows 7 operation system and Internet connection in the IT class. Wireless Internet is also available for laptop computers. All the requirements for WISE system were satisfied. Thirty-six teachers teach approximately 950 students who attend this school.

The population of this study is seventh-grade students in public middle schools in Istanbul. The sample of this study is 75 seventh-grade students from three different classes of two science teachers. Thirty-five of the participants are male, 40 of them are female. There are 28 students in class A, 19 students in class B and 28 students in class C.

Participants were selected based on purposeful sampling method (Patton, 2002). The main purposes were to reach a group of students who are unfamiliar with technology-enhanced learning environments. Since the school is located in a disadvantaged area, students are mostly exposed to traditional teaching methods as expected. The second reason is that students were able to readily use computer room since seventh and eighth graders do not have computer courses in their curriculum. For the qualitative part of the study, the maximal variation sampling method was used to select the students to reflect the full range of performance on Knowledge Integration Scales. According to Creswell (2012), this is a purposeful sampling strategy, which is to sample individuals that differ on some characteristic or trait. In this study, three participants that differed on their knowledge integration improvements were sampled.

3.3 The WISE unit on heat and temperature

In this study, WISE was used as the main learning environment. In order to answer research questions, an online learning unit was developed by the researcher employing dynamic visualizations as part of the online learning process. The existing units in the WISE Library were not included into the study since WISE is more likely to improve students' science understanding when teachers customize WISE activities according to their needs (Gerard, Varma, Corliss & Linn, 2011). Because American and Turkish national curricula are different, the researcher designed and developed a specific online unit. In this unit, there are six inquiry activities on "heat and temperature" concepts targeting three alternative conceptions. Each activity was designed based on knowledge integration principles and patterns, which were broadly described in the literature review section. In brief, students were required to predict outcomes, observe results within simulations and explain their ideas. In the following parts, I represented how I apply these principles and processes to my online inquiry unit in detail.

3.3.1 Heat and temperature unit based on knowledge integration design principles

Each activity makes science accessible with the design of science content by selecting the scope, level of analysis, examples, and details for scientific material such that it integrates new ideas with current student ideas. In fact, activities are designed by targeting three alternative conceptions (scope), by providing observation via simulation and asking them to evaluate the results based on their findings (level of analysis) regarding relevant science topics to everyday life, like sensations of different hot spoons, temperature of water mixtures etc. (example) and detailed instruction in activity steps.

There are three possibilities related to making students thinking visible (Linn et al., 2003). One way is to create models, simulations and alternative representations of science content. Other ways are to make teachers thinking visible in response to students' notes and activities and to make students thinking visible in assessment. I designed and developed interactive simulations to make science visible to students by considering the representations of heat and temperature.

It is important to learn from each other because a variety of views that helps students to sort out promising ideas and allow them to establish criteria for distinguishing ideas. For ensuring this, I gave students the opportunity to critique and revise ideas of from each other by enabling students' ideas visible in *Brainstorm Discussion* steps. Therefore, students are able to see each other's work and review. Also, they are allowed to talk each other, discuss and share their ideas while interacting with simulations and working on WISE.

Preparing students to become lifelong learners is an important issue. The *WISE Inquiry Map* enables students to carry out projects without having constant guidance from teachers or peers. Therefore, it helps their autonomous learning process. In my online inquiry unit, I also took advantage of this property of the WISE platform.

3.3.1.1 Design of simulations

Simulations were developed using Adobe Flash Professional CS6 except for the simulation in the first inquiry activity, which is developed by PhET ("Enerji biçimleri ve değişiklikleri," 2016). Students have the chance to investigate the concepts of "heat and temperature", which is not possible in real settings. Some guidelines offered by Chang and Linn (2013) for an effective and productive interaction with the visualization were considered in the design of these simulations. They suggested that it should follow the knowledge integration patterns in order to scaffold students, include critique activities to enhance its impact and virtual experiments to support autonomous learning. It should also integrate concrete and abstract level interactions to build coherent understanding and provide opportunities for teachers to review.

Similarly, Kali and Linn (2008) identified four principles to aid in the design of visualizations incorporated into curriculum materials. These principles are as follows: (1) reducing visual complexity to help learners recognize salient information, (2) scaffolding the process of generating explanations, (3) supporting student-initiated modeling of complex science, and (4) using multiple linked representations (see Appendix A). In this study, in order to determine the optimal level of complexity, I diagnosed the repertoire of ideas of the students through literature review. Simulations enable students to observe the cases of each activity, to manipulate and to collect data for proposed research questions. Students are requested to make explanations to integrate the results of the data collection in those steps for the second principle. The third principle was not implemented since there is not much time for intervention and it is beyond the scope of this study. Providing calorimeter, temperature and symbolic representation of heat in simulations ensures the fourth principle. In each simulation, students have the chance to observe changes in heat energy and the temperature of an object. The representations for those changes are shown with calorimeter, thermometer and symbols of heat energy respectively. In short, students can see those changes in three different representations and have an opportunity to understand that heat and temperature are related concepts.

3.3.2 Heat and temperature unit based on knowledge integration processes

There are four processes in the knowledge integration instruction pattern: eliciting ideas, adding ideas, distinguishing among ideas based on empirical criteria and sorting out ideas. Each activity in this study covers knowledge integration patterns (see Appendix B). I elicit students' ideas by asking them to make predictions and to generate explanations about a scientific situation. Designed and developed simulations about heat and temperature provided opportunities for students to add ideas into their repertoire by interacting them and collecting data. Students distinguish among ideas based on their experimentation through simulations and collaboration with their classmates; which leads them to analyze and evaluate the data they collect. In the case of need for guidance, knowledge integration guidance, which encourages students to revisit the simulation to collect additional evidence and revise their explanations provided to the students through the system and during the class time. Knowledge integration guidance navigates the students to distinguish among their ideas rather than providing students with the correct answer (Donnelly, Vitale & Linn, 2015). Finally, each activity has a reflection step in which students evaluate their own learning by comparing their predictions and the results of the experiments.

3.3.3 Inquiry activities in heat and temperature unit

There are six different inquiry activities in the WISE-based unit. Each activity includes pivotal cases, which represent incidences of three intuitive ideas of students within real life contexts. These activities consist of various simulations of representative pivotal cases. The simulations were designed and developed based on the knowledge integration design principles mentioned above. Students are able to observe heat and temperature and make changes in the cases. For example, in order to heat a jar of sand, the students need to shake the jar and observe the changes in calorimeter and temperature as well.

3.3.3.1 Activity 1: Heat is a kind of energy

This was an introduction activity to show different energy forms and their relation to heat (see Figure 3). In order to elicit students' previous ideas, the students were asked to describe energy and its forms and what can be done with heat energy. The Turkish version of "Energy Forms and Change Simulation" by PhET, which includes some mechanisms to visualize energy forms, energy transfer, heat energy and temperature were used in the process of adding new ideas. This simulation could not be embedded into WISE due to some compatibility issues. Therefore, the students needed to use it externally. In the PhET simulation, the students set up four different energy transformation settings and answered questions about energy forms and transformation in these settings. Furthermore, they turned on/off the heater and observed the change in heat and temperature of different materials. The students were expected to distinguish among ideas by explaining change in the heat and temperature of the materials (iron, brick and water) and the cause of this change. Finally, they were asked the similar questions in eliciting process to allow them to sort their ideas. To effectively run the PhET simulation, the students were guided with instructions in the steps on WISE and also by the researcher and teachers.

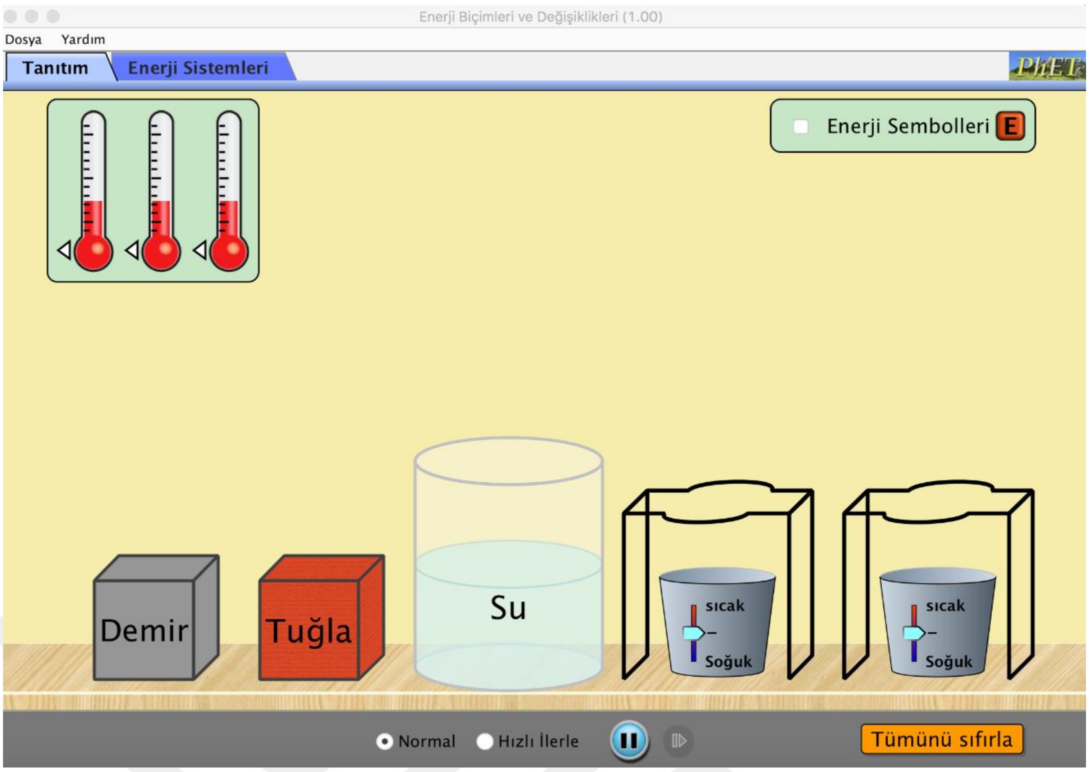


Figure 3. PhET simulation screen in activity 1

3.3.3.2 Activity 2: How does the sand get warm?

In this activity, the students were introduced how things heat up and its relation with the transformation of energy (see Figure 4). They were shown a picture of a jar filled ¾ full with sand and asked to predict changes in the heat and temperature of the sand and the reason for these changes. The students interacted with a simulation about of shaking a jar full of sand and observed the change in temperature and heat. Then, they filled out a table after shaking the jar each time to record the temperature and heat of sand, and answered the following questions and to explain the reason for the changes in order to distinguish among their ideas. In the final process, sorting ideas, they were asked to compare what they predicted and what they learned and finally explain the similarities and differences.

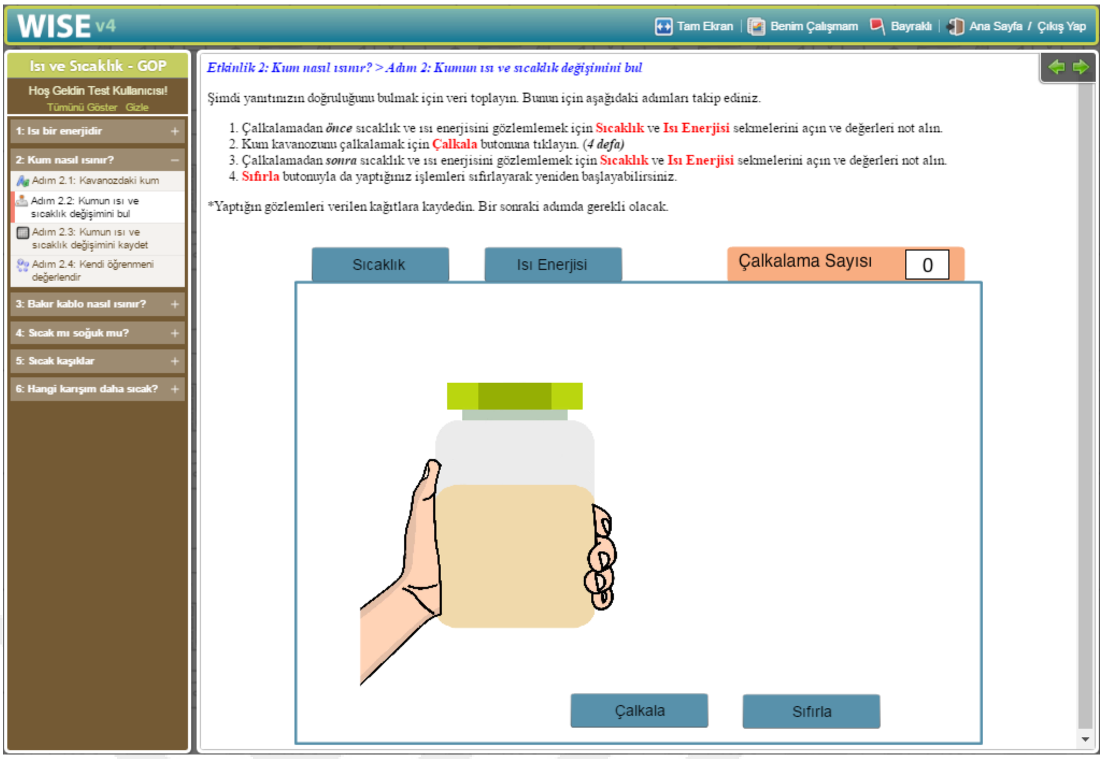


Figure 4. Adding ideas screen in activity 2

3.3.3.3 Activity 3: How does the copper cable get warm?

In this activity, the students were introduced to how things heat up and its relation with the transformation of energy as in the previous activity (see Figure 5). The students were shown a picture of a copper wire and asked about the changes in the heat and temperature of the wire and the reason for changes to get their predictions. They interacted with the simulation by observing the temperature and heat change after bending copper wire back and forth several times. After each bending, the temperature and heat of the wire were shown on the screen. The students filled out a table after bending the wire each time interval by observing temperature and heat of wire and explained the reason for the changes. The students were asked to compare what they predicted and what they learned to explain the similarities and differences. So, they were able to reflect on their learning process.

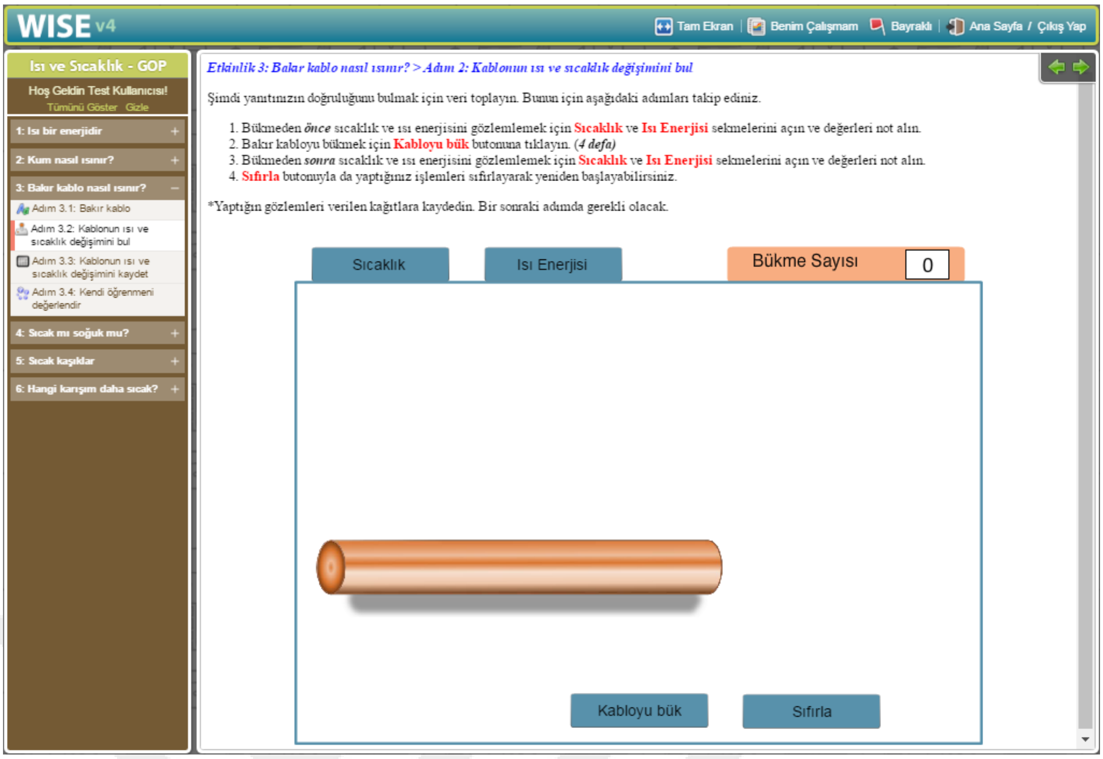


Figure 5. Adding ideas screen in activity 3

3.3.3.4 Activity 4: Hot or cold?

In this activity, the students were introduced to why some materials feel colder or hotter depending on heat transfer and thermal equilibrium (see Figure 6). The students were presented with a case about touching water with different temperatures and asked to predict how to feel. The students used a simulation about three water containers with different temperatures (hot, cold and warm). Putting hands into these containers and consequently changes in temperature and heat, were animated. They filled out a table about heat and temperature change when the right hand touched hot water, left hand touched cold water, right hand touching hot water touches warm water and left hand touching cold water touches warm water. Then, they were expected to explain the reason for those changes of hands. In the final step, they were asked to compare what they predicted and what they learned by explaining the similarities and differences.

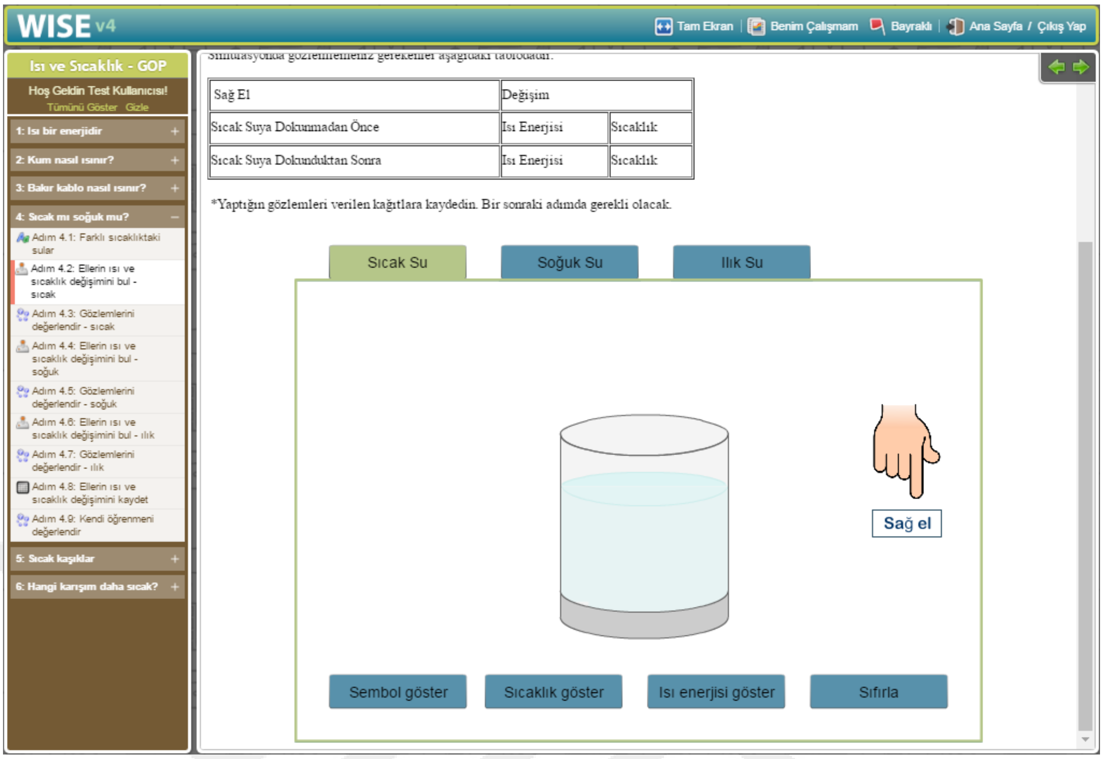


Figure 6. Adding ideas screen in activity 4

3.3.3.5 Activity 5: Hot spoons

In this activity, the students were introduced to why some materials feel colder or hotter depending on heat transfer and thermal equilibrium (see Figure 7). They were shown picture of a metal and a wooden spoon in a cup of hot chocolate and asked to predict which feels hottest and why. In the simulation about two spoons from different materials (metal and wooden), they virtually measured the temperature and heat of these spoons and the finger. Consequently, changes in temperature and heat were animated. After the students interacted with the simulation in order to add ideas about which gets hot more quickly and why. Then, they were asked to compare what they predicted and what they learned and explain the similarities and differences.

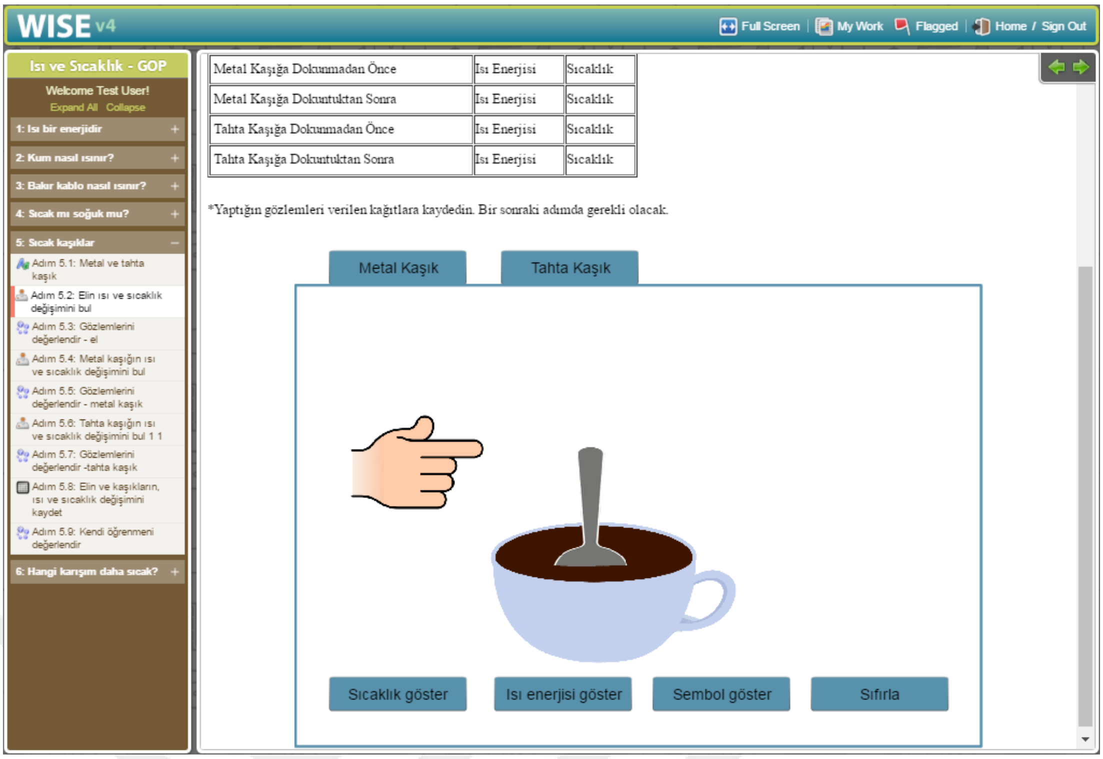


Figure 7. Adding ideas screen in activity 5

3.3.3.6 Activity 6: Which mixture of water is hotter?

In this activity, it is aimed to show the students what affects the final temperature of a water mixture (see Figure 8). The students were shown a picture of a mixture of hot and cold water and asked to predict the temperature of a mixture of cold water and hot water and the relation of change with the amount of water. Simulation aims to demonstrate the final temperature of three different water mixtures varying in amount and temperature. The students made some mixtures and filled the table to record data after thermal equilibrium is reached. The students filled out a table about heat and temperature change for the following mixtures: Mixture 1 (same amount of cold and hot water), Mixture 2 (less cold and more hot water) and Mixture 3 (more cold and less hot water). They were asked the reason for the difference in the final temperature of these mixtures. Finally, they compared what they predicted and what they learned to explain the similarities and differences.

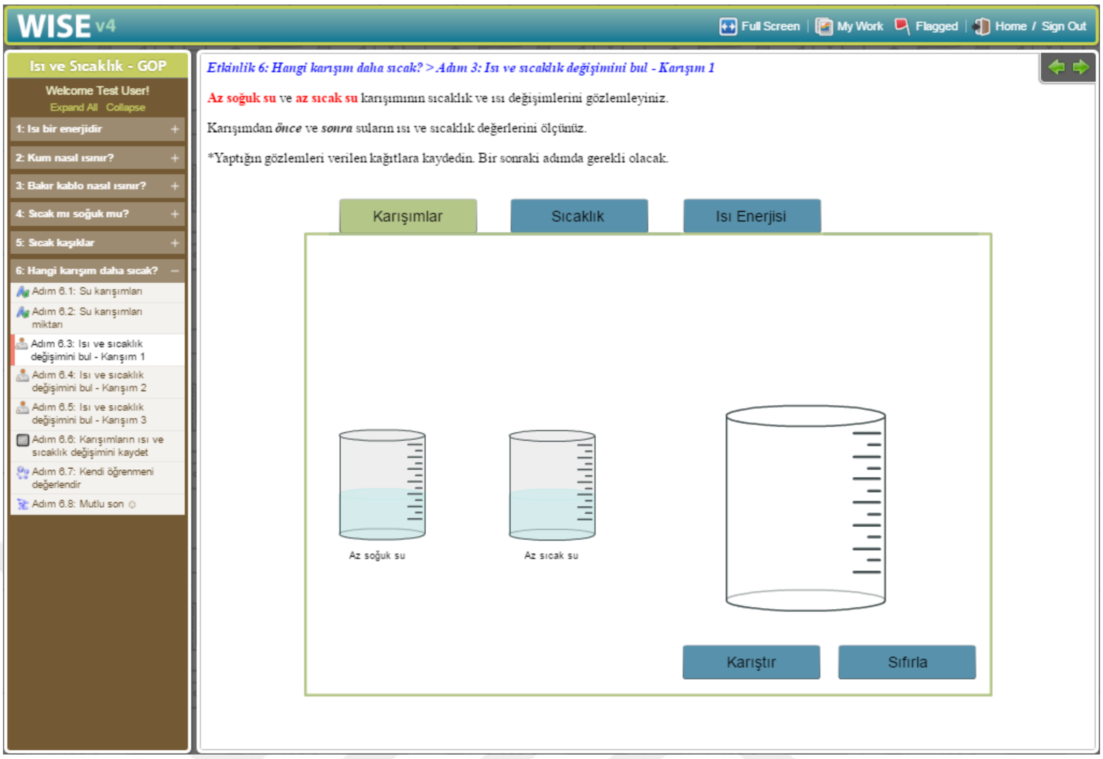


Figure 8. Adding ideas screen in activity 6

3.4 Data collection instruments

The data of this research was collected through the Knowledge Integration Scale on heat and temperature concepts and finally through students' logs on WISE platform.

3.4.1 Knowledge integration scale for heat and temperature

The dependent variable of the study is knowledge integration construct which refers to the process of linking, connecting, distinguishing, and structuring ideas including facts, patterns, views, theories etc. about complex scientific phenomena (Clark & Linn, 2003; Linn, Davis & Bell, 2004). Knowledge integration highlights eliciting students' initial repertoire of ideas to help them build on and improve their repertoire of ideas (Ryoo & Linn, 2015). Knowledge integration is defined as students' knowledge and ability to elicit and integrate scientifically normative and relevant ideas in explaining a scientific phenomenon or justifying their claim in a scientific problem (Lee & Liu, 2010; Lee et al., 2011). Knowledge integration is characterized as a cognitively dynamic process that can be captured in explanations and its assessment goes beyond measuring recall of isolated ideas or processes (Lee et al., 2011; Liu et al., 2011).

It is not reasonable to assess knowledge integration with multiple-choice questions since it focuses on how adequately students integrate ideas to explain complex phenomena. Since there is no available Turkish instrument to assess knowledge integration on this topic, the researcher developed a knowledge integration scale consisting of 10 open-ended items (Appendix C and Appendix D) based on the following three alternative conceptions identified by science education researchers (Erickson, 1985; Jason & Oberem, 2002; Quan, 2011; Thomaz et al., 1995):

a) Heat is seen as a kind of substance, not a form of energy

b) Confusion between temperature and sensation of an object

c) Inability to differentiate heat and temperature

Content experts (three science teachers and two education researchers) reviewed the items for whether it assesses the three alternative conceptions or not to ensure content validity.

Each item of the scale is scored according to a Knowledge Integration Rubric. The scoring rubric is developed to appropriately categorize and rank student responses. It reveals scientifically valid links among ideas of students rather than identifying whether ideas are correct or incorrect (Ryoo & Linn, 2015). Each level of the rubric is qualitatively unique to adequately capture different levels of scientific reasoning of students. Moreover, they are adequately comprehensive to capture all possible responses of students.

I examined some of the available knowledge integration rubrics submitted for the WISE units and used in the related research studies. Afterwards, the same content experts also examined the rubric. Based on their feedback, the instrument was refined. In order to find out whether the instrument is reliable or not, Cronbach's alpha, which is a measure of reliability used to assess internal consistency (Field, 2009) was calculated based on the data of 104 seventh-grade students from four different schools (different than the study participants) who took the scale.

3.5 Data collection procedures

Before data collection, the approval was taken from the Institutional Review Board and Ethics Committee of the university and the administration of the participating school. Teachers and students were informed about the study. Consent forms were distributed to the students before the intervention. After deciding the study schedule with administers and teachers, the list of students were obtained and their WISE accounts were created based on their names and student IDs.

Before students work with the inquiry activities on WISE, Knowledge Integration Scale was given as pretest. These tests took about 45 minutes to complete. One week later, students started to work on the unit about heat and temperature on WISE. Treatment process lasted about eight class hours and completed within three weeks as seen in Table 1, 2, and 3. For treatment, students came to computer class to study with the WISE unit to ensure that students learn from each other, which is the third design principle of knowledge integration. The registered students logged into their accounts with the issued usernames and passwords. In the first day of treatment, logging procedures, WISE interface and the online curriculum were introduced to the students in the first10 minutes. The majority of the time spent during instruction was interacting with WISE on computers. The science teachers of the classes were also present during the application of the WISE unit. The researcher and teachers moved around the classroom while students worked at their desks on computers. For this research, the teachers took a distinctively less active role than normal; they mainly encouraged students to complete the activities. Chang (2013) concluded that informing students was more effective when they needed rather than when the teacher planned.

Table 1. Data Collection Schedule for Class A

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1					Pretest
Week 2				Introduction / Activity 1	Activity 1
Week 3			Activity 2	Activity 3	Activity 4-5
Week 4			Activity 6		
Week 5				Posttest	

Table 2. Data Collection Schedule for Class B

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1				Pretest	
Week 2					Introduction / Activity 1
Week 3				Activity 2-3	Activity 4-5
Week 4				Activity 6	
Week 5				Posttest	

Table 3. Data Collection Schedule for Class C

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1				Pretest	
Week 2				Introduction / Activity 1	Activity 1
Week 3		Activity 2-3		Activity 4-5	
Week 4		Activity 6			
Week 5		Posttest			

The researcher played the active role as the facilitator of the activities in the unit. A review/feedback session was coordinated before starting each activity in the unit. The feedback and knowledge integration guidance was given both verbally and through the system by using *Grading Tools* (Figure 9). The researcher and the science teachers answered the questions from the participants. They also provided verbal feedback on their articulations on the WISE steps and scaffolding to deal with unexpected system circumstances such as errors in the computers or WISE system. Only the researcher gave feedback through the WISE system and evaluated their explanations and progress. The students were required to revisit some steps or to reconsider their entries to the corresponding activities. After five weeks of WISE implementation, the students were given the same instrument again as a post-test.

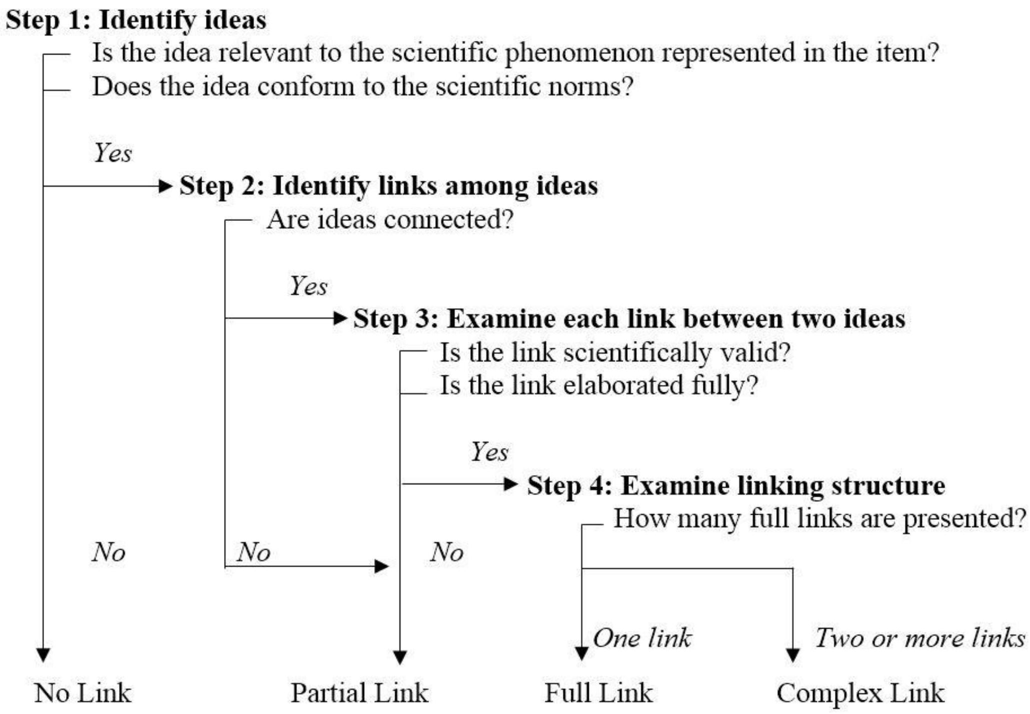
Figure 9. Screen of WISE grading tool

3.6 Data analysis

To answer the first research question, first all items of Knowledge Integration instruments were scored based on the Knowledge Integration Rubric (Figure 10, Appendix E and Appendix F). Students' answers on the Knowledge Integration scale items were scored according to the links among their ideas (Figure 10 and 11).

Score	KI Level	Description
0	No answer	Blank responses
1	Irrelevant	Off-task or incorrect responses
2	No Link	Non-normative or scientifically invalid links and ideas
3	Partial Link	Normative ideas without scientifically valid connections between ideas
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas

Figure 10. Knowledge integration rubric



Source: [Liu et al., 2008]

Figure 11. A four-step scoring scheme of knowledge integration

The minimum and maximum scores that a student can have from the instrument are 0 and 50, respectively. In order to assess the degree to which different raters give consistent estimates of the Knowledge Integration Rubric, an inter-rater reliability was administered. A science teacher rescored 25% of participants' Knowledge Integration Scale. The percent of agreement between the researcher and second rater was 84.7, which is acceptable (McMillan & Schumacher, 2001). Disagreements were resolved by discussion. These data were entered into the IBM SPSS Statistics program for conducting statistical tests.

The first research question: "Do Turkish seventh grade students significantly improve knowledge integration level after participating in the WISE instructional unit about heat and temperature?" was answered as follows. First, the Shapiro-Wilk normality test was applied in order to check the distribution of students' knowledge integration scores. Since the pre knowledge integration scores were not normally distributed, a nonparametric, Wilcoxon signed-rank test was conducted in order to analyze knowledge integration improvement on heat and temperature.

In order to answer the second research question (How does Turkish seventh grade students' interaction with the WISE environment in the heat and temperature unit explain different levels of knowledge integration gains?), three students were selected based on maximal variation sampling method considering their initial knowledge integration score and their knowledge integration improvement. That is, all these three students' initial knowledge integration scores were the same or very close. However, their post knowledge integration scores substantially differed.

These three participants' WISE records were analyzed with the constant-comparative data analysis method (Creswell, 2012) in order to reveal factors that lead to a successful WISE experience (higher knowledge integration gains). The constant-comparative method includes coding and analyzing at the same time (Glaser, 1965). The three students' WISE logs and students' interaction with the system were coded and compared based on knowledge integration patterns. Furthermore, students' articulation of their heat and temperature understanding associated with three alternative conceptions were broadly analyzed through their explanations in all unit steps.

Three codes emerged from this analysis: (a) revision frequency, (b) revision quality and (c) reflection. Revision frequency was obtained by counting the number of times a unit step is revisited. The quality of the revisions was nominated according to integrated normative ideas in students' revised explanations. Reflection demonstrated the extent of comparing the predictions and findings for each activity in the unit.

CHAPTER 4

RESULT

In this chapter, answers to the research questions that include descriptive statistics that provide a concise summary of the knowledge integration data, inferential statistics that describe and make inferences about the population based on the participants' knowledge integration data and finally the qualitative findings were reported.

4.1 Knowledge integration improvement

Research Question 1: Do Turkish seventh grade students significantly improve knowledge integration level after participating in the WISE instructional unit about heat and temperature?

In order to analyze knowledge integration improvement, first normality of data was checked to decide which statistics would be applied. The results of Shapiro-Wilk statistic, which assesses normality (see Table 4 and 5), indicated that pre knowledge integration scores with skewness of -.933 (*SE* = 0.306) and kurtosis of .644 (*SE* = 0.546) are not normally distributed. On the contrary, post knowledge integration scores had a normal distribution with skewness of .648 (*SE* = 306) and kurtosis of 3.93 (*SE* = 0.546).

Table 4. Descriptive Statistics of KI Scores

	N	Skewness	Kurtosis	Min	Max	Mean	Median	SD
Pre KI	61	-.933	.644	19	29	25.62	26	2.17
Post KI	61	.648	.391	20	41	29.20	28	4.26

Table 5. Shapiro-Wilk Result of the KI Scores

	Shapiro-Wilk		
	Statistic	df	Sig.
Pre KI	.919	61	.001
Post KI	.964	61	.067

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The Wilcoxon Signed Rank Test revealed a statistically significant increase in the knowledge integration scores of the middle school students after the WISE unit, *z* = -5.828 (see Table 6 and 7), *p* = .000, with a large effect size (*r* = .75). The median score on the Knowledge Integration Scale increased after online WISE unit treatment (*Md* = 28) compared to before treatment (*Md* = 26).

Table 6. Wilcoxon Signed Rank Test for KI Improvement

		N	Mean Rank	Sum of Ranks
KI Post- KI Pre	Negative Ranks	6[a]	9.83	59.00
	Positive Ranks	47[b]	29.19	1372.00
	Ties	8[c]		
	Total	61		

a. KI_Post_Total < KI_Pre_Total

b. KI_Post_Total > KI_Pre_Total

c. KI_Post_Total = KI_Pre_Total

Table 7. Wilcoxon Signed Rank Test Result

	KI Post- KI Pre
Z	-5.828[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

4.2 The mechanisms of WISE interaction that leads to higher knowledge integration gains

Research Question 2: How does Turkish seventh grade students' interaction with the WISE environment in the heat and temperature unit explain different levels of knowledge integration gains?

Three students were selected to further investigate the types of interactions with the WISE environment that led to better knowledge integration gains. These students started with similar knowledge integration scores but had different levels of improvement after studying the unit on WISE. Ekin revised her alternative ideas and integrated them with normative ones relying on her experiences within the WISE environment. Ada moderately added new ideas to previously held alternative ideas within her repertoire and did not successfully integrate them during the study. Finally, Nehir developed neither a scientific understanding nor knowledge integration with her repertoire of ideas.

Although these students' pre-KI scores were the same or very close (Ekin = 26, Ada = 27, Nehir = 26) and they all experienced the heat and temperature WISE curriculum, their performance on the post-test was different (Figure 12). Using the constant comparative method, a number of differences were identified among these students' experiences within the WISE environment. It appeared that there were substantial differences among them in terms of their revision frequency, revision quality and reflection in the WISE environment.

The data of revision frequency were obtained by counting the number of revisited steps in the WISE unit. Revision quality inferred a student's revision of the explanation with integrated normative ideas (see Appendix G). Lastly, the final steps of each activity, which asks for self-reflection aiming sorting out ideas that is fourth pattern of knowledge integration, were examined to discover students' reflection of their own learning.

Below, an in-depth analysis of how these students' understanding of heat and temperature regarding the three alternative conceptions developed over the course of the unit was explained in terms of these three factors.

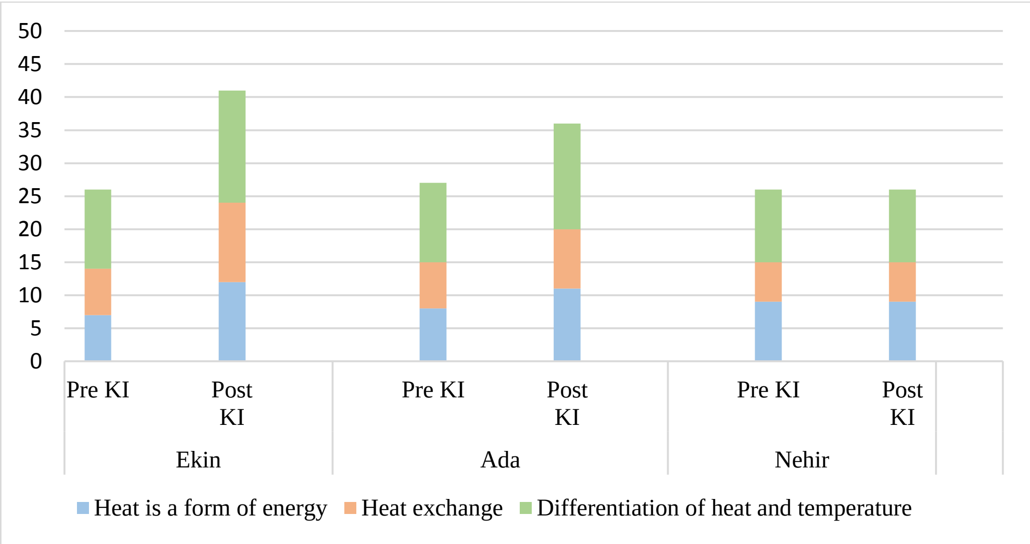


Figure 12. KI improvements regarding alternative conceptions

4.2.1 Revision count

Revision count was obtained based on the revisiting for a step. If a step was revisited at least twice, then it is considered as revised. Ekin and Nehir revisited 40% of steps whilst Ada's revision count was 24% among the 47 steps. The distribution of revision count percentages for the three alternative conceptions was shown in the Table 8.

Table 8. Revision Counts Regarding Alternative Conceptions

	Ekin	Ada	Nehir
Heat is a kind of substance, not a form of energy	60%	80%	60%
Confusion between temperature and sensation of an object	100%	100%	100%
Inability to differentiate heat and temperature	88%	58%	72%

4.2.2 Revision quality

The quality of revisions was designated according to integrated normative ideas after revision. If students had more integrated normative ideas after revision, their revision quality is considered to be higher. The analysis of students' explanations in the revisited steps indicated that 80% of Ekin's explanations were highly qualified whereas this percentage was 45% for Ada's and only 19% for Nehir. Not surprisingly, Ekin's revisions were more qualified than Nehir's although their revision counts were the same. Below is a detailed discussion about their revision quality for each alternative idea investigated in this study.

Heat is a kind of substance, not a form of energy

Initially Ekin had limited but relevant ideas about forms of energy and she revised them throughout Activity 1. She used scientific terms and statements in the course of the unit. She revised her description of energy that consists of scientifically relevant ideas to ones that included scientifically valid ideas and links. For example, she added the following normative idea "I mean it is a measure of the ability of something to do work" into her repertoire of energy (see Appendix G).

Furthermore, she was confused in the Activity 2 targeting energy transformation, in particular mechanical energy to heat energy and could not accurately explain why the sand becomes hotter. However, she improved her understanding of energy forms in the Activity 3, which is similar to Activity 2 and had more scientifically valid ideas and links. Although she revised her understanding, she still needed to add more links. For example, she was able to understand the relation between mechanical energy and heat energy as “Because there is mechanical energy. It transforms into heat energy.” However, she was not able to form a link between heat and temperature. Ekin’s knowledge integration on heat as a form of energy was successively improved since she was able to integrate heat energy with her repertoire of ideas.

Ada had relevant ideas on the forms of energy and she slightly revised them throughout Activity 1. However, she held onto the non-normative ideas and occasionally recalled them in the following steps in the unit. In the beginning of the unit, she made no scientifically valid links between the ideas, but later she was only able to make partial links as she progressed. She revised her own definition of energy by adding scientifically valid ideas. Her use of terms somewhat improved throughout studying the unit. For example, she added, “Mechanical energy transformed to heat energy,” which included more normative ideas, however she did not link heat energy and temperature.

Similarly, before starting the WISE unit, Nehir had some relevant but non-normative ideas on energy and energy transformation yet she was not able to make scientifically valid links within her WISE experience. She could not normatively define energy as seen in this statement “Energy is electricity. For example, we gain energy when we walk.” Furthermore, she was not able to improve her explanations on energy formation and she did not link her ideas within a scientific frame. Throughout the activities related to this concept, she gained normative ideas but she needed scientifically valid links among those ideas. For example, her final explanation on why the cable becomes hotter after bending several times was "the temperature of cable increased with each bending." She was aware of the relation between the hotness of the cable and bending it but she was not able to explain this scientifically.

Confusion between temperature and sensation of an object

Ekin corrected her alternative conceptions on temperature and sensation of an object throughout the WISE unit. For example, she had the idea that wooden objects do not conduct heat. At the end of the Activity 5 that aimed to overcome those conceptions, she revised her ideas as wooden objects conduct heat but not as good as metal objects (see Appendix G). She could relate why heat and temperature of hands changed after touching glasses of water with different temperature with heat exchange after several revisions on step 8 of Activity 4. She had progressively added scientifically valid ideas and linked them.

Ada could develop a coherent understanding of the different heat transfer rate of materials during the unit. She could explain the cases in the Activity 5 why we sense some materials differently but she could not link the cases with the concept of heat exchange (see Appendix G). In Activity 4, she had scientifically valid ideas and links but her statements needed more normative phrases. On the contrary, Nehir built no solid grounds to her ideas as the other students did. Nehir's explanations were rather superficial. For example, she did not provide any reasons for step 8 of Activity 4. She merely expounded this: "Metal spoon burns the hand but wooden spoon does not."

Inability to differentiate heat and temperature

Ekin knew about heat exchange but she was not able link heat and temperature. She sometimes used the terms improperly. After each simulation, there were two separate questions that ask for an explanation for the reason for changes in heat and temperature. In some of these steps, she used the words heat and temperature interchangeably. For example, she expressed temperature exchange instead of heat exchange as seen in this statement: “The temperature of the spoon is passed to the hand and the temperature of the spoon decreased.”

Ada’s ideas about heat and temperature were not normative in the first place. Although her progress was not satisfactory, she occasionally used the terms in correct forms. For instance, she articulated this idea after interacting with the cable simulation: “The mechanical energy of cable creates heat energy. Consequently, its temperature increased.” On the other hand, she replied to the question which asks for how the heat energy of hand changes when it touches hot water as follows: “The value of temperature increased.” There were very few indicators as to whether Nehir differentiated heat and temperature since she did not provide any profound explanations in the steps over the WISE unit.

4.2.3 Reflection

According to the Knowledge Integration principle *sorting ideas*, students need to reflect on their own learning. For this reason, in the final steps of each activity, students were required to compare their predictions and findings from simulations and provide an explanation as to why they were successful or not. The analysis of these steps particularly of the students’ comparisons and explanations demonstrates that Ekin was better at reflecting on her own learning than the other students.

Ekin seemed to know how to evaluate her understanding and she was able to compare her predictions and findings. For instance, in Activity 5, she stated that her predictions and outcomes were different because she supposed that wooden spoon did not conduct heat but it was not correct. Similarly, in the final activity, she argued that her prediction was not correct because she thought all the mixtures would be cold. However, other students' performance was fair in those reflection steps. Ada revised her repertoire of ideas in consequence of interacting with simulations and providing explanations in the steps but she was not successful in evaluating her own performance and learning process. In the reflection steps, she believed that her predictions were true. In fact, she inadequately predicted or explained the cases in the activities. For instance, her prediction in the final activity was briefly that they will be warm but she asserted that she predicted correctly although she did not (The final temperatures of all the mixtures were not warm). Nehir did not provide grounded explanations on their predictions and findings. For example she said, "Since the heat energy of all are different." This reply does not reflect a self-evaluation. As seen in those interactions and stated by WISE researchers, the reflection is very important in developing a coherent science understanding.

4.2.4 Summary of findings

The analysis of three students showed that their WISE interactions differed in three dimensions: revision count, revision quality and reflection unit (see Table 9). Ekin revised her ideas with more normative ones than other students when they started the WISE. At the end of the unit, she was better in stating normative ideas and making scientifically valid links. In addition, she was able to reflect on her learning process in the WISE unit.

Table 9. Summary of Findings

	Revisions Count	Revision Quality	Reflective Behavior
Ekin	40%	She showed improvement in 14.5 steps out of 18 revised steps. Her explanations were dramatically improved and made scientific links among them.	She has learned how to reflect on her own understanding through the unit. Towards the end of unit, she was able to properly compare her predictions and data in the simulations.
Ada	24%	She just improved in 5 steps out 11. Her explanations were gradually improved but they had non-scientific ideas and links.	She believes that her predictions and findings of simulations are similar. In fact, her predictions were not fully correct and her explanations to simulations were not scientifically valid.
Nehir	40%	She just improved in 3.5 steps out 18. There is no sign of improvement in her explanations.	There is no reflection on her own understanding in each activity of WISE unit.

Comparison of the three students' experiences and interactions with the WISE unit demonstrates that even though their level of knowledge was very similar at first (i.e., they had similar ideas about heat and temperature initially), Ekin's performance ended up being better than the other students after studying with the WISE unit. This can be explained with the following two explicit differences in the processes of unit interaction as summarized in the Table 9. First, Ekin revised her inaccurate or limited explanations more than others. Ekin's revision was successful in 80% of steps while Ada revised only 45% of the steps and Nehir, not surprisingly, corrected only 19% of her understandings in the unit. Ekin was persistent in correcting her explanations. She revised one step over five times until she improved, while other students revised a step only once and then they moved to the next question or did not effectively make any high quality of revisions.

Secondly, the reflective behavior in unit interaction differed amongst the three participants. Ekin knew how to evaluate her own understanding and she was able to compare her predictions and findings and explanations of the simulations. On the other hand, other students' performance was inadequate in those reflection steps. They were not articulate in evaluating their own performances and learning processes.

CHAPTER 5

DISCUSSION AND CONCLUSION

The present study examined the use of a WISE-based unit on heat and temperature on Turkish middle school students' knowledge integration. The designed WISE-based unit consisted of six inquiry activities and applied to 75 public school attending seventh-grade students within three weeks. The first question in this study sought to answer was whether WISE was effective in improving the knowledge integration level of seventh-grade public school students, who usually have less opportunities to engage in inquiry activities in science classes. The results showed that students' level of knowledge integration significantly improved after studying the heat and temperature unit on WISE for only three weeks. The analysis of the three participants regarding revision count, revision quality and reflection supported the importance of the knowledge integration pattern in the design and implementation of inquiry science activities.

5.1 Knowledge integration improvement

The analysis showed that seventh grade public school students who used the online WISE unit on heat and temperature significantly improved their understanding of heat and temperature with respect to the knowledge integration construct. This result supports previous literature, which links WISE and knowledge integration (Chiu & Linn, 2011; Clark & Linn, 2013; Linn, 1995; Linn, 2002; Linn et al., 2003; Slotta, 2004). International WISE researchers have examined the effectiveness of WISE and its features in promoting knowledge integration within different research contexts. They found that WISE is an effective tool for improving knowledge integration of students (Chiu & Linn, 2014; Clark & Linn, 2003; Lee et al., 2010; Linn, 2002; Linn et al., 2015; Visintainer & Linn, 2015; Williams & Linn, 2002). This finding is corroborating other studies but it is still significant given that this study was conducted with public school students from a relatively disadvantaged area in Istanbul and who had very limited, if none, experience with inquiry learning or computer use in their science classes.

Technology Enhanced Learning in Science (TELS) community researchers have stated that WISE interface is easy-to-use and the technical and cognitive tools of WISE help students to manage their inquiry processes without constant help (Linn et al., 2003; Linn et al., 2015; Linn & Slotta, 2000; McElhaney, Matuk, Miller, & Linn, 2012; Okada, 2013; Slotta, 2004; "Web-based Inquiry Science Environment", n.d.). Linn and colleagues suggested that effective computer use in previous experiences is another indicator of WISE effectiveness. They found that students who used computer in their lessons improved more knowledge integration using WISE (Liu et al., 2011; Liu, Rios, Heilman, Sato & Svihla, 2016). The participants of this study significantly increased although they have not used computer as a tool in their science lessons. This finding, while preliminary, suggests that seventh-grade Turkish students enhanced their knowledge integration after WISE unit in spite of limited WISE implementation time, which was only 8 hours of instruction.

It seems that the dynamic visualizations embedded in the heat and temperature unit helped students' scientific understanding, which is consistent with the results of a body research studies on simulations (Clark & Linn 2013; McElhaney et al., 2014; Ryoo & Linn, 2011; Svihla & Linn, 2012; Zhang & Linn, 2011; Zhang & Linn, 2013). In addition, it can therefore be assumed that the online WISE unit embedded with simulations was effective in supporting the findings of previous studies (Chang & Linn, 2013; Chiu & Linn, 2014; Kali & Linn, 2008; Svihla & Linn, 2012; Williams & Linn, 2002).

Furthermore, these results also suggest that the guidance provided by the researcher and teachers, and feedback given by the researcher on WISE platform were sufficient to support the articulation of student's ideas through explanations (Chang & Linn, 2013; Ryoo & Linn, 2014; Vitale et al., 2016). However, the findings of this study also suggest that the knowledge integration gains of students can be related to the way they interacted with the WISE platform, which was discussed in the next section.

5.2 The importance of tracking knowledge integration patterns

A qualitative analysis of three students' WISE records revealed that their experience with WISE unit differed with respect to three dimensions. These are revision frequency, the quality of revisions showing how they improved their understanding and explanations throughout the WISE unit, and the amount of reflective thinking they engaged. These three factors may explain the different knowledge integration gains. According to knowledge integration patterns, after eliciting students' ideas, students need to add new ideas through dynamic visualizations and to distinguish among their ideas within their explanations, and to sort their ideas with their reflections (Clark & Linn, 2003; Clark & Linn, 2013; Lee et al., 2011; Linn et al., 2015; Ryoo & Linn, 2015). These dimensions clarified that the cases differed with respect to knowledge integration patterns (adding ideas, distinguishing among ideas and sorting out ideas). Ekin improved her understanding in heat and temperature more than Ada and Nehir. A possible explanation for this difference might be that

Ekin's interaction was more in compliance with knowledge integration patterns compared to others.

WISE logs that all of the cases shown, their existing ideas would be obtained via prediction steps that ask for an explanation of each situation in the activities. For example, in Activity 3 that targets energy transformation in particular mechanical energy to heat energy, the ideas of participants about heat energy were elicited and they all had scientifically invalid ideas and links. Ekin held the idea of that "the temperature of the cable will not change because only its shape will change". Ada's previous ideas were not as invalid as Ekin's. She had the idea that is "the heat will increase because there is heat exchange as a result of bending and it will heat the environment". Nehir's elicited ideas were not accurate; "the heat of cable becomes hot when it is burned". It can therefore be assumed that the first pattern of knowledge integration had come true as expected from interacting with the online unit. This pattern is important because it enables students to realize that new ideas are added to their existing ideas as well as integrating those existing and new ideas (Chiu & Linn, 2011; Linn, 2006; Linn et al., 2015; Linn & Songer, 1991; Ryoo & Linn, 2011).

The cases varied with the following knowledge integration patterns: adding new ideas, distinguishing among ideas; and sorting ideas. Ekin added more ideas to her repertoire than others since she revised and revisited steps in the unit. This result may be explained by the fact that she could effectively use the simulations and collect proper data in the activities. This finding corroborates with the idea that adding new ideas may be assisted with multiple opportunities such as experiments, models, demonstrations and dynamic visualization. Adding new ideas as knowledge integration pattern signifies that students make sense of the new scientific ideas and connect them to their existing ideas (Chiu & Linn, 2011; Linn, 2006). Analysis of revisiting logs indicates that students who revisited the visualization (adding ideas steps) produced significantly higher gains from initial to final drawings than students who did not revisit (Vitale et al., 2016).

In a study by Chang and Linn (2013), it was found that the thermodynamics visualization could add ideas to the repertoire of students who observe that visualization contributed to their learning. Similarly, Ryoo and Linn (2011) found that dynamic visualizations helped students to add normative ideas to their repertoire as well as to have more integrated ideas about abstract concepts. Therefore, this study supports the benefit of dynamic visualization in helping students to add normative ideas to their repertoires.

Ekin distinguished among her ideas during the WISE unit interaction, which can be observed through the improvements in the quality of her explanations. These results support the knowledge integration framework, which argues that developing criteria to evaluate ideas is a necessity in order to distinguish among them (Chiu & Linn, 2011; Linn, 2006; Linn et al., 2015). Chang and Linn (2013) suggest that virtual experiments are more likely to help students' understanding when coupled with the evaluating the investigation comparison with when coupled with reviewing experiment guidelines and conducting virtual experiments. The results of the study by Ryoo and Linn (2014) showed that generating explanations is more helpful than reading explanations for middle school students to comprehend scientific concepts during dynamic visualization interaction. Therefore, the current study advocates the importance of guiding students to help them develop criteria for distinguishing among their ideas.

Finally, Ekin was able to sort many of her ideas within the reflection steps compared to other students. The findings seem to be consistent with previous literature, which claims that the collection of new evidence, reflection on the evidence, and connection among ideas are the requirements for forming an integrated perspective and finding gaps or discrepancies in their understanding (Chiu & Linn, 2011; Linn, 2006; Linn et al., 2015; Ryoo & Linn, 2011; White, 2000). The researchers' point is that making predictions, adding ideas, and distinguishing among ideas are supportive to achieve accurate scientific understanding, however reflection is also needed. The results of the study further support the idea of that reflection is critical for an accurate science understanding.

The evidence from this study suggests that WISE facilitates inquiry instruction, particularly integration of students' ideas with the normative ones within personally relevant experience. Results so far have been promising for tracing knowledge integration design principles and patterns to design inquiry activities, units and projects. These results constitute an excellent initial step towards understanding and improving the mechanisms of WISE interaction: revision count, revision quality and reflection. Therefore, some modifications or improvements to provide instructional support are needed in the WISE platform. First, students might see their revision count and revision history for each step and not be allowed to pass to the next step without reconsidering their ideas and integrating them with normative ideas. Second, the *Reflection Note* feature of WISE should be modified in the way that it pushes students to reflect on their learning experience.

Students might be provided with scaffolding from the WISE system itself so that they can add more ideas and make links among their ideas. McElhaney et al. (2014) made some suggestions regarding the design of supporting instruction for dynamic visualizations. They wound up that students take advantage of visualization with inquiry-oriented supports, scaffolds supporting investigations and inquiry prompts. Therefore, WISE should offer practical ways to integrate visualizations with inquiry activities and supports. It may be useful to provide features that structure automated prompts and feedbacks. Consequently, use and integration of c-rater, which is an automated scoring engine that measures a student's short explanations, could be easier to operate in the WISE system.

5.3 Recommendations and implications for future research

The present study contributes to the science education research in the following ways. Firstly, it provides a Turkish WISE unit and the Turkish interface for WISE. This makes teachers to easily integrate WISE into their classrooms and create their own activities. This is very important since there is a discrepancy and need for effective methods in Turkish science education (Ayvacı et al., 2014; Dağhan et al., 2015; Dursun et al., 2013; Kula-Wassink & Sadi, 2016; Özkale & Koç, 2014; Pamuk et al., 2013). In addition, this study demonstrates that WISE facilitates inquiry instruction, which is challenging to conduct (Slotta, 2004; Williams et al., 2004).

Secondly, the results and findings extend our knowledge of the effective applications of science education. In particular, it is seen that an online WISE unit was effective in promoting students’ science understanding in a context where students did not have any experience with WISE or inquiry instruction. Also, knowledge integration was found to be a useful framework for guiding the design of inquiry science instruction. This combination of findings provides some support for the conceptual premise that an inquiry science unit designed based on knowledge integration principles and patterns have the potential to improve students' coherent science understanding in relatively disadvantaged settings.

Thirdly, qualitative data analysis showed that revisiting; revising and reflecting over the course of WISE unit are important indicators for achieving knowledge integration. The evidence from this study suggests that knowledge integration patterns are essential for science instruction, which promote accurate science understanding and links between student's ideas as suggested by Linn and colleagues in previous research.

With this study, WISE is now available in Turkish to provide technology-enhanced inquiry activities, which has been a need in Turkish science education. In addition, heat and temperature unit featuring simulations and knowledge integration scale with reliability and validity check were introduced. However, this study was limited in regards to students' familiarity with the WISE platform and time issues. WISE should be introduced to the students and a pilot implementation of WISE should be conducted before an actual research study. In this sense, students would be familiar with the system and be more focused on knowledge integration processes in the study. This is important as it helps to identify the strengths and weaknesses of the unit and improve it as well (Chiu & Linn, 2014; Williams & Linn, 2002). Linn (2006) points out the importance of iterative refinement in the design of instruction from the knowledge integration perspective. Therefore, this study can be replicated by adding a pilot study, which is needed both to improve the online unit and to make students familiar with WISE within experimental contexts. In addition, the efficiency of WISE with different online inquiry units and for different participants who are familiar with inquiry teaching might be investigated. Studies found that students of the teachers with more inquiry experience had better learning outcomes from inquiry instruction (Lee et al 2010).

One of the design principles suggested by Kali and Linn (2008) which supports student-initiated modeling of complex science was not met in this study. Some researchers discovered that students integrated more ideas when they draw their ideas than they observed visualizations. Zhang and Linn (2011) found that the drawing task prompted learners to observe more carefully and integrate more ideas from the visualization. A similar result emerged from study by Zhang and Linn (2013) in which complex selection and generation helped learners studying chemical reactions more than typical selection. Therefore, further research may focus on designing and developing an environment/activity in which students can create their own model related to heat and temperature.

In this study, students were provided guidance and feedback in both the classroom and WISE. TELS researchers have been studying the types of guidance such as specific, generic, knowledge integration, automated etc. and which one is more effective in the context of WISE system. For example, it is seen that knowledge integration guidance is helpful when students need to integrate their ideas (Gerard et al., 2016). Similarly, Vitale et al. (2016) stated that specific guidance did not promote more integrated understanding of general concepts although it helped students to add ideas. Apart from these, Donnelly et al. (2015) could not detect a difference between automated critique-based guidance versus automated revisiting-based guidance on developing students' understanding. Therefore, further research may investigate the effect of guidance on the Turkish students' science understanding since guidance is important in supporting distinguishing among ideas.

5.4 Limitations of the study

Notwithstanding the WISE researchers suggest that online WISE units are effective when students are familiar with the system. When they have experienced inquiry units before, they take advantage from these units more and their level of knowledge integration respectfully improved. Liu et al. (2015) aimed to study the students' performance change (comparison of Year 1 and Year 2 scores). The results show that Year 2 students outperformed Year 1 students. The number of online inquiry units studied was a significant indicator of science understanding after controlling some variables like prior science knowledge, grade level, gender, school, and language. Students who received instruction for two years significantly improved their understanding of energy compared to students who received instruction for only one year. However, this does not seem applicable in this study due to practical constraints particularly lack of access to the students' science class time.

Besides, WISE should be utilized long enough in order to have an impact on knowledge integration. Clark and Linn, (2003) aimed to investigate the impact of instructional time of inquiry curriculum on Knowledge Integration (KI) level of students. The results of the study show that there is a strong relation between instruction time and knowledge integration improvement level. Shortening the inquiry curriculum significantly decreased learning. Since there is no available school, which tolerates a long period of time for the implementation of WISE, I needed to design and develop a WISE unit for 8 hours despite the national curriculum suggesting 16 hours. Hence, these issues related to timing might have masked a larger knowledge integration gain of students.

APPENDIX A

THE DESIGN OF ACTIVITIES BASED ON KNOWLEDGE INTEGRATION PRINCIPLES

KI Principles	Design Procedure
Make Science Accessible	*Scope:* Targeting most recognized three alternative conceptions about heat and temperature
	Level of analysis: Providing observation via simulations and asking students to evaluate the results based on their findings in those simulations
	Example: Providing relevant science topics to everyday life like sensations of different hot spoons, temperature of water mixtures etc.
Make Thinking Visible	*Content:* Creating simulations and other representations of science content based on principles suggested by Kali and Linn (2008). *Principle 1:* For "reducing visual complexity to help learners recognize salient information", I diagnosed the repertoire of ideas of the students through literature review. *Principle 2:* For "scaffolding the process of generating explanations", students need to explain the results of the data collection in each activity. *Principle 3:* "Supporting student-initiated modeling of complex science" was not implemented since there is no much time for intervention. *Principle 4:* Providing calorimeter, temperature and symbolic representation of heat in simulations ensures principle of "using multiple linked representations".

	Teacher Thinking: WISE features especially feedback tool makes teachers thinking visible in response to students' notes and activities.
	Student Thinking: Students need to explain many ideas about the topic and the results of the data collection in each activity.
Help students learn from each other	The opportunity is given to students to critique and revise ideas of each other by enabling students' ideas visible in some steps. Therefore, students are able to see each other's work and review. Also, they are allowed to talk each other while interacting with simulations and working on WISE.
Promote autonomous lifelong learning	The WISE inquiry map enables students to carry out projects without having constant guidance from teachers or peers. Therefore, it helps their autonomous learning process.

APPENDIX B

THE DESCRIPTION OF ACTIVITIES BASED KNOWLEDGE INTEGRATION PATTERNS

Activity	Description	Simulation	Knowledge Integration Processes			
			Eliciting Ideas	Adding New Normative Ideas	Distinguishing among Ideas Using Scientific Evidence	Encouraging Reflection
Activity 1: Heat is a kind of energy	This is an introduction activity to show different energy forms and their relation to heat to the students.	PhET: Energy forms and change simulation will be used. It includes some mechanisms to visualize energy forms, energy transfer, heat energy and temperature.	Students will be asked the following questions. What is energy? (Students are forced to relate the idea of energy with energy of human body.) What are the forms of energy? What can we do with heat energy?	Students will use PhET simulation that allows students to experience energy forms and transfer. They will set up four different energy transformation mechanisms and answer questions about energy forms and transformation. Furthermore, they will turn on/off the heater and will observe change in heat and temperature of different materials.	Students will answer following questions based on the simulations. What happens the heat and temperature of the materials (iron, brick and water)? What can cause this change? Explain Scientific Explanation: When the heater is on, heat energy of the materials get higher meaning their temperature will be high since temperature is the measurement of heat energy.	What is heat/thermal energy? Does energy disappear? Are heat energy and temperature the same? Why?
Activity 2: How does the sand get warm?	In this activity, students are introduced how things heat up and its relation with transformation of energy.	Students will use a simulation about shaking a jar full of sand and observe the change in temperature and heat.	Students will be shown a picture of a jar filled ¾ of it with sand and asked the question below to get their predictions. 1- How does heat of the sand change? 2-How does the temperature of the sand change? 3-What do you think caused the change in temperature? Scientific Explanation: Each time of shaking sand gets hotter.	Students will interact with the simulation by observing the temperature and heat change.	Students will fill out a table after shaking the jar each time interval by observing temperature and heat of sand and explain the reason for changes. Scientific Explanation: Shaking is about a form of energy (mechanic). The energy of sand's motion is transferred to heat energy of the sand. Heat is also energy. The heat energy in the sand causes increase of temperature.	Students will be asked to compare what you predict and what you learned explain the similarities and differences.

Activity 3: How does the copper cable get warm?	In this activity, students are introduced how things heat up and its relation with transformation of energy.	In the simulation in this activity, copper wire is bended back and forth several times. After each bending, the temperature and heat of the wire shown on the screen.	Student will be shown a picture of copper wire and asked the question below to get their predictions 1-How does heat of the wire change? 2-How does the temperature of the wire change? 3-What do you think caused the change in temperature? Scientific Explanation: Each time the wire gets hotter.	Students will interact with the simulation by observing the temperature and heat change.	Students will fill out a table after bending the wire each time interval by observing temperature and heat of wire and explain the reason for changes. Scientific Explanation: Bending things produces heat energy. Bending is about a form of energy (mechanic). The energy of wire's motion is transferred to heat energy of the wire. The heat energy in the wire causes increase of temperature.	Students will be asked to compare what you predict and what you learned explain the similarities and differences.
Activity 4: Hot or cold?	In this activity, students will be introduced why some materials feel colder or hotter depending on heat transfer and thermal equilibrium.	Simulation is about three water containers with different temperatures (hot, cold and warm). Putting hands into these containers and consequently changes in temperature and heat will be animated.	They are presented a case about touching water with different temperature and asked the questions below to get their predictions. There are three containers full of water with different temperatures. If you put your right hand into hot one and left hand to cold one for a while, how do you feel the warm one when you put your both hands after a while? Do they feel same? Expected answer: Warm water will feel cold by right hand, hot by left hand.	Students will interact with the simulation by observing the temperature and heat change. Students will observe changes for three conditions in separate steps.	Students will fill a table about heat & temperature change for the following when: • Right hand touches hot water • Left hand touches cold water • Right hand touching hot water touches warm water • Left hand touching cold water touches warm water Students will be expected to answer the reason for those changes of hands. Scientific explanation: Heat moves from the hotter body (higher temperature) to the colder one (lower temperature). Right hand gets heat from the hot water and gets hotter. Cold water suck heat from left hand and left hand gets colder. When you put your right hand (hotter hand) to warm water, your hand transfers heat to water and it feels colder. When you put left hand (colder hand) to warm water, your hand transfers heat from water and it feels hotter.	Students will be asked to compare what you predict and what you learned explain the similarities and differences.
Activity 5: Hot spoons	In this activity, students will be	Simulation is about temperature and	Students will be shown picture of a metal spoon and a wooden	Students will interact with the	Students will be expected to answer following questions.	Students will be asked to compare what you predict

	introduced why some materials feel colder or hotter depending on heat transfer and thermal equilibrium.	heat change of two spoons from different materials (metal and wooden). Touching these spoons and consequently changes in temperature and heat will be animated.	spoon in cup of hot chocolate and asked the question below to get their predictions. If you leave them in the cup of hot chocolate for a while, which feels hottest? Do your hand feel the same? Do you know why? Scientific Explanation: Metal spoon feels hottest and wooden spoon feels less than metal. Metal transmit the heat of chocolate more quickly and feels hottest.	simulation by observing the temperature and heat change. Students will virtually measure the temperature and heat of these spoons and the finger.	1-Which types of materials got hotter more quickly? 2-Do you have any ideas why? Scientific Explanation: Heat moves from the hotter body (higher temperature) to the colder one (lower temperature). Right hand transmits heat of hot water and gets hotter. Cold water transmits heat of left hand and left hand gets colder. When you put your right hand to warm water, it transfers heat of your hand, feels colder. When you put left hand to warm water, your hand transfer heat of water, feels hotter.	and what you learned explain the similarities and differences.
Activity 6: Which mixture of water is hotter?	In this activity, it is aimed to show students what affects the final temperature of a water mixture.	Simulation aims to demonstrate final temperature of three different water mixtures varying in amount and temperature.	Students will be shown a picture of a mixture of hot and cold water and asked the question below to get their predictions. What happens to the temperature to determine when they mix cold water and hot water? Does the amount of hot water and cold-water matter?	Students will make some mixtures and fill the table to record data after thermal equilibrium is reached.	Students will fill out a table about heat and temperature change for the following mixtures: • Mixture 1 (same amount of cold and hot water) • Mixture 2 (less cold and much hot water) • Mixture 3 (much cold and less hot water) Students will be expected to answer following question. Why do temperature and heat of those mixtures are different? Scientific Explanation: Heat moves from the hotter body (higher temperature) to the colder one (lower temperature). Until thermal equilibrium is ensured, heat flow continues and the amount of the water will affect the final temperature.	Students will be asked to compare what you predict and what you learned explain the similarities and differences.

APPENDIX C

KNOWLEDGE INTEGRATION SCALE FOR HEAT AND TEMPERATURE

(TURKISH)

ISI VE SICAKLIK ÖLÇEĞİ

Sevgili Öğrenciler,

Bu ölçek, sizin "***Isı ve Sıcaklık***" konusu ile ilgili bilgilerinizi belirlemek amacıyla geliştirilmiştir. Burada belirteceğiniz görüşler yalnızca araştırma amacıyla kullanılacak ve sonuçlar tüm grubun yanıtları göz önüne alınarak değerlendirilecektir. Bu araştırmanın güvenirliği için sizin gerçek düşüncelerinizi ve bilgilerinizi bizimle paylaşmanız çok önemlidir.

- Lütfen hiçbir maddeyi boş bırakmayınız.
- Lütfen her bir maddeyi dikkatlice okuyunuz ve cevabınızı tüm ayrıntısıyla yazınız.
- Sadece kendi fikirlerinizi yazınız.
- Ölçeği tamamlamak için süreniz 45 dakikadır.

Adı Soyadı:
Okul Numarası:
Sınıfı:

1- Sizce ısı ile sıcaklık aynı şey midir? Neden? Bilimsel olarak açıklayınız.

2- Çok soğuk bir kış gününde evde saatlerce çizgi film izleyen Mert üşümüştür. Kombiyi kontrol etmesi için annesine ricada bulunur. Annesi üşümesinin sebebinin kombi değil hareketsizlik olduğunu anlar ve ona biraz hareket etmesini söyler. Mert biraz yürüyerek, zıplayarak, elini kolunu sallayarak hareket eder ve artık üşümediğini, vücut sıcaklığının arttığını fark eder. Mert'in vücut sıcaklığı neden artmış olabilir? Bilimsel olarak açıklayınız.

3- Havanın çok soğuk olduğu bir gün Mertlerin evinin kombisi bozulmuş. Mert okuldan eve döndüğünde odasının çok soğuk olduğunu görmüş. Annesi, elektrikli sobayı yakmış. Mert, ısınmak için ellerini sobaya uzatmış ve bir süre sonra ısındığını hissetmiş. Sobayı yaktıktan sonra odanın sıcaklığı nasıl değişmiştir? Bilimsel olarak açıklayınız.

4- Mertlerin tüm evi fayansla kaplıdır. Mert'in annesi, çorap veya terlik giymeden salonda gezinmemesi konusunda onu uyarmış. Fakat Mert annesinin sözünü dinlemeyip oyun oynarken salonda yalın ayak gezinmiştir. Mert halının üzerinde gezinirken ayağı üşümemiş ve çoraba ne gerek var ki diye düşünmüş. Fakat fayansa bastığında ayağı üşümüş. Mert'in ayağının halıda ve fayansta farklı sıcaklık hissetmesinin nedeni ne olabilir? Bilimsel olarak açıklayınız.

Not: Aynı ortamda bulunan nesnelerin sıcaklığı aynıdır.

5- Mert ailesi kamp yapmak için ormana gider. Ateş yakmak için kuru odun toplarlar. Tam ateşi yakacakken kibrit ya da çakmak almayı unuttuklarını fark ederler. Mert'in babasının aklına bir yöntem gelir ve iki parça odunu bir süre birbirine sürterek yanmalarını sağlar. Odunların yanmasını sağlayan olay ne olabilir? Bilimsel olarak açıklayınız.

6- Mert, sıcak yaz günlerinde buz gibi meyve suyu içmeyi çok severmiş. Buzdolabına bakmış ama hiç meyve suyu kalmamış. Annesi ona marketten yenilerini alıp getirdiğini söylemiş. Meyve suyu Mert'e biraz ılık gelmiş. Buzluktan bir miktar buz alarak meyve suyuna eklemiş. Ilık meyve suyu ve buz karıştığında karışımın sıcaklığı nasıl değişir? Bu değişikliği bilimsel olarak nasıl açıklarsınız?

7- Mertlere akşam yemeği için misafir gelmiş. Çok kalabalık olduklarından dolayı annesi aynı tür ısıtıcıların üzerinde aynı miktarda iki tencere çorbayı aynı anda pişiriyormuş. Annesine yardım etmek isteyen Mert çorbaları karıştırmak istemiş. Çorba tencerelerinin birinde tahta kaşık diğerinde ise metal kaşık varmış. Mert metal kaşığa dokununca eli yanmış. Fakat tahta kaşığa dokunduğunda eli yanmamış. Sizce Mert metal kaşığa dokunduğunda eli neden yanmıştır? Bilimsel olarak açıklayınız.

Not: Kaşıklar aynı süre boyunca tencerelerde beklemiştir. Metal ve tahta kaşık aynı sıcaklıktadır.

8- Çok soğuk bir kış gününde okula giden Mert'in elleri çok üşümüş. Yanında eldiveni hatta montunun cebi de yokmuş. Ellerini birbirine sürtmüş ve ellerinde sıcaklık hissetmeye başlamış. Sizce sürtünmeden sonra Mert'in elinin sıcaklığı neden artmış olabilir? Bilimsel olarak açıklayınız.

9- Mert'in kardeşi hasta olmuş ve annesi ona ıhlamur çayı hazırlamış. Fakat çay çok sıcak olduğundan kardeşi içememiş ve annesi ıhlamur çayına az bir miktar soğuk su eklemiş ve Mert'in kardeşi çayını içebilmiştir. Sıcak çay ve soğuk su karıştığında ne olur? Karışımın sıcaklık değişimi ile ilgili bilimsel bir açıklama yapınız.

10- Mert ve arkadaşı yeni açılan mahalle parkına oynayamaya gitmiş. Bir süre oynadıktan sonra arkadaşı tahta banka, Mert ise yanındaki plastik banka oturmuş. Mert oturduğunda bank, ona soğuk gelmiş. Arkadaşı çağırınca onun yanına gitmiş ve tahta banka oturmuş ama tahta bankın soğuk olmadığına çok şaşırmış. Sizce, aynı ortamda olmasına rağmen plastik ve tahta bank neden farklı hissettirmiştir? Bilimsel olarak açıklayınız.

Not: Aynı ortamda bulunan nesnelerin sıcaklığı aynıdır.

APPENDIX D

KNOWLEDGE INTEGRATION SCALE FOR HEAT AND TEMPERATURE

HEAT AND TEMPERATURE SCALE

Dear Students,

This scale has been developed in order to specify your knowledge about "Heat and Temperature". For his reason, it is crucial that you share your actual thoughts and knowledge with us.

- Please do not leave any question empty.
- Please read every item carefully and write your answer in detail.
- Please write only your own opinions.
- You have 45 minutes to complete the scale.

Name- Surname:
School Number:

1- In your opinion, is heat and temperature the same? Why? Please explain.

2- On a very cold winter day, Mert who has watched cartoons for hours, feels cold. He asks his mum to check the central heating boiler. His mother finds out that the reason for Mert's feeling cold is not because of the central heating boiler due to inaction. She tells him to do some exercise a bit. Mert does exercise by walking, jumping, and moving his hands and arms and then he realizes that he doesn't feel cold anymore and his body temperature has increased. Why has the temperature of Mert's body increased? Please explain.

3- On a very cold day, the central heating boiler of Mert's house breaks down. When Mert gets home from the school, he realizes that his room is very cold. His mum turns on the electric heater. Mert reaches out his hands toward the electric heater to warm up. He doesn't pull off his coat since the room has not warmed up yet. After a while, Mert thinks that he is warm and pulls off his coat. How does the room temperature change after the electric heater is turned on? Please explain.

4- Mert's entire home is covered with tiles. One day, Mert's mum picks up carpets of living room in order to clean and warns Mert not to walk in the living room without putting on socks or slippers. However, Mert doesn't obey his mother's advice and he walks barefooted in the living room while he is playing. Afterwards, Mert continues to play on the carpet when his mum brings the carpet back. What can be the reason for Mert's feet detecting different temperatures on the carpet and on the tile? Please explain.

5- Mert goes camping with his family. They collect dry wooden to make a fire but they realize they have forgotten a match or lighter. Mert's father thinks of rubbing two pieces of wooden and makes a fire. Mert is very surprised by the situation. According to you, what can be the scientific incident causes the wood to burning? Please explain it.

6- Mert loves drinking cold fruit juice on hot summer days. He looks in the fridge; but there is not any fruit juice. His mum says to Mert that she has brought new ones from the supermarket. Mert thinks that the new fruit juice is warm. He takes some ice from the icebox and adds it into the fruit juice. How does the temperature of the mixture change when the fruit juice and ice mix? How do you explain the change scientifically?

7- Mert's family has guests for dinner. Because they are too crowded, Mert's mum is cooking the same amount of soup in different cooking pots on the same kind of heaters at the same time. Mert wants to help his mum and wants to stir the soup. There is a wooden spoon in one of the cooking pots and there is a metal spoon in the other cooking pot. When Mert touches the metal spoon, his hand gets burnt. However, his hand doesn't get burnt when he touches the wooden spoon. According to you, why does his hand gets burnt when Mert touches the metal spoon? Please explain.

Note: Both spoons stay in cooking pots for the same length of time. Metal and wooden spoons are at the same temperature.

8- On a very cold winter day, Mert's hands are very cold in the way of school. He doesn't have his gloves with him and his coat also doesn't have any pockets. He rubs his hands and begins to feel warmth in his hands. In your opinion, what may be the reason that the warmth of Mert's hands has increased after rubbing? Please explain.

9- Mert’s younger sister gets ill and his mother prepares linden tea for her. But, his sister can’t drink the tea because it is too hot. Then, his mum adds a little cold water into the linden tea and his sister can drink the tea. What happens when hot tea and cold water mix? Please make a scientific explanation regarding the temperature change of the mixture.

10- Mert goes to the newly opened neighborhood park to play. While he slides down the plastic slide with his friends, he gets tired and sits on a wooden bench to have a rest. When Mert sits on the bench, he realizes that wooden bench is not cold. After he rests, he sits on the plastic slide. But, the plastic slide is cold. In your opinion, why do the plastic slide and the wooden bench make different feel even though they are in the same environment? Please explain.

Note: The temperature of the objects at the same environment is the same.

APPENDIX E

KNOWLEDGE INTEGRATION RUBRICS FOR EACH ITEM

IN HEAT AND TEMPERATURE KI SCALE (TURKISH)

SORU 1 – Sizce ısı ile sıcaklık aynı şey midir? Neden?

Ana fikirler

- Sıcaklığı yüksek olan maddeden sıcaklığı düşük olan maddeye akan enerjiye ısı enerjisi denir. Isı, maddenin yapısındaki enerjiler toplamıdır.
- Isının etkisi ile maddede ya da ortamda meydana gelen enerji değişiminin ölçümü ya da maddenin yapısındaki taneciklerin enerjisinin ortalama hızı/ölçüsüne ise sıcaklık denir.
- Ölçümleri farklı araçlarla yapılır.

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Isı ve sıcaklık aynıdır. Isı ve sıcaklık farklıdır. (Konu dışı bağlantılar)
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir	Isı ve sıcaklık farklıdır. Isı enerjidir, sıcaklık değildir. Isı ve sıcaklık farklıdır. Sıcaklık termometre ile ölçülür isi ise kalorimetre ile.
4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir	Sıcaklığı yüksek olan maddeden sıcaklığı düşük olan maddeye akan enerjiye ısı enerjisi denir. Isının etkisi ile maddede ya da ortamda meydana gelen enerji değişiminin ölçümüne ise sıcaklık denir.

			Isı bir enerjidir, sıcaklık onun ölçümüdür.
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Sıcaklığı yüksek olan maddeden sıcaklığı düşük olan maddeye akan enerjiye ısı enerjisi denir. Isı, maddenin yapısındaki enerjiler toplamıdır. Isının etkisi ile maddede ya da ortamda meydana gelen enerji değişiminin ölçümü ya da maddenin yapısındaki taneciklerin enerjisinin ortalama hızı/ölçüsü ise sıcaklık denir. Isı kalorimetre ile ölçülürken sıcaklık termometre ile ölçülür.

SORU 2 – AK 1: Isı, bir enerji biçimi olarak değil madde olarak görülüyor.

Çok soğuk bir kış gününde evde saatlerce çizgi film izleyen Mert üşümüştür. Kombiyi kontrol etmesi için annesine ricada bulunur. Ama annesi üşümesinin sebebinin kombi değil hareketsizlik olduğunu anlar ve ona biraz hareket etmesini söyler. Mert biraz yürüyerek, zıplayarak, elini kolunu sallayarak hareket eder ve artık üşümediğini, vücut sıcaklığının arttığını fark eder. Mert'in vücut sıcaklığı neden artmış olabilir? Açıklayınız.

Ana fikirler

- Yürümek, koşmak, egzersiz gibi bazı hareketler sonucunda ısı enerjisi açığa çıkabilir.
- Isınan maddelerin sıcaklıkları artar.
- Isı enerjisi artan maddelerin sıcaklıkları artar.

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Mert'in vücudu soğuktur. Mert üşümüştür.
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir	Zıplayınca, yürüyünce, hareket edince Mert'in vücudu ısınmıştır. Hareket edince kan dolaşımı hızlanır ve ısı açığa çıkar.

4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir	Zıplama ve yürüme hareketinden kaynaklı enerji, ısı enerjisine dönüşmüştür. Hareket edince kan dolaşımı hızlanır böylece hareket enerjisi isi enerjisine dönüşmüş olur.
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Zıplama ve yürüme gibi hareketlerden kaynaklı enerji ısı enerjisine dönüşmüştür. Böylece Mert'in vücudu ısınmıştır, ısınma sonucunda vücut sıcaklığı artmıştır. Hareket edince kan dolaşımı hızlanır böylece hareket enerjisi isi enerjisine dönüşür ve sonuç olarak ısınan cisimlerin sıcaklıkları artar.

SORU 3 – AK 3: Isı ve sıcaklığı ayırt edemiyorlar.

Havanın çok soğuk olduğu bir gün Mertlerin evinin kombisi bozulmuş. Mert okuldan eve döndüğünde odasının çok soğuk olduğunu görmüş. Annesi, elektrikli sobayı yakmış. Mert, ısınmak için ellerini sobaya uzatmış. Henüz oda ısınmadığı için montunu bile çıkarmamış. Mert bir süre sonra ısındığını düşünmüş ve montunu çıkarmış. Sobayı yaktıktan sonra odanın sıcaklığı nasıl değişmiştir? Açıklayınız.

Ana fikirler

- Isı alışverişi, sıcaklığı yüksek olan maddeden soğuk olan maddeye doğru olur.
- Sobadan havaya doğru ısı akışı olur.

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Oda soğuktur. Soba sıcaktır.
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir	Kombi çalışmadığı için oda soğuktur. Elektrikli soba yanınca oda

			ısınmıştır.
4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir	Isı alışverişi, sıcaklığı yüksek olan maddeden sıcaklığı düşük olana doğru olduğundan elektrikli soba yanınca oda ısınmıştır. Odanın ısısı artığından sıcaklığı da artmıştır.
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Isı alışverişi, sıcaklığı yüksek olan maddeden sıcaklığı düşük olana doğru olduğundan elektrikli soba yanınca oda ısınmıştır. Odanın ısısı artığından sıcaklığı da artmıştır. Soba ile oda arasında olan ısı alışverişi her ikisinin de son sıcaklıkları eşit oluncaya kadar devam eder. Bu yüzden Mert ilk başta montunu çıkarmamış.

SORU 4 – AK 2: Sıcaklık ve sıcaklık hissi arasındaki fark anlaşılmıyor. (Isı aktarma hızı)

Mertlerin tüm evi fayansla kaplıdır. Bir gün Mert'in annesi salondaki halıları temizlemek için kaldırmış ve çorap veya terlik giymeden salonda gezinmemesi konusunda Mert'i uyarmış. Fakat Mert annesinin sözünü dinlemeyip oyun oynarken salonda yalın ayak gezinmiştir. Daha sonra annesi halıyı getirince Mert halının üzerinde oyun oynamaya devam etmiştir. Mert'in ayağının halıda ve fayansta farklı sıcaklık hissetmesinin nedeni ne olabilir? Açıklayınız.

Not: Aynı ortamda bulunan nesnelerin sıcaklığı aynıdır.

Ana fikirler

- Fayans, halıya oranla ayak ısısını daha hızlı alır.
- Fayans ve halının sıcaklığı aynı olmasına rağmen fayans daha soğuk hissettirir.
- Isısı azalan cisimlerin sıcaklıkları düşeceğinden soğuk hissettirir

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***

0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Fayans soğuktur. Fayans halıdan daha soğuktur. Halı sıcaktır. Fayans ve halı farklı maddelerden yapılmıştır.
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir (Fayans ve halı arasında karşılaştırma –farklı cisimlerin iletimi-yok)	Fayans ısıyı daha iyi aktarır./ Fayans daha iyi bir iletkendir. Fayans ayaktaki ısıyı hızlı alır.
4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir (İki cismi karşılattırır ya da nasıl hissettirdikleri hakkında yorum yapar)	Fayans ve halı aynı sıcaklıkta olmasına rağmen ayaktan fayansa daha hızlı ısı aktarılır. Fayans halıya göre daha hızlı ısıyı alır.
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Fayans ve halı aynı sıcaklıkta olmasına rağmen ayaktan fayansa daha hızlı ısı aktarıldığı için ayak hızla ısı kaybeder. Ayak, ısı kaybettiği (Isı enerjisi azalan cisimlerin sıcaklığı azaldığı) için sıcaklığı azalır ve böylece soğuk hissettirir.

SORU 5 – AK 1: Isı, bir enerji biçimi olarak değil madde olarak görülüyor.

Mert ailesi kamp yapmak için ormana gider. Ateş yakmak için kuru odun toplarlar. Tam ateşi yakacakken kibrit ya da çakmak almayı unuttuklarını fark ederler. Ama babasının aklına bir yöntem gelir. İki parça odunu bir süre birbirine sürterek yanmalarını sağlar. Odunların yanmasını sağlayan olay bilimsel olarak ne olabilir? Açıklayınız.

Ana fikirler

- Sürtünme gibi bazı hareketler ile ısı enerjisi açığa çıkabilir.
- Isınan maddelerin sıcaklıkları artar.
- Isı enerjisi artan maddelerin sıcaklıkları artar.

Puan	*Bilgi Birleştirme Seviyesi*	*Açıklama*	*Öğrenci Cevabı Detayı*
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Sürtünmeyle odun yanar.
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir	Sürtünme hareketiyle odunlar yanar.
4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir	Sürtünme hareketinden kaynaklı enerji, ısı enerjisine dönüşmüştür. Enerjisi artan odunlar yanmıştır. Sürtünme hareketinden kaynaklı enerji, ısı enerjisine dönüşmüştür. Enerjisi artan odun yanmıştır.
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Odunlar birbirine sürtünme hareketten kaynaklı enerji, ısı enerjisine dönüşmüştür. Isı enerjisi artan odunların sıcaklığı da artmıştır ve bu nedenle odunlar yanmıştır.

SORU 6 - AK 3: Isı ve sıcaklığı ayırt edemiyorlar.

Mert, sıcak yaz günlerinde buz gibi meyve suyu içmeyi çok severmiş. Buzdolabına bakmış ama hiç meyve suyu kalmamış. Annesi ona marketten yenilerini alıp getirdiğini söylemiş. Meyve suyu Mert'e biraz ılık gelmiş. Buzluktan bir miktar buz alarak meyve suyuna eklemiş. Ilık meyve suyu ve buz karıştığında karışımın sıcaklığı nasıl değişir? Bu değişikliği bilimsel olarak nasıl açıklarsınız?

Ana fikirler

- Isı alışverişi, sıcaklığı yüksek olan maddeden soğuk olan maddeye doğru olur.
- Meyve suyundan buza doğru ısı akışı olur.

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Meyve suyu ılıktır. Buz soğuktur.
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir	Ilık meyve suyuna buz eklenince meyve suyu soğumuştur.
4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir	Ilık meyve suyundan buza doğru ısı akışı olur. Çünkü ısı akışı, sıcak maddeden soğuk maddeye doğru olur.
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Isı alışverişi, sıcaklığı yüksek olan maddeden soğuk olan maddeye doğru olduğundan ılık meyve suyundan buza doğru ısı akışı olur. Meyve suyu ve buzun sıcaklığı aynı oluncaya kadar ısı alışverişi devam eder.

SORU 7 – AK 2: Sıcaklık ve sıcaklık hissi arasındaki fark anlaşılmıyor. (Isı aktarma hızı)

Mertlere akşam yemeği için misafir gelmiş. Çok kalabalık olduklarından dolayı annesi aynı tür ısıtıcıların üzerinde aynı miktarda iki tencere çorbayı aynı anda pişiriyormuş. Annesine yardım etmek isteyen Mert çorbaları karıştırmak istemiş. Çorba tencerelerinin birinde tahta kaşık diğerinde ise metal kaşık varmış. Mert metal kaşığa dokununca eli yanmış. Fakat tahta kaşığa dokunduğunda eli yanmamış. Sizce Mert metal kaşığa dokunduğunda eli neden yanmıştır? Açıklayınız.

Not: Kaşıklar aynı süre boyunca tencerelerde beklemiştir. Metal ve tahta kaşık aynı sıcaklıktadır.

Ana fikirler

- Metal kaşık, tahtaya oranla ısısını ele doğru daha hızlı aktarır.
- Metal ve tahtanın sıcaklığı aynı olmasına rağmen metal kaşık daha sıcak hissettirir. Isısı azalan cisimlerin sıcaklıkları düşeceğinden soğuk hissettirir.

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Tahta ılıktır. Metal kaşık tahta kaşıktan daha sıcaktır. Metal sıcaktır.
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir (Karşılaştırma yok)	Metal kaşık, ısıyı iyi iletir. Metal kaşık, ısıyı ele iyi iletir. Tahta ısıyı iyi iletmez. Metal iyi bir iletkendir.
4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir (Cisimleri karşılaştırma var ya da nasıl hissettirdikleri ve sıcaklıkları arasındaki farkı açıklar.)	Metal ve tahta kaşık aynı sıcaklıkta olmasına rağmen metal olan ısıyı ele daha iyi/hızlı ilettiğinden metal kaşık hemen ısı kaybeder, el ise hemen ısı alır ve yanma hisseder. Metal daha sıcak hissettirir çünkü metal ısıyı tahtaya göre daha iyi iletir
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir (Cisimleri karşılaştırma var ve nasıl hissettirdikleri ve sıcaklıkları arasındaki farkı açıklar)	Metal ve tahta kaşık aynı sıcaklıkta olmasına rağmen metal olan ısıyı ele daha iyi/hızlı ilettiğinden metal kaşık hemen ısı kaybeder, el ise hemen ısı alır ve yanma

			hisseder. Elin ısı enerjisi arttığı için sıcaklığı artar ve tahta kaşığa göre metal kaşığı daha sıcak hisseder. Metal isi enerjisini daha iyi iletir. Bu nedenle Metale dokunulduğunda daha sıcak hissettirir.

SORU 8 – AK 1: Isı, bir enerji biçimi olarak değil madde olarak görülüyor.

Çok soğuk bir kış gününde okula giden Mert'in elleri çok üşümüş. Yanında eldiveni hatta montunun cebi de yokmuş. Ellerini birbirine sürtmüş ve ellerinde sıcaklık hissetmeye başlamış. Sizce sürtünmeden sonra Mert'in elinin sıcaklığı neden artmış olabilir? Açıklayınız.

Ana fikirler

- Sürtünme gibi bazı hareketler ile ısı enerjisi açığa çıkabilir.
- Isınan maddelerin sıcaklıkları artar.
- Isı enerjisi artan maddelerin sıcaklıkları artar.

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Mert'in elleri soğuktur. Mert'in ellerinde ısı yoktur. Mert'in ellerindeki ısı soğuk havaya geçmiştir.
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir	Sürtününce Mert'in elleri ısınmıştır.

4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir	Sürtünme hareketinden kaynaklı enerji ısı enerjisine dönüşmüştür. Böylece Mert'in elleri ısınmıştır.
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Sürtünme gibi hareketlerden kaynaklı enerji ısı enerjisine dönüşmüştür. Böylece Mert'in elleri ısınmıştır. Isınma sonucunda Mert'in ellerinin sıcaklığı artmıştır.

SORU 9– AK 3: Isı ve sıcaklığı ayırt edemiyorlar.

Mert'in kardeşi hasta olmuş ve annesi ona ıhlamur çayı hazırlamış. Fakat çay çok sıcak olduğundan kardeşi içememiş ve annesi ıhlamur çayına az bir miktar soğuk su eklemiş ve Mert'in kardeşi çayını içebilmiştir. Sıcak çay ve soğuk su karıştığında ne olur? Karışımın sıcaklık değişimi ile ilgili bilimsel bir açıklama yapabilir misiniz?

Ana fikirler

- Isı alışverişi, sıcaklığı yüksek olan maddeden sıcaklığı düşük olan maddeye doğru olur.
- Sıcak maddelerden soğuk maddelere ısı akışı olur (Çaydan suya doğru).

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Çay sıcaktır. Su soğuktur.
3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir	Sıcak ıhlamur çayına soğuk su eklenince çay ılımıştır.
4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve	Sıcak ıhlamur çayından soğuk suya doğru ısı akışı olur.

		ayrıntılı bağlantı bulunan fikir	
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Isı alışverişi, sıcaklığı yüksek olan maddeden sıcaklığı düşük olan maddeye doğru olduğundan çaydan suya doğru ısı akışı olur. Çay ve suyun sıcaklığı aynı oluncaya kadar ısı alışverişi devam eder.

SORU 10 – AK 2: Sıcaklık ve sıcaklık hissi arasındaki fark anlaşılmıyor. (Isı aktarma hızı)

Mert, yeni açılan mahalle parkına oynayamaya gitmiş. Arkadaşlarıyla plastik kaydıraktan kayarken yorulmuş ve dinlenmek için tahta banka oturmuş. Banka oturduğunda Mert, tahta bankın soğuk olmadığını fark etmiş. Dinlendikten sonra, plastik kaydırağa oturmuş. Ama plastik kaydırak soğukmuş. Sizce, aynı ortamda olmasına rağmen plastik kaydırak ve tahta bank neden farklı hissettirmiştir? Açıklayınız.

Not: Aynı ortamda bulunan nesnelerin sıcaklığı aynıdır.

Ana fikirler

- Plastik kaydırak, tahta banka oranla vücut ısısını daha iyi alır.
- Plastik ve tahtanın sıcaklığı aynı olmasına rağmen plastik ısıyı daha iyi aktardığından daha soğuk hissettirir.

Puan	***Bilgi Birleştirme Seviyesi***	***Açıklama***	***Öğrenci Cevabı Detayı***
0	Cevap yok		
1	Konu dışı		Bilmiyorum. Fikrim yok. Çünkü ben öyle düşünüyorum.
2	Bağlantı yok	İdeal olmayan ya da bilimsel olarak geçersiz bağlantı veya fikir	Tahta ılıktır. Plastik kaydırak, tahta banktan daha soğuktur. Plastik kaydırak soğuktur. Plastik kaydırak ve tahta bank farklı maddelerden yapılmıştır.

3	Kısmi Bağlantı	İdeale yakın ama aralarında bilimsel olarak geçersiz bağlantı bulunan fikir	Plastik kaydırak, ısıyı daha iyi iletir. Plastik kaydırak, ısıyı ele iyi iletir.
4	Tam Bağlantı	İdeale yakın ve aralarında bir tane bilimsel olarak geçerli ve ayrıntılı bağlantı bulunan fikir	Plastik ve tahtanın sıcaklığı aynı olmasına rağmen plastiğin ısı alışverişi/iletimi daha iyi olduğundan plastik vücut ısısını daha hızlı alır ve vücut soğuk hisseder.
5	Karmaşık Bağlantı	İki tane bilimsel olarak geçerli bağlantı içeren fikir	Plastik ve tahtanın sıcaklığı aynı olmasına rağmen plastiğin ısı alışverişi daha iyi olduğundan plastik daha hızlı vücut ısısını alır. Vücudun ısı enerjisi azaldığı için sıcaklığı azalır ve tahta banka göre plastik kaydırağı daha soğuk hisseder.

APPENDIX F

KNOWLEDGE INTEGRATION RUBRICS FOR EACH ITEM

IN HEAT AND TEMPERATURE KI SCALE

QUESTION 1 – In your opinion, is heat and temperature the same? Why?

Main Ideas

- The energy flowing from the material that has high temperature to the material that has low temperature is called heat energy. Heat is the accumulation of energies being in the structure of the material.
- The measurement of energy change that occurs in the material or in the environment with the effect of heat or average velocity/ measurement of energy of the particles in the structure of materials is called temperature.
- Their measurements are made with different tools.

Score	*Knowledge Integration Level*	*Description*	*Detailed Student Answer*
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don’t have any idea. Because I think so.
2	No link	Non-normative or scientifically invalid links and ideas	Heat and temperature is the same. Heat and temperature are different. (Irrelevant links)
3	Partial Link	Normative ideas without scientifically valid connections between ideas	Heat and temperature are different. Heat is a kind of energy, temperature is not. Heat and temperature are different. Temperature is measured with thermometer; but heat is measured with calorimeter.
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	The energy flowing from the material that has high temperature to the material that has low temperature is called heat energy. Heat is the accumulation of energies being in the structure of the material.

			Heat is a kind of energy; temperature is the measurement of it.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	The energy flowing from the material that has high temperature to the material that has low temperature is called heat energy. Heat is the accumulation of energies being in the structure of the material. The measurement of energy change that occurs in the material or in the environment with the effect of heat or average velocity/ measurement of energy of the particles in the structure of materials is called temperature. While heat is measured with calorimeter, temperature is measured with thermometer.

QUESTION 2 – AC 1: Heat is a kind of substance, not a form of energy.

On a very cold winter day, Mert who has watched cartoons for hours, feels cold. He asks his mum to check the central heating boiler. His mother finds out that the reason for Mert's feeling cold is not because of the central heating boiler due to inaction. She tells him to do some exercise a bit. Mert does exercise by walking, jumping, and moving his hands and arms and then he realizes that he doesn't feel cold anymore and his body temperature has increased. Why has the temperature of Mert's body increased? Please explain.

Main Ideas

- Heat energy can come out as a result of some movements such as walking, running, and exercise.
- The temperature of the materials getting warmer increases.
- The temperature of the materials of which heat energy increases goes up.

Score	***KI Level***	***Description***	***Detailed Student Answer***
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don't have any idea. Because I think so.

2	No link	Non-normative or scientifically invalid links and ideas	Mert's body is cold. Mert feels cold.
3	Partial Link	Normative ideas without scientifically valid connections between ideas	Mert's body gets warmer when he jumps, walks, and exercises/moves. As you move, blood circulation speeds up and heat comes out.
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	The energy arising from jumping and walking movements turns into heat energy. As you move, blood circulation speeds up; thus motional energy turns into heat energy.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	The energy arising from movements like jumping and walking turns into heat energy. So as Mert's body gets warmer, body temperature increases as a result of warming. As you move, blood circulation speeds up; thus motional energy turns into heat energy and consequently the temperature of the objects that get warmer increases.

QUESTION 3 – AC 3: Inability to differentiate heat and temperature

On a very cold day, the central heating boiler of Mert's house breaks down. When Mert gets home from the school, he realizes that his room is very cold. His mum turns on the electric heater. Mert reaches out his hands toward the electric heater to warm up. He doesn't pull off his coat since the room has not warmed up yet. After a while, Mert thinks that he is warm and pulls off his coat. How does the room temperature change after the electric heater is turned on? Please explain.

Main Ideas

- Heat exchange occurs from the material that has high temperature to the cold material.
- Heat flow occurs from the heater to the air.

Score	***Knowledge Integration Level***	***Description***	***Detailed Student Answer***
0	No answer	Blank responses	

1	Irrelevant	Off-task or incorrect responses	I don't know. I don’t have any idea. Because I think so.
2	No Link	Non-normative or scientifically invalid links and ideas	The room is cold. The heater is hot.
3	Partial Link	Normative ideas without scientifically valid connections between ideas	The room is cold since the central heating boiler is not working. When the electric heater is on, the room gets warmer.
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	Because heat exchange occurs from the material that has high temperature to the one that has low temperature, the room gets warmer when the electric heater is on. Since the heat of the room increases, its temperature increases too.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	Because heat exchange occurs from the material that has high temperature to the one that has low temperature, the room gets warmer when the electric heater is on. Since the heat of the room increases, its temperature increases too. The heat exchange between the heater and the room continues until ultimate temperature of both becomes equal. So Mert doesn’t take off his coat at the beginning.

QUESTION 4 – AC 2: Confusion between temperature and sensation of an object

Mert’s entire home is covered with tiles. One day, Mert’s mum picks up carpets of living room in order to clean and warns Mert not to walk in the living room without putting on socks or slippers. However, Mert doesn’t obey his mother’s advice and he walks barefooted in the living room while he is playing. Afterwards, Mert continues to play on the carpet when his mum brings the carpet back. What can be the reason for Mert’s feet detecting different temperatures on the carpet and on the tile? Please explain.

Main Ideas

- A tile conducts the heat of foot faster than a carpet.
- Although the temperature of the tile and the carpet is the same, the tile makes feel colder.
- Because the temperature of the objects of which heat decreases would go down, it makes feel colder.

Score	*Knowledge Integration Level*	*Description*	*Detailed Student Answer*
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don't have any idea. Because I think so.
2	No Link	Non-normative or scientifically invalid links and ideas	The tile is cold. The tile is colder than the carpet. The tile is hot. The tile and the carpet are made out of different materials.
3	Partial Link	Normative ideas without scientifically valid connections between ideas	The tile transfers heat better. / The tile is a better conductive. The tile takes the heat of foot quickly.
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	Although the tile and the carpet is at the same temperature, heat is transferred from the foot to the tile faster. The tile takes heat faster than the carpet.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	Although the tile and the carpet are at the same temperature, the foot loses heat quickly because heat is transferred from the foot to the tile faster. Because the foot loses heat (The temperature of the objects of which heat energy decreases, goes down), its temperature decreases, so it makes feel cold.

QUESTION 5 – AC 1: Heat is a kind of substance, not a form of energy.

Mert goes camping with his family. They collect dry wooden to make a fire but they realize they have forgotten a match or lighter. Mert's father thinks of rubbing two pieces of wooden and makes a fire. Mert is very surprised by the situation. According to you, what can be the scientific incident causes the wood to burning? Please explain it.

Main Ideas

- Heat energy can comes out with some actions like friction.
- The temperature of the materials that get heated increases.
- The temperature of the materials of which heat energy increases, goes up.

Score	***Knowledge Integration Level***	***Description***	***Detailed Student Answer***
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don't have any idea. Because I think so.
2	No Link	Non-normative or scientifically invalid links and ideas	The wood burns with friction.
3	Partial Link	Normative ideas without scientifically valid connections between ideas	Woods burn with friction movement.
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	The energy arising from friction movement turns into heat energy. Woods, which energy increases, burn. The energy arising from friction movement turns into heat energy. Woods, which energy increases, burn.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	The energy arising from friction movement of woods turns into heat energy. The temperature of woods of which heat energy increases, goes up too; thus woods burn.

QUESTION 6 - AC 3: Inability to differentiate heat and temperature

Mert loves drinking cold fruit juice on hot summer days. He looks in the fridge; but there is not any fruit juice. His mum says to Mert that she has brought new ones from the supermarket. Mert thinks that the new fruit juice is warm. He takes some ice from the icebox and adds it into the fruit juice. How does the temperature of the mixture change when the fruit juice and ice mix? How do you explain the change scientifically?

Main Ideas

- Heat exchange occurs from the material that has high temperature to the cold material.
- Heat exchange occurs from the fruit juice to ice.

Score	***Knowledge Integration Level***	***Description***	***Detailed Student Answer***
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don’t have any idea. Because I think so.
2	No Link	Non-normative or scientifically invalid links and ideas	The fruit juice is warm. The ice is cold.
3	Partial Link	Normative ideas without scientifically valid connections between ideas	When ice is added into the warm fruit juice, the fruit juice becomes cold.
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	Heat flow occurs from the warm fruit juice to the ice. Because heat flow occurs from hot materials to cold materials.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	Since heat exchange occurs from the material that has high temperature to the cold material, heat flow occurs from the warm fruit juice to the ice. Until the temperature of fruit juice and ice becomes the same, heat exchange continues.

QUESTION 7 – AC 2: Confusion between temperature and sensation of an object

Mert's family has guests for dinner. Because they are too crowded, Mert's mum is cooking the same amount of soup in different cooking pots on the same kind of heaters at the same time. Mert wants to help his mum and wants to stir the soup. There is a wooden spoon in one of the cooking pots and there is a metal spoon in the other cooking pot. When Mert touches the metal spoon, his hand gets burnt. However, his hand doesn't get burnt when he touches the wooden spoon. According to you, why does his hand gets burnt when Mert touches the metal spoon? Please explain.

Note: Both spoons stay in cooking pots for the same length of time. Metal and wooden spoons are at the same temperature.

Main Ideas

- Metal spoon transfers its heat towards the hand faster than wooden one.
- Although the temperature of the metal and the wood is the same, metal spoon makes feel hotter. Because the temperature of the objects of which heat decreases, goes down; it makes feel cold.

Score	***Knowledge Integration Level***	***Description***	***Detailed Student Answer***
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don't have any idea. Because I think so.
2	No Link	Non-normative or scientifically invalid links and ideas	The wood is warm. Metal spoon is hotter than wooden spoon. Metal is hot.
3	Partial Link	Normative ideas without scientifically valid connections between ideas	Metal spoon transfers heat well. Metal spoon transfers heat to the hand well. The wood does not transfer heat well. Metal is a good conductive.
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	Although the temperature of the metal and the wood is the same, metal spoon conducts heat better and loses its energy

			faster. So hands feel hotter as touching metal spoon.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	Although the temperature of the metal and the wood is the same, metal spoon conducts heat better and loses its energy faster. So hands feel hotter as touching metal spoon. Since heat of hands increased, the temperature increased as well and hands feel hotter. Metal conducts heat better. That's why it makes feel hotter.

QUESTION 8 – AC 1: Heat is a kind of substance, not a form of energy.

On a very cold winter day, Mert's hands are very cold in the way of school. He doesn't have his gloves with him and his coat also doesn't have any pockets. He rubs his hands and begins to feel warmth in his hands. In your opinion, what may be the reason that the warmth of Mert's hands has increased after rubbing? Please explain.

Main ideas

- Heat energy can come out as a result of some movements such as rubbing.
- The temperature of the materials heated increases.
- The temperature of the materials of which heat energy increases goes up.

Score	***Knowledge Integration Level***	***Description***	***Detailed Student Answer***
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don't have any idea. Because I think so.
2	No Link	Non-normative or scientifically invalid links and ideas	Mert's hands are cold. There is no heat in Mert's hands. Heat of Mert's hands goes to the weather.
3	Partial Link	Normative ideas without scientifically valid connections	Rubbing makes Mert's hands warm.

		between ideas	
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	Heat energy can come out as a result of some movements such as rubbing. So Mert's hands get heated.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	Heat energy can come out as a result of some movements such as rubbing. So Mert's hands get heated. This means, the temperature of the hands increased as well.

QUESTION 9– AC 3: Inability to differentiate heat and temperature

Mert's younger sister gets ill and his mother prepares linden tea for her. But, his sister can't drink the tea because it is too hot. Then, his mum adds a little cold water into the linden tea and his sister can drink the tea. What happens when hot tea and cold water mix? Please make a scientific explanation regarding the temperature change of the mixture.

Main ideas

- The heat energy was transferred from the material that has high temperature to the material that has low temperature.
- Heat flows from hot materials to cold materials (From tea to water).

Score	***Knowledge Integration Level***	***Description***	***Detailed Student Answer***
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don't have any idea. Because I think so.
2	No Link	Non-normative or scientifically invalid links and ideas	Tea is hot. Water is cold.
3	Partial Link	Normative ideas without scientifically valid connections	Linden tea becomes warm when cold water added.

		between ideas	
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	Heat flows from hot linden tea to cold water.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	Heat flows from hot linden tea to cold water since the heat energy was transferred from the material that has high temperature to the material that has low temperature. Heat transfer continues until they reach same temperature.

QUESTION 10 – AC2: Confusion between temperature and sensation of an object

Mert goes to the newly opened neighborhood park to play. While he slides down the plastic slide with his friends, he gets tired and sits on a wooden bench to have a rest. When Mert sits on the bench, he realizes that wooden bench is not cold. After he rests, he sits on the plastic slide. But, the plastic slide is cold. In your opinion, why do the plastic slide and the wooden bench make different feel even though they are in the same environment? Please explain.

Note: The temperature of the objects at the same environment is the same.

Main Ideas

- Plastic slide conducts heat from the body better than wooden bench.
- Plastic slide makes feel colder since it conducts heat energy better although plastic and wooden have the temperature.

Score	***Knowledge Integration Level***	***Description***	***Detailed Student Answer***
0	No answer	Blank responses	
1	Irrelevant	Off-task or incorrect responses	I don't know. I don’t have any idea. Because I think so.

2	No Link	Non-normative or scientifically invalid links and ideas	Wooden is warm Plastic slide is colder than wooden bench. Plastic slide is cold. Plastic slide and wooden bench produced from different materials.
3	Partial Link	Normative ideas without scientifically valid connections between ideas	Plastic slide conducts heat better. Plastic slide conducts heat to hands better.
4	Full Link	One scientifically valid and elaborated link between normative and relevant energy ideas	The body feels cold since it quickly gives its heat energy to the plastic and plastic conducts heat better although plastic and wooden have the temperature.
5	Complex Link	Two or more scientifically valid links between normative and relevant ideas	The body quickly gives its heat energy to the plastic and plastic conducts heat better although plastic and wooden have the temperature. Its temperature decreased since its heat energy decreased and feels colder plastic slide comparing to wooden bench.

APPENDIX G

THE DETAILS OF SAMPLE STUDENTS' WISE LOGS

Steps	Ideas	Ekin	Ada	Nehir
Act. 1 Step 10 Q 1	First	Heat symbols of brick is increasing and decreasing when we heat or cool it. This happens because of heat exchange.	Brick spreads its energy to room when it's heated; it gives its energy back to heater when it's cooled.	Temperature of all is different if it is measured.
	Revised	-	-	Yes. Iron, brick and water are in mine.
	Improvement	Already scientifically valid ideas and links	Relevant ideas but no scientifically valid links	No scientifically valid ideas and links
Act 1 Step 13 Q 1	First	Energy is a kind of power created by something like heat and light. Mechanical energy, heat and light are the examples of it.	Energy forms another energy transformed by heat or other energy sources. This makes easy our lives. For example, creating electricity with wind.	Energy is electricity. We have energy when we walk.
	Revision	Energy is a kind of power created by something like heat and light. Mechanical energy, heat and light are the examples of it. I mean it is a measure of the ability of something to do work.	-	Energy has many kinds. For example, we have energy when we walk, lie down, sleep, work or do sth. Besides it also means electricity.
	Improvement	Addition of scientific ideas and valid links.	Relevant ideas (on energy transformation) No abstract and valid idea on energy itself	Relevant ideas but not normative and no links

Act 1 Step 13 Q 3	First	I think they are not the same because temperature is the measure of a material; heat is a kind of energy of it.	Not the same because a source of heat keeps environment hot by providing heat. So, there is hotness in this environment.	No, not the same.
	Revision	-	-	Heat is a kind of energy; temperature is also a kind of energy.
	Improvement	Valid ideas but less scientific statements	Relevant ideas (on heat source) No abstract and valid idea and links on heat and temperature	No scientifically valid ideas and links.
Act 2 Step 3	First	Because sand is heated by mechanical energy and the heat of sand increased.	In the jar, vibrations of molecules movement create heat. There is heat exchange and it reflects on the sand.	Because the temperature can be different in each shaking.
	Revision	Because there is mechanical energy. So the heat and temperature of sand increased.	In the jar, vibrations of molecules movement create heat. There is heat exchange and it reflects on the sand. So, mechanical energy transformed to heat energy.	-
	Improvement	Normative ideas but need more solid links.	Addition of scientific ideas and links but not normative statements	Partial understanding, relevant ideas and links, need improvement
Act 3 Step 3	First	Because there is mechanical energy. It creates electricity.	There is heat exchange. It spreads hotness. There is an interaction because of bending. This creates heat and temperature.	-

	Revision	Because there is mechanical energy. It transforms into heat energy.	The mechanical energy of cable creates heat energy. Consequently, its temperature increased.	Because the temperature of the cable increases in each bending.
	Improvement	Scientifically valid ideas and links	Scientifically valid ideas and links	Relevant ideas but not normative ideas and links
Act 4 Step 8	First	Because there is heat exchange; their temperature are different.	There is heat exchange as a result of merging temperatures of hand and water.	When putting in another water.
	Revision	Because the heat of hands changes if its heat energy increased or decreased when we touch hands with different temperature to water with different temperature. This is related to heat exchange.	There is heat exchange as a result of merging temperatures of hand and water because their temperature is different. Therefore, temperature increases if heat energy increased; temperature decreases if heat energy decreased.	Heat changes progressively.
	Improvement	Scientifically valid ideas and links	Scientifically valid ideas and links but need improvements for statements	No scientifically valid ideas, links and statements
Act 5 Step 8	First	This is related to heat conduction. Metal spoon conducts heat but wooden spoon does not.	Metal spoon gets heat from the food. Then it gives its heat energy to the hand and hand’s temperature increased, so its heat energy does not exist anymore. However, there is no change in temperature or heat since wooden does not conduct heat.	Metal spoon burns the hand but wooden spoon do not.

	Revision	This is related to heat conduction. Metal spoon conducts heat but wooden spoon does not conduct as metals do.	Metal spoon conducts heat and gives its energy to the hand. Hand’s temperature increased. Wooden spoon also conducts heat but slowly.	-
	Improvement	Scientifically valid ideas and links	Scientifically valid ideas and links	Scientifically valid ideas and links but need improvements for statements
Act 6 Step 6	First	Because the temperature of each is not the same.	In fact, the temperature becomes high when it is mixed with highest degree temperature. However, temperature decreases if the water is very hot but less because there is heat exchange.	When they are mixed, mixture becomes warm.
	Revision	-		Their temperature changes because their degree changes when hot water and cold water are mixed.
	Improvement	No scientifically valid ideas and links	Relevant ideas but not valid links and statements	Relevant ideas but not valid links and statements

REFERENCES

Akkağıt, Ş. F. (2014). *Benzeşim ve animasyon kullanılan web tabanlı öğretimin dokuzuncu sınıf öğrencilerinin "elektrik ve manyetizma" ünitesindeki başarılarına etkisi* (Unpublished master's thesis). Fırat Üniversitesi, Elazığ, Turkey.

Anıl, Ö. & Batdı, V. (2015). A comparative meta-analysis of 5E and traditional approaches in Turkey. *Journal of Education and Training Studies, 3*(6), 212-219.

Ardaç, D. & Akaygün, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representations on students' understanding of chemical change. *Journal of Research in Science Teaching, 41*(4), 317-337.

Asan, A. (2007). Concept mapping in science class: A case study of fifth grade students. *Educational Technology & Society, 10*(1), 186-195.

Asoko, H. (2002). Developing conceptual understanding in primary science. *Cambridge Journal of Education, 32*(2), 153-164.

Atila, M. E. & Sözbilir, M. (2016). Fen ve teknoloji dersi öğretim programındaki yapılandırmacılığa dayalı öğelerin öğretmenler tarafından uygulanışı: Nitel bir çalışma. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 18*(2), 1418-1457.

Ayvacı, H. Ş., Bakırcı, H., & Başak, M. H. (2014). FATİH projesinin uygulama sürecinde ortaya çıkan sorunların idareciler, öğretmenler ve öğrenciler tarafından değerlendirilmesi. *YYU Journal of Education Faculty, 11*, 20-46.

Bağcı-Kılıç, G. (2002). Dünyada ve Türkiye'de fen öğretimi. *V. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi (63)*, 12-18 Eylül, ODTÜ, Ankara.

Bain, K., Moon, A., Mack, M. R., Towns, M. H. (2014). A review of research on the teaching and learning of thermodynamics at the university level. *Chemistry Education Research Practice, 15*, 320-335.

Balım, A. G., Deniş, H., Evrekli, E., & İnel, D. (2010). Turkey's position in terms of classroom teacher activities according to the PISA 2006 results in comparison to other countries. *Procedia Social and Behavioral Sciences, 2*, 2202-2206.

Bell, R. L., & Banch, H. (2008). The many levels of inquiry. *Science and Children, 46*(2), 26-29.

Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction. *The Science Teacher, 72*(7), 30-33.

Buckner, E. & Kim, P. (2014). Integrating technology and pedagogy for inquiry-based learning: The Stanford Mobile Inquiry-based Learning Environment (SMILE). *Prospects, 44*, 99-118.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins, effectiveness, and applications*, Colorado Springs: BSCS.

Carey, S. (2000). Science education as conceptual change. *Journal of Applied Developmental Psychology, 21*, 13-19.

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

Cengiz, E., Uzoğlu, M., & Daşdemir, İ. (2012). Öğretmenlere göre fen ve teknoloji dersindeki başarısızlık nedenleri ve çözüm önerileri. *Erzincan Üniversitesi Eğitim Fakültesi Dergisi, 14*(2), 393-418.

Chang, H-Y. (2013). Teacher guidance to mediate student inquiry through interactive dynamic visualizations. *Instructional Science, 41*, 895-920.

Chang, H-Y. & Linn, M. C. (2013). Scaffolding learning from molecular visualizations. *Journal of Research in Science Teaching, 50*(7), 858-886.

Chen, C. H., & Bradshaw, A. C. (2007). The effect of web-based question prompts on Scaffolding knowledge integration and ill-structured problem solving. *Journal of Research on Technology in Education, 39*(4), 359–375.

Chi, M. T. H., & Roscoe, R. D. (2002). The processes and challenges of conceptual change. In M. Limon & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 3-27). Dordrecht, the Netherlands: Kluwer Academic.

Chiu, J., & Linn, M. C. (2011). Knowledge integration and WISE engineering. *Journal of Pre-college Engineering Education Research, 1*(1), 1-14.

Chiu, J. L., & Linn, M. C. (2014). Supporting knowledge integration in chemistry with a visualization-enhanced inquiry unit. *Journal of Science Education and Technology, 23*(1), 37-58.

Clark, D. & Linn, M.C. (2003). Designing for knowledge integration: The impact of instructional time. *Journal of the Learning Sciences, 12*(4), 451-493.

Clark, D. B., & Linn, M. C. (2013). The knowledge integration perspective: Connections across research and education. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (2nd ed., pp. 520–538). New York: Routledge.

Clough, E. E., & Driver, R. (1985). Secondary students' conceptions of the conduction of heat: Bringing together scientific and personal views. *The Physical Educator, 20*, 176-182.

Clough, E. E. & Driver, R. (1986). A study of the consistency in the use of students' conceptual frameworks across different task contexts. *Science Education, 70*, 473-496.

Colburn, A. (2000). An inquiry primer. *Science Scope, 23*(6), 42-44.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston: Pearson Education.

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research.* Thousand Oaks, CA: Sage.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. (2003). Advanced mixed methods research designs. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of Mixed Methods in Social and Behavioral Research* (pp. 209-240). Thousand Oaks, CA: Sage.

Çetin, O. (2010). *Fen ve teknoloji dersinde "çoklu ortam tasarım modeli"ne göre hazırlanmış web tabanlı öğretim içeriğinin öğrenci başarı ve tutumlarına etkisi ile içeriğe yönelik öğretmen ve öğrenci görüşlerinin değerlendirilmesi* (Unpublished doctoral thesis). Dokuz Eylül Üniversitesi, İzmir, Turkey.

Dağhan, G. Nuhoğlu-Kibar, P. Akkoyunlu, B., & Atanur-Baskan, G. (2015). Öğretmen ve yöneticilerin etkileşimli tahta ve tablet bilgisayar kullanımına yönelik yaklaşımları ve görüşleri. *Turkish Journal of Computer and Mathematics Education, 6*(3), 399-417.

de Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educationa1 Research, 68*, 179-201.

diSessa, A. A. (1998). What changes in conceptual change? *International Journal of Science Education, 20*(10), 1155-1191.

Donnelly, D. F., Vitale, J. M., & Linn, M. C. (2015). Automated guidance for thermodynamics essays: Critiquing versus revisiting. *Journal of Science Education and Technology, 24*(6), 861-874.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*(7), 5-12.

Driver, R. & Erickson, G. (1983). Theories-in-action: Some theoretical and empirical issue in the study of students' conceptual frameworks in science. *Studies in Science Education*, *10*, 37-60.

Duit, R. & Treagust, D. (2003). Conceptual change: A powerful framework for improving science. *Teaching and Learning. International Journal of Science Education*, *25*(6), 671-688.

Duit, R., Treagust, D. & Widodo, A. (2008). Teaching science for conceptual change: Theory and practice. In Vosniadou, S. (ed), *International Handbook of Research on Conceptual Change* (pp. 629-646). New York: Routledge.

Dursun, Ö.Ö., Kuzu, A., Kurt, A.A., Güllüpınar, F., & Gültekin, M. (2013). Okul yöneticilerinin FATİH projesinin pilot uygulama sürecine ilişkin görüşleri. *Trakya Üniversitesi Eğitim Fakültesi Dergisi*, *3*(1), 100-113.

Duschl R. A., Schweingruber H. A., & Shouse A. W. (Eds.) (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Eastwell, P. (2006). Levels of enquiry. *The Science Education Review*, *5*(2), 61-63.

Erdoğan, Y., Bayram, S. & Deniz, L. (2008). Factors that influence academic achievement and attitudes in web based education. *International Journal of Instruction*, *1*(1), 31-47.

Enerji biçimleri ve değişiklikleri. (2016). Retrieved from https://phet.colorado.edu/tr/simulation/energy-forms-and-changes

Erickson, G. L. (1980). Children's viewpoints of heat: A second look. *Science Education*, *64(*3), 323-336.

Erickson, G. L. (1985). An overview of pupil's ideas. In R. Driver, E. Guesne & A. Tiberghien, *Children's ideas in science* (pp 55-66*)*. Milton Keynes, England: Open University Press.

Erlandson, B. E., Nelson, B. C., & Savenye, W. C. (2010). Collaboration modality, cognitive load, and science inquiry learning in virtual inquiry environments. *Education Technology*, *Research & Development*, *58*, 693-710.

Field, A. P. (2009). *Discovering statistics using SPSS* (3rd ed). London: Sage.

Fulmer, G. W. (2013). Constraints on conceptual change: How elementary teachers' attitudes and understanding of conceptual change relate to changes in students' conceptions. *Journal of Science Teacher Education, 29*, 1-18.

Gerard, L. F., Ryoo, K., McElhaney, K. W., Liu, O. L., Rafferty, A. N., & Linn, M. C. (2016). Automated guidance for student inquiry. *Journal of Educational Psychology, 108*, 60-81.

Gerard, L. F., Varma, K., Corliss, S. B. & Linn, M. C. (2011). Professional development for technology-enhanced inquiry science. *Review of Educational Research, 81*(3), 408-448.

Glaser, B. (1965). The constant comparative method of qualitative analysis. *Social Problems, 12*(4), 436–445.

Glynn, S. M. & Duit, R. (1995). Learning science meaningfully: Constructing conceptual models. In S. M. Glynn & R. Duit, *Learning science in the schools: Research reforming practice* (pp. 3-33). Mahwah, NJ: Lawrence Erlbaum Associates.

Grayson, D. (1994) Concept substitution: An instructional strategy for promoting conceptual change. *Research in Science Education, 24,* 102-111.

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis, 11*(3), 255-274.

Gunstone, R. (1990). 'Children's science': A decade of developments in constructivist views of science teaching and learning. *Australian Science Teachers Journal, 36*(4), 9-19.

Harrison, A. G., Grayson, D. J., & Treagust D. F. (1999) A.G. Investigating a grade 11 student's evolving conceptions of heat and temperature. *Journal of Research Science Teaching, 36*, 55-87.

Hashweh, M. Z. (1986). Towards an explanation of conceptual change. *International Journal of Science Education, 8*(3), 229-249.

Herron, H. D. (1971). The nature of scientific inquiry. *School Review*, *79*(2), 171-212.

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.

Howe C., Devine A. & Tavares J. T. (2013). Supporting conceptual change in school science: A possible role for tacit understanding. *International Journal of Science Education, 35*(5), 864-883.

Iordanou, K., & Constantinou, C. P. (2015). Supporting use of evidence in argumentation through practice in argumentation and reflection in the context of Socrates learning environment. *Science Education, 99*, 282-311.

İnam, A. (2011). *Ortaokul 5. sınıf matematik uygulamaları dersinin web destekli öğretiminin öğrenci performans ve motivasyonuna etkisi ile öğrenci görüşlerinin değerlendirilmesi* (Unpublished master's thesis). Gazi Üniversitesi, Ankara, Turkey.

Jasien, P. G. & Oberem, G. E. (2002). Understanding of elementary concepts in heat and temperature among college students and K-12 teachers. *Journal of Chemical Education, 79*(7), 889-895.

Jones, A. C., Scanlon, E., & Clough, G. (2013). Mobile learning: Two case studies of supporting inquiry learning in informal and semiformal settings. *Computers & Education, 61*, 21-32.

Kali, Y. & Linn, M. C. (2008). Designing effective visualizations for elementary school science. *The Elementary School Journal, 109*(2), 181-198.

Kang, N-H. & Howren, C. (2004). Teaching for conceptual understanding. *Science and Children, 42*(1), 28-32.

Kearney, M. (2004). Classroom use of multimedia-supported predict-observe-explain tasks in a social constructivist learning environment. *Research in Science Education*, *34*, 427-453.

Kearney, M., Treagust, D. F., Yeo, S. & Zadnik, M. G. (2001). Student and teacher perceptions of the use of multimedia supported Predict-Observe-Explain tasks to probe understanding. *Research in Science Education, 31*, 589-615.

Ketelhut, D. J., Dede, C., Clarke, J., & Nelson, B. (2010). A multi-user virtual environment for building higher order inquiry skills in science. *British Journal of Educational Technology, 41*, 56-68.

Kızılaslan, A., Sözbilir, M., & Yaşar, M. D. (2012). Inquiry based teaching in Turkey: A content analysis of research reports. *International Journal of Environmental & Science Education, 7*(4), 599-617.

Kim, H. (2011). Inquiry-based science and technology enrichment program: Green Earth enhanced with inquiry and technology. *Journal of Science Education and Technology, 20*(6), 803-814.

Kim, M. C., Hannafin, M. J., & Bryan, L. A. (2007). Technology-enhanced inquiry tools in science education: An emerging pedagogical framework for classroom practice, *Science Education, 91*(6), 1010-1030.

Kong, S. C., & Song, Y. (2014). The Impact of a principle-based pedagogical design on inquiry-based learning in a seamless learning environment in Hong Kong. *Educational Technology & Society, 17*(2), 127-141.

Krummel, R., Sunal, D. W., & Sunal, C. S. (2007). Helping students reconstruct conceptions of thermodynamics: Energy and Heat. *Science Activities: Classroom Projects and Curriculum Ideas, 44*(3), 106-112.

Kula-Wassink, F., Sadi, Ö. (2016). Türkiye'de Fen Bilimleri Eğitimi Yönelimleri: 2005 ile 2014 Yılları Arası Bir İçerik Analizi. *İlköğretim Online, 15*(2).

Lawson, A. E., Abraham, M. R. & Renner, J. W. (1989). *A theory of instruction: Using the learning-cycle to teach science concepts and thinking skills*. National Association of Research in Science Teaching Monograph, (1).

Lee, H-S., Linn, M. C., Varma, K., & Liu, O. L. (2010). How do technology-enhanced inquiry science units impact classroom learning? *Journal of Research in Science Teaching, 47*, 71-90.

Lee, H-S., & Liu, O. L. (2010). Assessing learning progression of energy concepts across middle school grades: The knowledge integration perspective. *Science Education, 94*, 665-688.

Lee, H-S., Liu, O. L. & Linn, M. C. (2011) Validating measurement of knowledge integration in science using multiple-choice and explanation items. *Applied Measurement in Education, 24*(2), 115-136.

Leonard, W. H. & Penick, J. E. (2009). Is the inquiry real? Working definitions of inquiry in the science classroom. *The Science Teacher, 76(*5), 40-43.

Levy, D. (2013). How dynamic visualization technology can support molecular reasoning. *Journal of Science Education and Technology, 22*, 702-717.

Lewis, E. L., and Linn, M. C. (2003). Heat energy and temperature concepts of adolescents, adults, and experts: Implications for curricular improvements. *Journal of Research in Science Teaching, 31*(6), 657-677.

Lin, L.-F., Hsu, Y.-S., & Yeh, Y.-F. (2012).The role of computer simulation in an inquiry-based learning environment: Reconstructing geological events as geologists. *Journal of Science Education and Technology, 21*(3), 370-383.

Linn, M. C. (1992). Science education reform: Building on the research base. *Journal of Research in Science Teaching, 29*(8), 821-840.

Linn, M. C. (1995). Designing computer learning environments for engineering and computer science: The scaffolded knowledge integration framework. *Journal of Science Education and Technology, 4*(2), 103-126.

Linn, M. C. (2006). The knowledge integration perspective on learning and instruction. In: R. K. Sawyer (Eds.), *The Cambridge Handbook of the Learning Sciences* (pp. 243-264). New York, Cambridge University Press.

Linn, M. C., Clark, D., & Slotta, J. D. (2003). WISE design for knowledge integration. *Science Education 87(*4), 517-538.

Linn, M. C. & Eylon, B-S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. New York: Routledge.

Linn, M. C., Eylon, B-S., Rafferty, A. & Vitale, J. M. (2015). Designing instruction to improve lifelong inquiry learning. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(2), 217-225.

Linn, M. C. & Muilenburg, L. (1996). Creating lifelong science learners: What models form a firm foundation? *Educational Researcher, 25*(5), 18-24.

Linn, M. C. & Slotta, J. D. (2000). WISE science. *Teaching the Information Generation, 58*(2), 29-32.

Linn, M. C. & Songer, N.B. (1991). Cognitive and conceptual change in adolescence. *American Journal of Education, 99*(4), 379-417.

Liu, O. L., Lee, H-S., Hofstetter, C. & Linn, M. C. (2008). Assessing knowledge integration in science: Construct, measures, and evidence. *Educational Assessment, 13*(1), 33-55.

Liu, O. L., Lee, H-S. & Linn, M. C. (2011). Measuring knowledge integration: Validation of four-year assessments. *Journal of Research in Science Teaching, 48*(9), 1079-1107.

Liu, O. L., Rios, R. J., Heilman, M., Gerard, L. & Linn, M. C. (2016). Validation of automated scoring of science assessments. *Journal of Research in Science Teaching, 53*(2), 215-233.

Liu, O. L., Ryoo, K., Linn, M.C., Sato, E. & Svihla, V. (2015). Measuring knowledge integration learning of energy topics: A two-year longitudinal study. *International Journal of Science Education, 37*(7), 1044-1066.

Lorsbach, A. W., & Tobin, K. (1992). Constructivism as a referent for science teaching. In: F. Lorenz, K. Cochran, J. Krajcik, & P. Simpson (Eds.) Research Matters - to the Science Teacher. NARST Monograph, Number Five. Manhattan, KS: National Association for Research in Science Teaching. *Information Systems Research, 9*(2), 126-123.

Matthews, M. R. (1993). Constructivism and science education: Some epistemological problems. *Journal of Science Education and Technology, 2*(l), 359-370.

Matuk, C. F., Linn, M. C., & Eylon, B. S. (2015). Technology to support teachers using evidence from student work to customize technology-enhanced inquiry units. *Instructional Science, 43*, 229-257.

McElhaney, K. W., Chang, H-S., Chiu, J. L. & Linn, M. C. (2014). Evidence for effective uses of dynamic visualisations in science curriculum materials. *Studies in Science Education, 51*(1), 49-85.

McElhaney, K., Miller, D., Matuk, C., & Linn, M. C. (2012). Using the Idea Manager to promote coherent understanding of inquiry investigations. In *ICLS'12: Proceedings of the 10th international conference for the learning sciences,* Sydney, Australia, 2012. International Society of the Learning Sciences.

McMillan, J., & Schumacher, S. (2001). *Research in education* (5th ed.). New York: Longman.

MEB (2013). *İlköğretim kurumları (ilkokullar ve ortaokullar) fen bilimleri dersi (3, 4, 5, 6, 7 ve 8. sınıflar) öğretim programı*. Ankara

Meral, M., Çolak, E. & Genç, H. H. (2012). Realisation and evaluation of the web based instruction courseware: Turkey example. *Procedia - Social and Behavioral Sciences, 47*, 152-160.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction - What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47(*4), 474-496.

Mulholland, P., Anastopoulou, S., Collins, T., Feisst, M., Gaved, M., Kerawalla, L., … Wright. M. (2012). nQuire: Technological support for personal inquiry learning. *IEEE Transactions on Learning Technologies, 5*(2), 157-169.

National Research Council (NRC) (1996). *National science education standards*. Washington, DC: The National Academies Press.

National Research Council (NRC) (2000). *Inquiry and the national science education standards, a guide for teaching and learning*. Washington, DC: National Academies Press.

Naylor, S. & Keogh, B. (1999). Constructivism in classroom: Theory into practice. *Journal of Science Teacher Education, 10*(2), 93-106.

Niaz, M. (2000b). A framework to understand students' differentiation between heat energy and temperature and its educational implications. *Interchange, 31*, 1-20.

OECD (2016). *PISA 2015 Results (Volume I): Excellence and equity in education*. Paris: OECD Publishing.

Okada, A. (2013). Scientific literacy in the digital age: Tools, environments and resources for co-inquiry. *European Scientific Journal, 4*, 263-274.

Özkale, A. & Koç, M. (2014). Tablet computers and their usage in educational settings: A literature review. *SDU International Journal of Educational Studies, 1*(1), 24-35.

Özkan, G. & Selçuk, G. S. (2015). Effect of technology enhanced conceptual change texts on students' understanding of buoyant force. *Universal Journal of Educational Research, 3*(12), 981-988.

Palmer, D. (1995). The POE in the primary school: An evaluation. *Research in Science Education, 25*(3), 323-332.

Pamuk, S., Çakır, R., Ergun, M. Yılmaz, H. B., & Ayas, C. (2013). Öğretmen ve öğrenci bakış açısıyla tablet PC ve etkileşimli tahta kullanımı: FATİH projesi değerlendirmesi. *Kuram ve Uygulamada Eğitim Bilimleri, 13*(3), 1799-1822.

Patro, E. T. (2008). Teaching aerobic cell respiration using the 5E. *The American Biology Teacher, 70*(2), 85-87.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Pintrich, P. R., Marx, R. W. & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.

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

Qian, Y. (2009). 3D Multi-user virtual environments: Promising directions for science education. *Science Educator, 18*(2), 25-29.

Quan (2011). Improvements of student understanding of heat and temperature. Retrieved from http://www.int.washington.edu/REU/2011/student_talks/quan_paper.pdf

Quellmalz, E. S., Davenport, J. L., Timms, M. J., DeBoer, D. Jordan, K., Huang, K. & Buckley, B. (2013). Next-generation environments for assessing and promoting complex science learning. *Journal of Educational Psychology, 105*(4), 1100-1114.

Quintana, C., Zhang, M., & Krajcik, J. (2005). A framework for supporting metacognitive aspects of online inquiry through software-based scaffolding. *Educational Psychologist, 40*(4), 235-244.

Ramsey, J. (1993). Developing conceptual storylines with the learning cycle. *Journal of Elementary Science Education, 5*(2), 1-20.

Read, J. R. (2004). Children's misconceptions and conceptual change in science education. Retrieved from http://acell.chem.usyd.edu.au/Conceptual-Change.cfm

Renken, M. D. & Nunez, N. (2013). Computer simulations and clear observations do not guarantee conceptual understanding. *Learning and Instruction, 23,* 10-23.

Roth, W.-M., Lee, Y. J. & Hwang S. (2008). Culturing conceptions: From first principles. *Cultural Studies of Science Education, 3,* 231-261.

Ruhf, R. J. (2003). A general overview of conceptual change research. Retrieved from http://www.x98ruhf.net/cenceptual_change.pdf

Ryoo, K. & Linn, M. C. (2011). Can dynamic visualizations improve middle school students' understanding of energy in photosynthesis? *Journal of Research in Science Teaching, 49*(2), 218-243.

Ryoo, K. & Linn, M. C. (2014). Designing guidance for interpreting dynamic visualizations: Generating versus reading explanations. *Journal of Research in Science Teaching, 51*(2), 147-174.

Ryoo, K. & Linn, M. C. (2015). Designing and validating assessments of complex thinking in science. *Theory Into Practice, 54*(3), 238-254.

Salman, U. A. (2016). *PISA 2015'teki düşüşün sebebi ne?* Retrieved from http://www.aljazeera.com.tr/al-jazeera-ozel/pisa-2015teki-dususun-sebebi-ne

Sarabando, C., Cravino, J.P, & Soares, A.A. (2014). Contribution of a computer simulation to students' learning of the physics concepts of weight and mass. *Procedia Technology, 13*, 112-121.

Scalise, K., Timms, M., Moorjani, A., Clark, L., & Holtermann, K. (2011). Student learning in science simulations. Design futures that promote learning gains. *Journal of Research in Science Teaching, 48*(9), 1050-1078.

Schwarz, C. (2009). Developing preservice elementary teachers' knowledge and practices through modeling-centered scientific inquiry. *Science Education, 93*(4), 720-744.

Schwarz, C., & Gwekwerere, Y. (2007). Using a guided inquiry and modeling instructional framework (EIMA) to support pre-service K-8 science teaching. *Science Education, 91*(1), 158-186.

Slotta, J. D. (2004). The web-based inquiry science environment (WISE): Scaffolding knowledge integration in the science classroom. In M.C. Linn & E.A. Davis & P. Bell (Eds.), Internet environments for science education (pp. 203-232). Mahwah, NJ: Lawrence Erlbaum Associates.

Slotta, J. D., Linn, M. C. & Lee, C. (2009). *WISE science: Web-based inquiry in the classroom (Technology, education-connections)*. New York: Teachers College Press.

Song, Y. (2014). "Bring Your Own Device (BYOD)" for seamless science inquiry in a primary school. *Computers & Education, 74,* 50-60.

Sözbilir, M., Şenocak, E., & Dilber, R. (2006). Öğrenci gözüyle fen bilgisi öğretmenlerinin derslerinde kullandıkları öğretim yöntem ve teknikleri. *Milli Eğitim Dergisi, 172*, 276-286.

Strauss, S. (1981). Cognitive development in school and out. *Cognition, 10,* 295-300.

Svihla, V. & Linn, M.C. (2012). A design-based approach to fostering understanding of global climate change. *International Journal of Science Education*, *34*(5), 651-676.

Tamkavas, Ç. H., Kıray, S. A., Koçak, A. & Koçak, N. (2016). Studies conducted on misconceptions about heat and temperature in Turkey between 2005-2015: A content analysis. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 10*(2), 426-446.

Tanahoung C., Chitaree R., Soankwan C., Sharma M. D., Johnston I. D. (2009). The effect of interactive lecture demonstrations on students' understanding of heat and temperature: a study from Thailand. *Research in Science & Technological Education*, *27*, 61-74.

Tatlı, Z., & Ayas, A. (2013). Effect of a virtual chemistry laboratory on students' achievement. *Educational Technology & Society, 16* (1), 159-170.

Thomaz, M. F., Malaquias, I. M., Valente, M. C. & Antunes, M. J. (1995). An attempt to overcome alternative conceptions related to heat and temperature. *Physics Education*, *30*, 19-26.

Treagust, D. F. & Duit R. (2008). Conceptual change: A discussion of theoretical, methodological and practical challenges for science education. *Cultural Studies of Science Education, 3*, 297-328.

Treagust, D. F. & Duit R. (2009). Multiple perspectives of conceptual change in science and the challenges ahead. *Journal of Science and Mathematics Education, 32*(2), 89-104.

Türkmen, H. (2009). An effect of technology based inquiry approach on the learning of “Earth, Sun, & Moon” subject. *Asia-Pacific Forum on Science Learning and Teaching, 10*(1), Article 5.

Usta, E. (2011). The examination of online self-regulated learning skills in web-based learning environments in terms of different variables. *TOJET: The Turkish Online Journal of Educational Technology, 10*(3), 278-286.

Visintainer, T. & Linn, M. C. (2015). Sixth-grade students’ progress in understanding the mechanisms of global climate change. *International Journal of Science Education, 24*, 287-310.

Vitale, J.M., McBride, E. & Linn, M.C. (2016). Distinguishing complex ideas about climate change: Knowledge integration vs. specific guidance. *International Journal of Science Education, 38*(9), 1548-1569.

Vosniadou, S. (2007). Conceptual change and education. *Human Development*, *50*, 47-54.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A. & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction, 11*, 381-419.

Web-based Inquiry Science Environment. (n.d.). Retrieved from http://telscenter.org/technology/wise

White, R. T. (2000). The knowledge integration environment: Commentary on research. *International Journal of Science Education, 22*(8), 873-880.

Williams, M. & Linn, M. C. (2002). WISE inquiry in fifth grade biology. *Research in Science Education*, *32*, 415-436.

Williams, M., Linn, M. C., Ammon, P. & Gearhart, M. (2004). Learning to teach inquiry science in a technology-based environment: A case study. *Journal of Science Education and Technology*, *13*(2), 189-206.

Williams, M., Linn, M. C., Hollowell, G. P. (2008). Making mitosis visible. *Science Scope, 31*(7), 42-49.

Wiser, M. (1986). *The differentiation of heat and temperature: An evaluation of the effect of microcomputer teaching on students' misconceptions*. Cambridge, MA: Educational Technology Center, Harvard Graduate School of Education.

Wiser, M. & Amin, T. (2001). "Is heat hot?" Inducing conceptual change by integrating every day and scientific perspectives on thermal phenomena. *Learning and Instruction*, *11*, 331-355.

Zhang, Z. H. & Linn, M. C. (2011). Can generating representations enhance learning with dynamic visualizations? *Journal of Research in Science Teaching, 48*(10), 1177-1198.

Zhang, Z. H. & Linn, M. C. (2013). Learning from chemical visualizations: Comparing generation and selection. *International Journal of Science Education, 35*(13), 2174-2197.

Zirbel, E. L. (2004). Framework for conceptual change. *Astronomy Education Review, 3*, 62-76.