EFFECTS OF EPISTEMOLOGICALLY ENHANCED INSTRUCTION ON NINTH GRADE STUDENTS' PHYSICS RELATED PERSONAL EPISTEMOLOGY AND ACHIEVEMENT IN PHYSICS

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ABSTRACT

EFFECTS OF EPISTEMOLOGICALLY ENHANCED INSTRUCTION ON NINTH GRADE STUDENTS' PHYSICS RELATED PERSONAL EPISTEMOLOGY AND ACHIEVEMENT IN PHYSICS

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This study investigated the effect of epistemologically enhanced instruction on ninth grade students' physics related personal epistemologies and physics achievement on heat and temperature unit. The participants of the study were 186 (109 female and 77 male) ninth grade students at one Anatolian teacher training high school in Ankara. For the current study, a quasi-experimental with matching only pretest-posttest control group research design was adopted. Six classes in the school were randomly assigned to treatments and control group. Two of the classes were taught based on the explicit epistemologically enhanced instruction (EEEI), while another two of six classes were taught based on the implicit epistemologically enhanced instruction (IEEI). Latter two classes were assigned as control groups and they were instructed based on the teacher's conventional instruction (CI). The study was completed in the second semester of the 2013-2014 academic year. The Heat and Temperature Achievement Test (HTAT) was administered to assess students' achievement and the Physics related Personal Epistemology Questionnaire (PPEQ) was administered to distinguish changes in students' epistemological understanding in physics. The Multivariate Analysis of Covariance (MANCOVA) was employed to examine the combined effect of teaching methods on the students' physics related personal epistemology and their physics achievement on heat and temperature unit when students' age, gender, previous semester physics course grades, pre-physics related personal epistemology and pre-physics achievement on heat and temperature unit were controlled. According to MANCOVA results, EEEI was found as the most effective method when compared to CI and IEEI on both students' physics achievement and their physics related personal epistemology. Also, IEEI was found as an effective method in terms of students' achievement on heat and temperature unit. This study revealed that embedding dimensions of personal epistemology via different activities in implicit instruction helped students to improve their physics achievement. However, making these dimensions visible explicitly to students improved both their physics achievement and their physics related personal epistemology.

Keywords: Physics related personal epistemology, physics achievement, explicit epistemologically enhanced instruction, implicit epistemologically enhanced instruction, heat and temperature, physics education

ÖZ

EPİSTEMOLOJİK YÖNDEN ZENGİNLEŞTİRİLMİŞ ÖĞRETİM METODUNUN DOKUZUNCU SINIF ÖĞRENCİLERİNİN FİZİK İLE İLGİLİ KİŞİSEL EPİSTEMOLOJİLERİNE VE FİZİKTEKİ BAŞARISINA ETKİLERİ

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Bu çalışma, epistemolojik yönden zenginleştirilmiş öğretim metodunun 9. sınıf öğrencilerinin fizik ile ilgili kişisel epistemolojileri ve ısı ve sıcaklık ünitesindeki fizik başarıları üzerindeki etkisini incelemektedir. Çalışmaya, Ankara'da bulunan bir Anadolu öğretmen lisesindeki 186 (109 kız ve 77 erkek) dokuzuncu sınıf öğrencisi katılmıştır. Çalışmada yarı deneysel araştırma deseni kullanılmıştır. Okuldaki altı sınıf deney ve kontrol grupları olarak rastgele atanmıştır. İki sınıfta belirtik olarak epistemolojik yönden zenginleştirilmiş öğretim metodu (EEEI) kullanılırken, diğer iki sınıfta örtük olarak epistemolojik yönden zenginleştirilmiş öğretim metodu (IEEI) kullanılmıştır. Geriye kalan iki sınıf çalışmaya katılan öğretmenin kendine has öğretim metodu (CI) ile öğrenim görmüştür. Çalışma 2013-2014 öğretim yılının ikinci döneminde tamamlanmıştır. Öğrencilerin fizik başarısı Isı ve Sıcaklık Başarı Testi (HTAT) ile ölçülmüş fizik ile ilgili epistemolojik anlayışları Fizik ile ilgili Kişisel Epistemoloji Anketi (PPEQ) ile değerlendirilmiştir. Çalışmanın verileri, Çok Değişkenli Kovaryans Analizi (MANCOVA) kullanılarak analiz edilmiştir. Bu analizde öğrencilerin yaşı, cinsiyeti, bir önceki dönem aldıkları fizik notları, ön fizik ile ilgili kişisel epistemolojileri ve ön ısı ve sıcaklık ünitesindeki başarıları kontrol edilerek öğretim metotlarının öğrencilerin kişisel epistemolojilerine ve başarılarına olan birleştirilmiş etkisi test edilmiştir. Analiz sonuçları EEEI'nin hem öğrencilerin fizik başarısı hem de epistemolojik anlayışları üzerinde CI ve IEEI ile karşılaştırıldığında daha etkili bir öğretim metodu olduğu ortaya koymuştur. Ayrıca IEEI'nin öğrencilerin fizik başarısında CI'ya göre daha etkili bir öğretim metodu olduğu sonucuna varılmıştır. Bu çalışma, örtük olarak epistemolojik boyutların öğretime entegre edilmesinin öğrencilerin fizik başarısını arttırdığını ancak epistemolojik boyutların belirtik olarak görünür hale getirilmesinin hem fizik başarısının hem de kişisel epistemolojinin gelişmesinde daha etkili bir yöntem olduğunu göstermiştir.

Anahtar Kelimeler: Fizik ile ilgili kişisel epistemoloji, fizik başarısı, belirtik olarak epistemolojik yönden zenginleştirilmiş öğretim metodu, örtük olarak epistemolojik yönden zenginleştirilmiş öğretim metodu, ısı ve sıcaklık, fizik eğitimi

To who seeks wisdom in this volatile world and to my family

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ATTHS	: Anatolian teacher training high school
EEEI	: Explicit epistemologically enhanced instruction
IEEI	: Implicit epistemologically enhanced instruction
CI	: Conventional instruction
NOS	: Nature of science
PPEQ	: Physics-related personal epistemology questionnaire
SK	: Structure of knowledge
SKC	: Coherent structure of knowledge
SKH	: Hierarchical structure of knowledge
JK	: Justification of knowledge
CK	: Changeability of knowledge
QL	: Quick learning and fixed ability
HTAT	: Heat and temperature achievement test
PPHYSCG	: Previous semester physics course grade
ANCOVA	: Analysis of covariance
MANCOVA	: Multivariate analysis of covariance
IV	: Independent variable
DV	: Dependent variable
SPSS	: Statistical package for social studies
AMOS	: Analysis of a moment structures
EFA	: Exploratory factor analysis
CFA	: Confirmatory factor analysis

CHAPTER 1

INTRODUCTION

Epistemology is one of the study areas of philosophy that concerns about nature of knowledge, its limits, and the justified beliefs. Philosophers' inquiry on how we do know became interest of educational psychologists after 20th century. As knowledge, knowing, and learning are interwoven entities; educational and instructional psychologists began to direct their attention on studying epistemological beliefs for educational purposes (Hofer, 2001; Vosniadou, 2007) and ongoing research has been revealing clues about how epistemic matters are embedded in human cognition (Chinn, Buckland, & Samarapungavan, 2011).

In educational research, mainly two kinds of epistemology occupy the literature: personal epistemology and epistemology of science. Personal epistemology refers to individual's conceptions about nature of knowledge and knowing (Hofer, 2001) whereas epistemology of science addresses the beliefs about nature of science and scientific knowledge (Sandoval, 2003; Sandoval, 2005).

The studies related to personal epistemology turned out to be a large body of research that attempt to theorize models for personal epistemology and epistemological development in early years. These models are recapitulated in Chapter 2. Most of the inquiries on personal epistemology were conducted with college students and adult learners where researchers assumed one's personal epistemology could be stable in those years (e.g. Perry, 1997; King & Kitchener, 1994). Consequently, less attention was given to elementary and high school students during the early years of the research.

Later on, few in number but particularly important studies were conducted for exploration of younger students' personal epistemologies (e.g. Kuhn, Cheney & Weinstock, 2000; Elder, 2002; Mansfield & Clinchy, 2002; Burr & Hofer; 2002; Haerle & Bendixen, 2008). These studies showed that even in early ages, students held various personal epistemologies ranging from naïve to sophisticated (Kuhn, 1991; Feucht, 2010). Consequently, related research implies a rationale to conduct intervention studies on development of younger students' personal epistemologies similar to experimental studies on students' understanding of nature of science (NOS), aka epistemology of science.

Studies related to epistemology of science took much more attention than personal epistemology especially by the community of science educators and quite an extensive research was conducted on epistemology of science. This is why research on epistemology of science seems to put some lights on the possible direction of research on personal epistemology. Previous research on epistemology of science mainly relied on identification of students' existing NOS profiles and reflections of these profiles in classroom instruction and discourse (Lederman, 2007). Inherent structure of scientific knowledge and scientific method was accounted as declarative knowledge (Hogan, 2000) that most frequently refers to importance of empirical testing, tentativeness, and amoral nature of scientific knowledge. Specification of such aspects led researchers to develop instruments about the variations of beliefs related epistemology of science (e.g. Views on Science Technology Society, Test of Understanding Science). Later, NOS research changed its trend to qualitative research methods which are heavily relied on interviews. These interviews also tapped student's views about epistemology of science.

As far as the methodologies of personal epistemology and epistemology of science are concerned, they followed similar traditions (initially descriptive, then quantitative measures followed by qualitative approach). However, implementation studies are mostly conducted on epistemology of science as NOS understanding became an essential component of the current science curriculum (Lederman, 2007) and developing instructional strategies to improve NOS became one of the major objectives of science educators. In addition, NOS research proposed consensus view on characteristic features of science and scientific method that presents a concrete framework to integrate NOS into classroom practices. If the multidimensional structure of personal epistemology suggested in literature is considered, these dimensions might be integrated into classroom context by using the approaches recommended in NOS studies in order to develop students' personal epistemology.

Initial NOS studies focused on modeling nature of science (e.g. Kimball, 1967) and scientific knowledge (e.g. Rubba & Anderson, 1978) through the use of history of science. In the literature, there are two approaches used to promote better NOS understanding: implicit approach and explicit and reflective approach (Akerson, Abd-El-Khalick & Lederman, 2000). The implicit approach suggested that students' NOS understanding would be enhanced by facilitating hands-on inquiry based activities and teaching science process skills. In other words, students would come to understand NOS aspects by doing science as scientists do automatically. Thus, advocators of implicit approach claim that NOS views are constructed as a consequence of the implicit inquiry (Schwartz, Lederman & Crawford, 2004). However, results of numerous empirical studies showed that implicit inquiry oriented instructions were not effective to improve students' NOS understanding (e.g. Abd-El-Khalick, Bell & Lederman, 1998; Bell, Abd-El-Khalick & Lederman, 1998). Khisfe and Abd-El-Khalick (2002) discussed that ineffectiveness of implicit approach was emerged from realizing NOS understanding as affective variable rather than "cognitive learning outcome" to be taught (p.554).

On the other hand, explicit and reflective approach aims to improve individual's NOS understanding through presenting NOS aspects during instruction in an organized way and explicitly addressed during inquiry-based activities (e.g. Abd-El-Khalick, 2001; Abell, Martini & George, 2001; Khisfe, 2008). To promote improvement in NOS understanding through explicit approach learning objectives, appropriate instructional strategies and assessment procedures should be regulated (Schwartz *et al*., 2004, p.614). In this approach, NOS aspects are purposively highlighted via class discussions, explicit reflection of ideas, scientific investigations, and specific examples from history and philosophy of science during instruction.

Meanwhile, personal epistemology studies were generally conducted in correlational designs after emergence of multidimensional view of personal epistemology. Development of quantitative measures (epistemological beliefs questionnaires) encouraged researchers to continue with this methodology. In these measures, there appear to be five common hypothetical dimensions of personal epistemology, which were referred as simplicity of knowledge (structure of knowledge), certainty of knowledge, source of knowledge, innate ability to learn and fixed ability. Schommer (1990) indicated relationship between some dimensions of epistemological beliefs (according to Schommer's model) and learning. Text comprehension studies revealed such relationship that students who adopt the information given in text as certain knowledge, their comprehension indicated absolute nature of knowledge. Other links between learning factors, such as learning strategies, academic achievement (e.g. Schommer, 1993), students' theories of knowledge (e.g. Hofer & Pintrich, 1997), and personal epistemology were revealed (Hofer, 2000). Conceptual change studies had also a particular interest in studying personal epistemologies. Qian and Alvermann (1995) found negative correlation between the success of conceptual change strategies and students' beliefs about knowledge as certain and simple.

Even though findings of correlational studies suggest that personal epistemology plays effective role in learning or cognitive processes, quite a few studies exist to clarify the possible links between instructional methods and personal epistemology (Hofer, 2001). Southerland, Sinatra and Matthews (2001) indicated that students' epistemological profile has a role in students' learning. For instance, Tsai (1999) investigated eight-grade students' epistemological views (domain-specific personal epistemology) and their learning in laboratory. Students who held constructivist view of science were found to perceive school laboratory activities differently than who held empiricist view of science. Constructivist students were likely to prefer laboratory activities where they believe they can engage with concepts deeply. On the other hand, empiricist students recognized laboratory activities as assist to memorize scientific truths.

Sandoval (2014) criticized that researchers have been proposed different theories for personal epistemology with very few empirical agreement "while also overly simplistic in conceptualizing disciplinary practices of knowledge production" (p.384). Since various relationships between personal epistemology and learning have been established, more empirical investigations are needed to support findings (Kuhn *et al*., 2000). Yet, the number of intervention studies to improve younger students' personal epistemology is very limited despite the importance of personal epistemology argued in literature (Feucht, 2010). Moreover, implicit and explicit approaches in intervention studies are few in number to make comparison about their effectiveness on enhancement of personal epistemologies (Yerdelen-Damar & Eryilmaz, 2016). Only one example of intervention study (i.e. Yerdelen-Damar, 2013) was found which investigated effectiveness of explicit epistemological instruction on students' epistemological beliefs and academic achievement in physics in Turkish setting.

1.1. Purpose of the Study

The purpose of this study is to contribute to the literature by exploring the effectiveness of implicit versus explicit epistemologically enhanced instruction on students' physics-related personal epistemologies and academic achievement in a physics unit. This elaboration will be realized by conducting a quasi-experimental design. With this design it is intended to reveal the effect of different instructional methods on students' personal epistemologies as well as achievements in physics related subjects.

1.2. The Main Problem

The main problem of this study is: What are the effects of the explicit epistemologically enhanced instruction (EEEI) and implicit epistemologically enhanced instruction (IEEI) compared to the conventional instruction (CI) on ninth grade Anatolian teacher training high school (ATTHS) students' physics achievement on heat and temperature and students' physics related personal epistemologies in Çankaya district of Ankara?

1.2.1. The Sub-Problems

The sub-problems (SPs) of the study are as follows:

SP1: What are the effects of the EEEI and IEEI compared to the CI on ninth grade ATTHS students' physics achievement on heat and temperature unit in Çankaya district of Ankara?

SP2: What are the effects of the EEEI, and IEEI compared to CI on ninth grade ATTHS students' physics-related personal epistemologies in Çankaya district of Ankara?

SP3: What are the effects of the EEEI and IEEI compared to the CI on ninth grade ATTHS students' physics-related personal epistemologies in terms of coherent structure of knowledge, hierarchical structure of knowledge, justification of knowledge, changeability of knowledge, source of knowledge and quick learning dimensions in Çankaya district of Ankara?

1.3. Null Hypotheses

The main problem and sub- problems are tested with the following null hypotheses:

$H_0$1: There is no significant overall effect of the instructions (EEEI, IEEI and CI) on the population means of the combined dependent variables of ninth grade ATTHS students' posttest scores on physics achievement in heat and temperature unit and posttest scores on physics related personal epistemology when students' age, gender, previous semester physics course grades, pretest scores on physics achievement in heat and temperature unit and pretest scores on physics related personal epistemology are controlled.

$H_0$2: There is no significant effect of the instructions (EEEI, IEEI and CI) on the population means of ninth grade ATTHS students' posttest scores on physics achievement in heat and temperature when students' age, gender, previous semester physics course grades, pretest scores on physics achievement in heat and temperature unit and pretest scores on physics related personal epistemology are controlled.

$H_0$3: There is no significant effect of the instructions (EEEI, IEEI and CI) on the population means of ninth grade ATTHS students' posttest scores on physics related personal epistemology when students' age, gender, previous semester physics course grades, pretest scores on physics achievement in heat and temperature unit and pretest scores on physics related personal epistemology are controlled.

$H_0$4: There is no significant effect of the instructions (EEEI, IEEI and CI) on the population means of ninth grade ATTHS students' posttest scores on physics related personal epistemology dimensions (i.e. coherent structure of knowledge, hierarchical structure of knowledge, justification of knowledge, changeability of knowledge, source of knowledge and quick learning) when students' age, gender, previous semester physics course grades, pretest scores on physics achievement in heat and temperature unit and pretest scores on physics related personal epistemology are controlled.

1.4. Significance of the Study

Related research on personal epistemology indicates links between personal epistemology and certain variables such as learning strategies and academic achievement. These relationships constitute a base for conducting empirical research to investigate causal relationships between these constructs. However, quite a few studies focused on how to improve students' personal epistemologies by instruction and consequently to foster students' academic achievement in physics (e.g. Hammer & Elby, 2002; Yerdelen-Damar, 2013). In the available studies, researchers used different instructional strategies such as explicit reflections (e.g. Brownlee, Purdie & Boulton-Lewis, 2001), refutational text (e.g. Gill, Ashton & Algina), inquiry-oriented instructions (e.g. Conley, Pintrich, Vekiri & Harrison, 2004) or conceptual change strategies (e.g. Yaman, 2013) to enhance students' personal epistemologies. However as the literature reveals a particular instructional method can tab only particular dimension of personal epistemology or cause no change at all. In this study, different approaches (implicit and explicit) were used to promote changes in dimensions of personal epistemology in high school level. For this aim, the researcher matched different instructional strategies (with epistemic potentials) to probe dimensions of personal epistemology.

The instructional practices in classrooms convey their epistemic considerations implicitly such as teacher-centered and student-centered approaches direct focus on different learning approaches: Teacher transfers knowledge to students and student is responsible for construction of his/her knowledge. In other words, implicit epistemic instruction can be done through the classroom practices. As in previous research studies (e.g. Yerdelen-Damar, 2013; Yaman, 2013), the researcher did not use a particular instructional method to enhance personal epistemologies in the current study. Instead, depending on subject matter the researcher elaborated which epistemological dimension would be probed adequately in that context by instructional strategies.

In present study, explicit epistemologically enhanced instruction aims to provoke individual awareness about how one can know. Knowing about self-learning/knowing process might be helpful for students to plan and monitor their goals about learning and achievement in physics. Instruction starts with a class discussion on an epistemological dimension (i.e. structure of knowledge, changeability of knowledge) and continues with covering physics subject matter (i.e. predict-observe-explain activities, laboratory investigations or historical stories and historical materials, problem solving). At the final quarter of the lesson, the teacher allowed students reflect their opinions about epistemological dimension by referring to scientific activity in that lesson. And the teacher covers up discussion by a final talk on epistemological aspect (s). In order to make comparison due to effectiveness of explicit integration of epistemological dimensions, implicit epistemologically enhanced instruction was designed. In implicit instruction, researcher avoided directly creating awareness of epistemology by students. Students engaged with subject matter through same procedures used in explicit instruction. By this way, overall effect of epistemic potentials of instructional strategies will be possible to detect through this intervention study.

In addition, most of the research conducted on personal epistemology focused on college level students and preservice teachers. However, the literature implies that students hold different levels of epistemological sophistication in early years of education (Kuhn, 1991; Hofer, 1997). These findings encourage researchers to investigate elementary (e.g. Conley *et al.*, 2004; Rosenberg, Hammer & Phelan, 2006; Ryu & Sandoval, 2012) and high school (e.g. Yerdelen-Damar, 2013; Yaman, 2013) students' personal epistemologies. The current study will also contribute to literature by investigating effectiveness of this type of epistemologically enhanced instruction in high school level in physics context and in Turkish educational setting.

1.5. Definition of Important Terms

The important constructs which built up the current study can be defined as follows:

Physics related personal epistemology refers to one's beliefs and views about nature of his/her own physics knowledge and learning. Dimensions of the personal epistemology were adopted and modified by using Schommer's (1990) and Hofer and Pintrich's (1997) schemes. These are structure of knowledge, justification of knowing, changeability of knowledge, and fixed ability and quick learning. In this study, physics related personal epistemology was measured by the Physics related Personal Epistemology Questionnaire (PPEQ) developed by the researcher (Appendix I).

Implicit epistemologically enhanced instruction (IEEI) is the instruction in which dimensions of personal epistemology is integrated by use of different instructional strategies. For instance, cognitive conflict strategy is used to remediate misconceptions related to heat and temperature unit. Remediation actually represents changeability of conceptions. Here, there is no voice for directly speaking on change in students' knowledge. Indirectly, students may develop understanding about their knowledge can change by adequate evidence or by use of logical reasoning. In this instructional method, students were expected to make their own realization about their physics knowledge. The lesson plans for IEEI are given in Appendix N.

Explicit epistemologically enhanced instruction (EEEI) is the instruction, which aims tab and improve students' personal epistemology by integrating epistemological discussions at the beginning and through the end of the lesson. For this purpose, the content is contextualized to probe students' personal epistemologies. For example, connecting and making links between previous and new knowledge was used to point out the structure of knowledge. Experimentation and observations as well as cognitive tools were used to focus on justification of knowing. Readings and discussions on history of science were used to show the dynamic nature of knowledge. Students' progression within time was also a part of discussions to demonstrate how students' knowledge develops and changes with effort and persistence. See Appendix N for lesson plans implemented in EEEI.

Conventional instruction (CI) refers to the instruction given by the physics teacher participated in this study. In CI classes of the study, students are mostly active listeners and respondents and teacher is in a role of transferring knowledge. Teacher regularly introduced content knowledge by herself, asked few conceptual questions and solved questions requiring mathematical calculations as much as possible. For more information, see section 3.5.2.1.

Physics achievement in heat and temperature is a measurement of students' knowledge and skills about heat and temperature according to learning objectives defined in Turkish ninth grade physics curriculum by Ministry of National Education (MoNE). In this study, students' achievement was measured by Heat and Temperature Achievement Test (HTAT) developed by the researcher (see Appendix E).

CHAPTER 2

REVIEW OF THE RELATED LITERATURE

In this chapter, theoretical background of personal epistemology research is presented by illustrating qualitative and quantitative approaches in the field. Accordingly, developed instruments aim to explore dimensions of personal epistemology are examined. Later, intervention studies on personal epistemology are introduced in detail. Finally, findings in literature are recapitulated in the last section of this chapter.

2.1. Personal Epistemology in Education Research

As a word, epistemology has been used by common people despite of complexity of defining the term. Etymology of the word indicates that it is the combination of two Greek words; "*episteme*" which means knowledge, and "*logos*" science of. The Oxford Handbook of Epistemology defines epistemology as "the study of the nature of knowledge and justification: in particular, the study of (a) the defining components, (b) the substantive conditions or sources, and (c) the limits of knowledge and justification" (Moser, 2002, p.3).

Inquiry of what constructs knowledge, how do we know, or to what extent knowledge can be known with certainty have been the major concern of the philosophers for ages (Kardash & Scholes, 1996). Educational psychologists also joined to this inquiry in mid-twentieth century as they recognized the effect of personal and social epistemologies on academic learning. Thus, for science learning we pose similar epistemological questions "what is learned, how it is learned, and by whom, and under what conditions" (Kelly, McDonald & Wickman, 2012, p.281). In their comprehensive review on science learning and epistemology, Kelly *et al.* (2012) presented conceptualizations of epistemology affecting science learning in three perspectives. In *disciplinary perspective,* epistemology (or scientific epistemology, NOS) is recognized as discipline (e.g. Lederman, 2007; Southerland *et al*., 2001) which examines structure of knowledge in science, nature of evidence, role of scientific methodology and so on (p.282). Psychological studies on learning promote *personal perspective* (e.g. Hofer, 2001) which examines how individuals construct knowledge and how their personal views of knowledge are effective on their learning. And third one is *social practices* perspective which investigates how learning, justification, making sense and construction of knowledge claims are negotiated in an epistemic culture. In the current study, researcher will focus on conceptualization of science learning in personal perspective.

Personal epistemology studies, in other words beliefs about nature of knowledge and knowing, started with comprehensive work of William Perry that addressed the questions of how epistemological beliefs change and develop (Conley *et al.*, 2004). Earlier studies focused higher education's role on advancement of personal epistemology separately from psychology and cognitive development studies. These studies were qualitative in nature and based on interviews with undergraduate and graduate students or adults (e.g. Perry, 1970; Belenky, Clinchy, Goldberger, & Tarule, 1986; Baxter Magolda, 1987). On the contrary, some studies revealed that epistemological sophistication can be observed in earlier ages (e.g. Kuhn, 1991; Hofer, 2001; Burr & Hofer, 2002; Pintrich, 2002) that more empirical evidence should be obtained by research on younger children as well.

In the light of initial research's findings, numerous studies proposed new models for epistemological development (Stathopoulou & Vosniadou, 2007). These models can be covered under three major theoretical positions: (1) personal epistemology has coherent unidimensional (unitary) structure that develops through stages (e.g. Perry, 1970; King & Kitchener, 1994), (2) personal epistemology is formed by small number of fragmented dimensions which are not necessarily interrelated (e.g. Schommer, 1990), and (3) individually held epistemology is a system formed by different dimensions which works in tandem with each other (e.g. Hofer & Pintrich, 1997). Additionally, Hammer and Elby (2002) proposed a newer model emanated from conceptual change literature that individuals hold various epistemological resources which become productive or unproductive resources in different contexts.

Quantitative studies on personal epistemology started with Schommer's attempt on developing questionnaire to explore dimensionality of the construct (Bråten, Strømsø & Samuelstuen, 2008). Further factor-analytic research on this methodology brought factors in two dimensions: (1) beliefs about nature of knowledge (certain knowledge and simple knowledge) and (2) beliefs about learning (quick learning) and intelligence (fixed ability). Hofer and Pintrich's (1997) attempt took attention that in their proposal of defining personal epistemology to avoid the dimensions about beliefs on learning and intelligence. Later, some researchers directed attention on content and context dependency of epistemological beliefs (Buehl & Alexander, 2001; Hofer, 2006; Limón, 2006) that issue of domain-generality and domain-specificity of personal epistemology were argued in the field. Meanwhile new quantitative instruments were developed in order to identify potential differences across domains. In next sections, detailed information related to aforementioned studies and more are presented and discussed.

2.1.1. Early Studies: Developmental Models

Epistemological beliefs research in psychology ignited with longitudinal studies of William Perry, in mid-1950s. Perry's work (1968) attained to form a model on college students' reflections on how they view their educational experiences. In order to collect data on students' experiences in university, he developed the Checklist of Educational Values (CLEV) instrument in order to select students for interviews.

Theoretically, CLEV was relying on personality and belief research. Sample questions in CLEV were including "It's a waste of time to work on problems which have no possibility of coming out with a clear-cut and unambiguous answer.", "There is nothing more annoying than a question that may have two answers.", "The best thing about science courses is that most problems have only one right answer." The checklist was implemented on 313 first year college students which were followed by interviews with 31 students. The main idea behind it was to show changes in the students' understanding of knowledge and how it affects their methods of knowledge acquisition (such as studying). According to preliminary findings from the interviews, Perry (1968) proposed the scheme of intellectual and ethical development with nine stages (or position) in four clustered sequential positions. The four clustered positions are listed as follows:

(a) *Dualism*

Position 1 – Basic duality: Individuals perceive the world as collection of duality such as right or wrong and good or bad. They display obedience to the authority.

Position 2 – Multiplicity pre-legitimate: Individuals perceive multiplicity not as an uncertainty of knowledge but others as wrong or unreal.

(b) *Multiplicity*

Position 3 – Multiplicity subordinate: Authority is still trusted source for individuals even though there are unanswered questions by authority.

Position 4 – Multiplicity correlate or relativism subordinate: Absolute knowledge may be questioned rather than right-wrong dualism. Conflict between ideas may exist, but truth is still knowable.

(c) *Relativism*

Position 5 – Relativism correlate, competing, or diffuse: There are some subject areas (e.g. physics) that authority has direct answers. However, relativism is required in some areas (e.g. literature).

Position 6 – Commitment foreseen: Individuals perceives relativism in their judgment with commitment emerged from logical necessity. The truth may change depending on the individual's perspective.

(d) *Commitment within relativism*

Position 7 – Initial commitment: Individuals affirm that their decisions are based on their experiences even though there may be other alternatives (including risk-analysis).

Position 8 – Orientation in implications of commitment: In order to fit in a world view, individuals seek out several commitments.

Position 9 – Developing commitment: Variety of ideas and judgments allow individuals to examine or compare the situations. Individuals have considered choice and take actions by self as being aware of relativism. Individuals take responsibility of their commitments and decide priority of different commitments that can be changed (tentative nature).

Second longitudinal study (four year long) for validation of the proposed scheme was conducted on randomly selected sample including109 freshman students (85 men and 24 women). Hofer (1997) noted that Perry reported only two women's results as fitting to their scheme without mentioning the other 22 women in the study. Besides the study has various limitations that only one college's students were participated voluntarily and the sample was including elite and mostly male college students at Harvard University. Perry acknowledged that students who had dualistic view at the beginning of their education came closer to relativistic view as they encountered with different viewpoints during their college education (Kardash & Scholes, 1996). In other words, college students progressed toward simple to complex view of knowledge as an outcome of their educational experience but not because of their personalities (Hofer, 1997).

After Perry's work, qualitative trend of research designs were followed by researchers. Well-known models in the field including women's way of knowing

(Belenky et al., 1986), epistemological reflection (Baxter Magolda, 1992), reflective judgment (King & Kitchener, 1994) and argumentative reasoning (Kuhn, 1991) were based on qualitative data collected by interview protocols.

Perry's work has been criticized for gender bias. However, he suggested the pattern identified for men could also be used for women (Perry, 1970). Another controversial study, this time conducted with only women, was designed by Belenky *et al*. (1986). 135 women were participated in the study and 90 of them were studying in different academic institutions. Phenomenological approach was adopted by researchers that data collection was done by semi-structured interviews. Due to education level of women, the interview protocol showed differences. More educated women were expected to give few comments on statements about knowledge. Then they were exposed to specific examples that they should make intellectual judgments. On the other hand, less educated ones responded five short questions about their learning. According to results of the study, Belenky and her colleagues (1986) concluded that individual's cognitive development relies on development of self and it is related with inner (self) and external (others) source of knowledge as well as understanding the knowledge by self. They proposed five epistemological perspectives in *Women's Way of Knowing* model. However, these perspectives were not defined as stages as in Perry's work. Five epistemological perspectives are summarized as follows:

(a) *Silence*: The individual exists without voice to make claim about knowledge and readily obey to authority.

(b) *Received knowledge*: The individual perceives the knowledge with dual nature and she believes in absolute truth (good or bad). The source of knowledge is authority (external) however they can speak about the knowledge.

(c) *Subjective knowledge*: The individual recognizes self as the source of knowledge or authority. Truth is subjectively known.

(d) *Procedural knowledge*: The individual seeks out rules and procedures of knowing to make judgments and justifications related with the knowledge. Reasoning is the main course of this perspective. There are two categorization of knowing: connected knowing and separate knowing. A separate knower tries to justify knowledge claims from others by using personal filters. On the contrary, a connected knower tries to evaluate knowledge by putting themselves on other's shoes.

(e) *Constructed knowledge*: The individual appreciates complexity, ambiguity and contradictions in knowledge during construction of knowledge. She seeks nature of knowledge as tentative: it can be decomposed, recomposed and composed again in time.

When Perry's (1970) and Belenky *et al*.'s (1986) works are compared, there are differences as well as similarities between two models. Perry indicated intellectual development evolves with transitions through stages. However, Belenky and her colleagues asserted less linear but varying epistemological perspectives in cognitive development of college students. These comprehensive studies shed light upon how epistemological perspectives changes within time, experience or developmental stages. The major criticism for these two studies was about gender bias that may influence the interpretation of results.

In order to fill the discrepancies of findings between studies with only men and only women participants, Baxter Magolda (1987) conducted a longitudinal study based on Perry's scheme with randomly selected 101 students from Miami University. The participants of the study included 50 male and 51 female students. Data collection was done through open-ended interviews and the Measure of Epistemological Reflection (MER) (Baxter Magolda, 1987). In MER, students were asked to write short essay according to questions about role of the lecturer, learners, classmates and role of evaluation of learning, and nature of knowledge. Coding scheme was matched with Perry's Position 1 to Position 5. 70 complete longitudinal sets were taken into account to develop the model, which is called *Epistemological Reflection* (ER) *Model*. According to the ER model, epistemological reflections refer to epistemological assumptions (i.e. nature of knowledge, limits of knowledge, certainty of knowledge). Findings were categorized into four qualitatively different categories in the college context which were also aligned with the Perry's model:

(a) The individuals who seek the source of knowledge from authorities are called as *absolute knower*.
(b) The individuals do not seek authorities as knowing all and view knowledge as uncertain are called as *transitional knower*.
(c) *Independent knower* judges the accuracy of knowledge conveyed from authorities and holds their ideas as valid as others.
(d) *Contextual knower* is the individual that construct their own perspective and able to question the validity of knowledge in the context.

Similar limitations existed in the Baxter Magolda's study as in previous studies, for instance study was conducted at one university. As the study adopted qualitative approach, researcher presented thick descriptions about the context of the university and cultural background of students. However, results of the study were in line with previous research that identifies the patterns of epistemological development. Later, Baxter Magolda (1992) mentioned the need of comparative studies across diverse student populations in different contexts.

Research studies after Perry's and Baxter Magolda's works continued focusing on categorization of younger students' perceptions on their learning experiences. Based on individual's argumentative reasoning, Kuhn (1991) examined epistemological theories about knowing via conducting interviews with children. She claimed that epistemological understanding started forming in childhood. Kuhn *et al.* (2000) identified four levels of epistemological understanding as:

(a) *Realistic theories*: Child perceives reality as directly observable and knowable through external reality. Therefore, knowledge comes from external source and it is certain in nature. There is no need of evidence for justification.

(b) *Absolutist theories*: Child recognizes reality can be interpreted in different ways (correct or incorrect). Still external reality is directly observable coming from external source. However, child makes comparisons based on his/her reasoning skills about knowledge's reliability.

(c) *Multiplist theories*: Adolescent perceives knowledge is constructed by self rather than adopted from an external source. It is a transition from perception of objective knowledge to subjective knowledge.

(d) *Evaluative theories*: Adolescent makes judgments on knowledge and justification of knowing by examining evidences and arguments.

Kuhn (2009) stated that consideration of epistemological understanding through developmental stages would be fruitful to support academic progress. For instance, realization of different theories existed in adolescences might be effective to challenge thinking in that level to develop more sophisticated intellectual values. Improvement of argumentative skills might trigger changes in epistemological understanding, or vice versa.

King and Kitchener (1994) explored the conceptions of knowledge and reality through a 15 years long study with a wide range of age groups from high school students to middle age adults. In the study, an interview was designed with four-ill-structured problems that participants were expected to justify their answers. Six-follow-up questions were directed to explore their views about nature of knowing and its possible sources. Trained and certified scorers completed the scoring that an inter-rater reliability coefficient is found to be .70. Internal consistency of individual scores was reported by a median alpha level across studies .77. As a result of the study, *Reflective Judgment Model* (RJM) was proposed including seven qualitatively different stages. The model can be seen as most extensive and elaborated scheme to explain development with epistemic elements. Developmental progression was classified into three levels (stage numbers refers to order of categories) in RJM (King & Kitchener, 2004, p.7-8):

(a) *Pre-reflective thinking*

Stage 1: Knowledge is perceived as concrete without any abstraction which is obtained by direct observations. There is no need for justified belief as the knowledge is the absolute truth.

Stage 2: Knowledge is perceived as certain which is obtained from observations or conveyed from a source of authority. Beliefs are justified due to source of knowledge or not justified (through observations).

Stage 3: Knowledge is perceived as absolute from source of authority. If there is any uncertainty, it is not permanent. Till the absolute knowledge is obtained, beliefs cannot be known. Justification of beliefs relies on credibility of authority.

(b) *Quasi-reflective thinking*

Stage 4: Knowledge is not absolute due to inherent ambiguity in situations. Justification of beliefs relies on provided reasons and evidence.

Stage 5: Knowledge is subjective because of personal judgment. Beliefs are justified by inquiry in the context. Context specific beliefs can exist.

(c) *Reflective thinking*

Stage 6: Knowledge is the product of individual processing due to evaluation of various sources. Therefore, individuals justify their beliefs by comparing different evidences and views from others and weighing these sources according to self evaluation criteria.

Stage 7: Justification of belief relies on different factors such as interpretation of evidence and their explanatory values, possibility of arriving wrong conclusions, etc. and contribution of all these factors.

Hofer (1997) criticized that only investigating the reasoning about ill-structured problems to explore epistemological beliefs is one of the limits of King and

Kitchener's (1994) study. These hypothetical problems do not give sufficient understanding about how students' beliefs are activated in a real experience. And there is no implication for how reflective judgment develops within years and how education makes difference.

In general, developmental models draw same pattern to understand how epistemological beliefs are constructed (Hofer, 2001). The pattern emerged from the studies shows that development starts with the objectivist perspective and dual nature of knowledge and continues with multiplicity and more uncertain nature of knowledge. And in final stages, nature of knowledge becomes evolutionary rather than static and the knowledge is constructed by the learner. Different terms were also suggested such as evaluatism, empiricism, logical positivism, relativism etc. (Huglin, 2003) to define epistemological perspectives. Objectivist perspective separates the objective knowledge with emotions of individual where the authority plays an essential role as source of knowledge. In educational context, teacher is the source of objective knowledge where students take passive role in classroom. The other end of the continuum, subjectivism, is based on individual's interpretation of knowledge which denies the separation of knowledge from one's feelings or emotions. In fact, learners are active makers of meaning that refers to "person construct reality" paradigm (Huglin, 2003, p.13).

For instance, Roth and Roychoudhury (1994) conducted a gender biased study on 42 high school students (all male, 4 from Grade 10 and 38 from Grade 11, all college-bound physics students) to document students' epistemologies and perceptions about knowing and learning. Qualitative and quantitative data were collected by using interview protocols, essay writing task, short answer questions, and classroom environment inventory. Students were informed about the content at the beginning of each unit in introductory physics course, which was illustrated by "experiments, reading and concept mapping, textbook problems, and essay problems" (p.8). Thus, students had opportunity to make their own investigation about daily life phenomena.

After completing problem-solving, students were expected to write essays on "knowing and learning physics" and "objectivity in science" (p.9). Results of data analysis showed that students had a spectrum of epistemological commitments ranged between objectivism and constructivist-relativism. Some students had already constructivist views about their learning and knowing physics. But most of the students held also experientialist position that experience (of oneself or others) is a criterion for knowledge production or justification. Developmental stage models assert that older people hold more sophisticated epistemologies and students are seen as progressing between stages (Louca, Elby, Hammer & Kagey, 2004). Moreover, constructivist learning environment in a classroom did not necessarily cause change in students' epistemologies. The study implies that students may develop sophisticated personal epistemologies in younger ages but constructivist interventions are not sufficient enough to promote change.

2.1.2. Personal Epistemology as Independent Belief System

After several proposals on developmental models, an alternative approach was suggested by Schommer (1990). By referring to Ryan's (1982) work on epistemological standards, Perry's unidimensional personal epistemology assumption was criticized by Schommer. Ryan (1982) categorized participants according to Perry's scheme as dualists and relativists in order to compare their text comprehension skills (knowledge monitoring vs. comprehension/application monitoring). Results indicated significant positive difference between two groups in terms of knowledge monitoring. Even though dualists preferred knowledge monitoring mostly, 44 percent of relativists did also. Schommer's standing point was beliefs about knowledge, knowing and learning were more or less independent rather than developing in an organized way and gradually reaching more sophisticated levels (Schommer, 1990; Hofer, 2001). Thus she developed a quantitative instrument, the Epistemological Beliefs Questionnaire (EBQ), by elaborating the initial qualitative studies' findings such as Perry's and King and Kitchener's works. The instrument was designed to measure five hypothetical dimensions with 12 sub-dimensions. However, factor analyses suggested four-factor structure for EBQ (see Table 2.1) that source of knowledge dimension was not generated as a factor in empirical work.

Table 2.1 Factors in Schommer's (1990) Epistemological Beliefs Questionnaire (p.500)

Hypothetical Dimensions	Factors
1. Simple Knowledge	
1.1 Seek single answers	Factor 2: Simple Knowledge
1.2 Avoid integration	Factor 2: Simple Knowledge
2. Certain Knowledge	
2.1 Avoid ambiguity	Factor 2: Simple Knowledge
2.2 Knowledge is certain	Factor 4: Certain Knowledge
3. Omniscient Authority	
3.1 Don't criticize authority	Loaded into any factor
3.2 Depend on authority	Loaded into any factor
4. Innate Ability	
4.1 Can't learn how to learn	Factor 1: Innate Ability
4.2 Success is unrelated to hard work	Factor 1: Innate Ability
4.3 Ability to learn is innate	Loaded into any factor
5. Quick Learning	
5.1 Learning is quick	Factor 3: Quick Learning
5.2 Learn first time	Factor 1: Innate Ability
5.3 Concentrated effort is a waste of time	Loaded into any factor

According to Schommer (1990), results indicated multi-dimensional structure of epistemological beliefs rather than a one-factor solution as suggested in previous research. Schommer's approach encouraged a group of researchers to explicitly measure the relationship between epistemological beliefs and learning (Schommer-Aikins, 2004). Epistemological belief system approach facilitates studying on subcomponents of personal epistemology. But it is still a controversial issue that whether these factors constitute the personal epistemology adequately (Conley *et al.*, 2004). It is argued that quick learning and fixed ability factors are not epistemological dimensions instead related with the nature of learning.

2.1.3. Epistemological Theories

Another proposal that advocates the structure of the personal epistemology as the interrelated epistemological theories was suggested by Hofer and Pintrich (1997). Epistemological theory should be seen as "an explanatory structure with some coherence and not a well-formed scientific theory" (Stathopoulou & Vosniadou, 2007, p.256). This model is similar to proposed multidimensional structure as in Schommer's model. However, the dimensions were found to be interrelated with each other rather than independent system as in Schommer's (1990, 1993) model. In fact, how we define personal epistemology gained importance for further research on the construct. Hofer and Pintrich (1997) attempted to clarify the definition of construct by focusing on beliefs about knowledge and knowing and avoiding the intelligence factor as found in Schommer's study (Bråten, Strømsø & Samuelstuen, 2008). They proposed two main dimensions associated with four sub-dimensions as core of epistemological theories (Hofer, 2004):

(a) *Nature of knowledge* questions "what one believes knowledge is" (p.130).

Certainty of knowledge refers to views range between fixed or absolute truth exists (existing knowledge is never subject to change) and knowledge can be refined or change.

Simplicity of knowledge refers to views range between knowledge is discrete (not related with each other) and knowledge is "relative, contingent and contextual" (p.131).

(b) *Nature/process of knowing* questions "how one comes to know" (p.131).

Source of knowledge refers to views range between knowledge is transmitted from external source (authoritative source) and knowledge is constructed by individual due to his/her relation with environment.

Justification for knowing refers to action of the process of making knowledge reasonable to oneself. One can justify his/her beliefs by logical reasoning or can do justification depending on authority.

Differently from Schommer's categorization (e.g. fixed ability), they put emphasis on latter factor justification of knowing. The factor refers to justification of knowledge via authority, observation, intuitions of oneself, inquiry and use of different sources for evaluation. Hammer and Elby (2002) mentioned advantageous use of defining personal epistemology in terms of theories that these are more understandable for introducing epistemological considerations. They associated theories in personal epistemology with alternative conceptions in students' intuitive content knowledge. This stance was proposed as active and inactive epistemological resources in different contexts. This proposal is explained in the next section.

2.1.4. Epistemological Resources

Epistemological resources model emerged parallel to conceptual change literature, especially associated with diSessa's studies on phenomenological primitives (p-prims) (Hammer & Elby, 2002). Naïve physics understanding of students are made up almost by misconceptions (e.g. if an object moves, there is an active force on the objective in the direction of motion) as cognitive science accepted that differ from expert's understanding (e.g. if there is net force, the object accelerates). Hammer (2000) presented a potential link between epistemological resources and conceptual resources. For instance, misconceptions can be emanated from conceptual resources which might be productive in another context. Therefore conceptual structure can be built up from mixture of these resources. Same goes for epistemological resources or beliefs that some resources are activated in different context. Hammer and Elby (2002) exemplified similarity with epistemology studies as unsophisticated beliefs (e.g. scientific knowledge is certain) differs from sophisticated beliefs (e.g. scientific knowledge is tentative).

Hammer and Elby (2002) listed and explained epistemological resources framework in detail by categorizing resources (a) *for understanding the nature and source of knowledge*: knowledge as propagated stuff, knowledge as free creation, knowledge as fabricated stuff, (b) *for understanding epistemological activities*: accumulation, formation, checking , (c) *for understanding epistemological forms*: stories, rule systems, songs, etc., and (d) *for understanding epistemological stances:* doubting, understanding, acceptance. Comparing to previous models, epistemological resources are still new and not much is known about them. However, it challenges existing models attempting to describe more situated structure of personal epistemology which is consistent across contexts. In other words, research on this approach indicates consistency of epistemological beliefs in a particular context such as in physics course.

2.2. Domain Generality-Specificity in Personal Epistemology

Dominance of early studies on stage models (i.e. Kuhn, 1991; Baxter Magolda, 1987) of epistemological sophistication was influential on viewing personal epistemology as domain general construct in literature (Op't Eynde, De Corte, & Verschaffel, 2006). Students' personal epistemologies were recognized as evolving from naive to sophisticated beliefs independent from the context. Although understanding of the personal epistemology construct became clearer by collected comprehensive data, some issues such as domain-generality and domain-specificity issues emerged in the field (Limón, 2006). Actually main issue was related to how the "domain" should be conceptualized (Hofer, 2006; Limón, 2006). Hofer (2006) identified two major use of domain word in literature that some researchers indicated domain as academic discipline (or subject area) and others referred to domain as judgment (e.g. aesthetics, values). Buehl and Alexander (2001) pointed out classification in academic disciplines as well-structured (e.g. mathematics, physics) and ill-structured domains (e.g. history, reading). As the approaches and types of knowledge in both domains are different from each other inherently, researchers preferred to study within a specific domain rather than crossing domains. Hofer (2006) discussed that if domain knowledge was accepted as knowledge in an academic discipline, it would restrict the domain knowledge into “schooled knowledge” (p.87). And she suggested using discipline term rather than domain. Mathematics and science are the major academic disciplines in which discipline-specific personal epistemology research is conducted.

When epistemological models are examined in terms of role of content, some of the developmental models consider possible differences across content domain (i.e. Kuhn & Weinstock, 2002; King & Kitchener, 2004). In independent belief system models, as in Schommer’s (1990), domain-general epistemological beliefs were measured without any emphasis on domain-specific beliefs. In their study, Schommer and Walker (1995) tested whether college students’ epistemological beliefs were independent from academic domains. Results showed that students displayed consistency in terms of epistemological sophistication across social science or mathematics. On the other hand, Buehl and Alexander (2001) suggested coexistence of domain-general and domain-specific epistemological beliefs. Hofer (2000) showed differences in personal epistemologies emerged across different disciplinary domains (psychology and science) and differences between domain-general and domain-specific epistemological beliefs in her study. Epistemological resources model also took the disciplinary content into account such as physics (Elby & Hammer, 2002). Palmer and Marra (2004) emphasized notion of differences in epistemological perspectives across academic domains (knowledge in science and social science) in their grounded theory of domain epistemologies.

The domain generality and specificity discussions in field led researchers to develop new instruments to identify the difference across different contexts and contents (Hofer, 2006). In the next section, measurement of personal epistemology and developed instruments are discussed starting from earlier studies to domain-specific instruments.

2.2.1. Domain-General and Domain-Specific Measurement of Personal Epistemology

As mentioned before in Section 2.1.2, Schommer (1990) developed an instrument called EBQ to reveal multidimensional structure of epistemological beliefs. 63 statements were written for five hypothetical dimensions (see Table 2.1). 28 statements were written in the form of negative sentence, and others were in affirmative sentences. Likert type scale was used in which 1 indicates strongly disagree and 5 indicates strongly agree. The instrument aims to assess domain-general epistemological beliefs without seeking difference across different domains. Factor analyses of the questionnaire within different studies (Schommer, 1990; 1993) yielded four-factor solution for EBQ. These factors are (a) certain knowledge (tentativeness versus certainty of knowledge), (b) simple knowledge (body of isolated concepts versus interrelated concepts), (c) quick learning (quick versus gradual learning), and (d) fixed ability (intelligence is fixed versus intelligence is a result of growth).

Qian and Alvermann (1995) modified and shortened Schommer's questionnaire by eliminating the fifth hypothetical factor (omniscient authority). The questionnaire included 53 statements on other four factors (i.e. certain knowledge, innate ability) which were rated on likert-type scale (from 1 to 5). According to factor analysis results, 21 items were deleted due to factor loadings (less than .30). Remaining 32 items were distributed into three factors: (a) 15 items loaded into "learning is quick" factor with internal consistency coefficient (α) was found .79, (b) 11 items in "simple/certain knowledge" with α=.68, and (c) 6 items in "ability to learn is innate" with α=.62. Differently from the Schommer's (1990) factors, three factors were yielded that certain and simple knowledge dimensions were merged into one factor (p.286).

The results of Schommer's (1990, 1993) work on multi-dimensionality in epistemological beliefs structure inspired Schraw, Dunkle and Bendixen (1995) to develop the Epistemic Beliefs Inventory (EBI). Preliminarily 60 items (12 item for each dimension) were written for five dimensions hypothesized by Schommer (1990). After pilot studies, the EBI was formed by 32 items rated on a likert-type scale. Bendixen, Schraw and Dunkle (1998) attained five-factor structure for EBI that results of the factor structure is summarized in Table 2.2. Researchers emphasized that they produced different statements for Schommer's omniscient authority dimension. The dimension could not be found in her results because of irrelevant items in the EBQ.

Table 2.2 Factors of EBI (Bendixen *et al*., 1998, p.200)

Factor	Sample Item	Eigenvalue	Cronbach's Alpha
Certain knowledge	"What is true today will be true tomorrow."	1.77	.76
Innate ability	"Some people will never be smart no matter how hard they work."	1.27	.87
Quick learning	"If you don't understand something the first time through, going back over it won't help."	1.24	.74
Simple knowledge	"Instructors should focus on facts instead of theories."	1.21	.67
Omniscient authority	"When someone in authority tells me what to do, I usually do it."	1.16	.76

Halloun and Hestenes (1996) introduced the Views about Science Survey (VASS) to assess both students' views about science and science learning. For this purpose researchers included four epistemological (i.e. "structure and validity of scientific knowledge") and three pedagogical (i.e. learnability of science) dimensions in the instrument. By considering potential differentiation in students' views on different content (different laws in a theory), researchers provided same type of questions in different contexts. After revisions on instrument, mathematics dimension in epistemology of science was integrated into methodology dimension (Halloun & Hestenes, 1998). VASS-P204 version includes 50 items for physics course (Halloun 2004) and researcher modified the taxonomy of VASS in revised version. As concern of the current study is students' physics related epistemologies about knowledge and knowing, examining pedagogic dimensions of VASS could be fruitful. These are *readiness to learning* (7 items), *reflective thinking* (10 items) and *personal relevance* (5 items). Sample items related to pedagogical dimension of VASS are presented in Table 2.3. Readiness to learning dimension resembles to innate ability and quick learning dimensions in Schommer's EBQ. Researcher also included strategies related to studying physics such as making preparations before the subject matter covered in classroom, examining different resources for scientific information and discussing findings with classmates. Reflective thinking dimension is parallel with justification of knowledge and knowing (as suggested by Hofer, 2000). Halloun (2004) integrated "model a situation and investigate it in many ways, instead of relying exclusively on a formula-centered approach" into this dimension. Personal relevance dimension concerns with understanding the relevance of science into individual's life and therefore studying physics is not a frustration but "self-satisfying experience".

Table 2.3 Sample items from VASS-P201 (Halloun, 2004)

Sample Items	Dimensions
41. I would like my physics course to allow me relate physics: (a) to the way I think about certain things in the natural world. (b) to other sciences and their ways of dealing with the natural world.	Personal relevance
31. I go over the main body of a physics chapter: (a) before the chapter is covered in class. (b) after the chapter is covered in class.	Readiness to learning
37. After the teacher solves a physics problem for which I got a wrong solution: (a) I discard my solution and learn the one presented by the teacher. (b) I try to figure out how the teachers' solution differs from mine.	Reflective thinking

Redish, Saul and Steinberg (1998) emphasized the students' cognitive expectations and beliefs about nature of science were important determinant in their science learning. By referring to Perry's and Belenky *et al.*'s studies in university level, they underlined students' expectations about their knowledge evolved in time. In order to assess students' expectations in university level, Redish *et al.* (1998) developed Maryland Physics Expectations (MPEX) survey based on particularly three dimensions proposed by Hammer (1994). Dimensions in Hammer's (1994) basic framework were (a) beliefs about the structure (pieces versus coherence), (b) beliefs about the content of physics knowledge (formulas versus concepts) and (c) beliefs about learning physics (by authority versus independent) (pp.157-161). He modified the basic framework after interviews with six students were analyzed. Modified framework is illustrated in Figure 2.1.

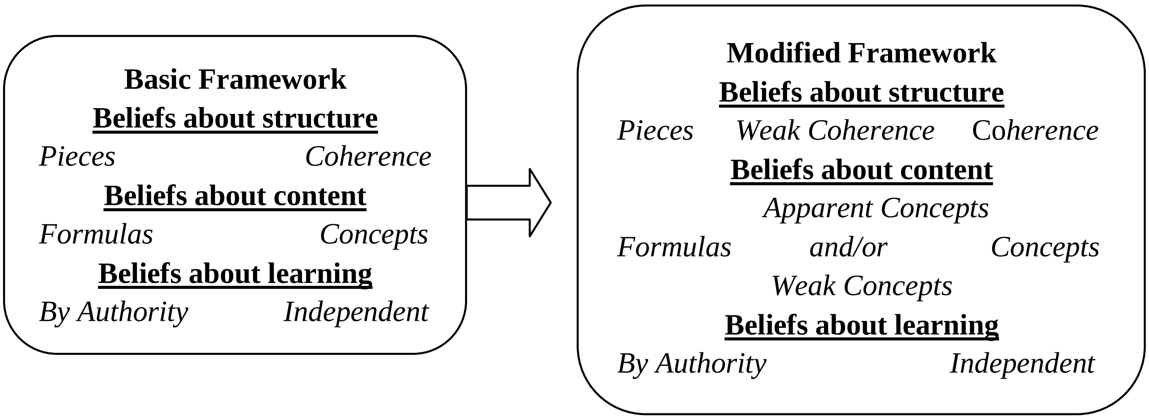


Figure 2.1 Hammer's (1994) frameworks for beliefs about physics knowledge (p.157, p. 163)

In addition to Hammer's framework, Redish *et al*. (1998) proposed three more dimensions for MPEX survey as shown in Table 2.4. These are: (a) *reality link* (beliefs about making connections with real life experiences and physics knowledge), (b) *math link* (beliefs about use of mathematics in physics knowledge) and (c) *effort* (beliefs about or students' expectations to learn physics throughout different activities or tasks). Factor analysis or reliability analysis of empirical work were not reported by the researchers.

Table 2.4 Hypothetical factors of MPEX (Redish et al., 1998, p.218-220)

Factors	Sample Item	N of items
Independence	"Learning physics is a matter of acquiring knowledge that is specifically located in the laws, principles, and equations given in class and/or in the textbook."	6
Coherence	"Knowledge in physics consists of many pieces of information each of which applies primarily to a specific situation."	5
Concepts	"The most crucial thing in solving a physics problem is finding the right equation to use."	5
Reality link	"Physical laws have little relation to what I experience in the real world."	4
Math link	"The derivations or proofs of equations in class or in the text have little to do with solving problems or with the skills I need to succeed in this course."	5
Effort	"I go over my class notes carefully to prepare for tests in this course."	5

In the following year, White, Elby, Frederiksen and Schwarz (1999) developed another domain-specific instrument which was called the Epistemological Beliefs Assessment for Physical Science (EBAPS) survey. The survey was aim to assess students' epistemological beliefs not only in physics (as in MPEX) but science in general. Researchers adopted multidimensional perspective from Schommer's studies (1990) however criticized the dimensions proposed in the literature (Elby & Hammer, 2001, p.556). Moreover, they sought to measure students' beliefs rather than students' expectations as in MPEX. Multiple types of items were used in EBAPS such as 17 agree/disagree likert type items, six multiple choice (MC) questions and seven debate items (as shown in Figure 2.2). In total, the EBAPS consists of 30 items for five dimensions: (a) structure of scientific knowledge (5 likert, 3 MC, and 2 debate items), (b) nature of knowing and learning (5 likert, 1 MC, and 2 debate items), (c) real-life applicability (2 likert, 1 MC, and 1 debate items), (d) evolving knowledge (1 likert and 2 debate items), and (e) source of ability to learn ((3 likert, 1 MC, and 1 debate items). Construct-related validity evidence by factor analysis or any reliability analysis was not provided by the researchers.

Justin: When I'm learning science concepts for a test, I like to put things in my own words, so that they make sense to me.

Dave: But putting things in your own words doesn't help you learn. The textbook was written by people who know science really well. You should learn things the way the textbook presents them.

(a) I agree almost entirely with Justin.
(b) Although I agree more with Justin, I think Dave makes some good points.
(c) I agree (or disagree) equally with Justin and Dave.
(d) Although I agree more with Dave, I think Justin makes some good points.
(e) I agree almost entirely with Dave.

Figure 2.2 Sample debate item in nature of knowing and learning dimension in EBAPS (Redish, 2003, p.114)

Another quantitative measurement instrument, the Epistemic Doubt Questionnaire (EDQ) was developed by Krettenauer, Hallett and Chandler (as cited in Hallett, 2000). The questionnaire was based on Chandler, Boyes and Ball's (1990) restructured epistemological positions adopted from Perry's scheme as (a) realism, (b) dogmatism, (c) skepticism and (d) rationalism. The EDQ consists of 12 items and dilemmatic knowledge claims were presented in each item (Hallett, 2000, p.26). Accordingly each item contains four response options based on different epistemic positions. And participants rate each response options from 1 (completely agree) to 5 (completely disagree). A sample question in the EDQ is presented in Figure 2.3. Hallett (2000) reported that EDQ was unable to make distinction between dogmatism and realism. Instead, a new stance was added in the form of "objectivism" (Hallett, Chandler, & Krettenauer, 2002, p.296). Objectivism was also divided into two categories, Obj1: Objectivism (expertise) and Obj2: Objectivism (personal certainty).

Indicate your answer by placing one of the following numbers on the line beside the statement:

1 = completely agree
2 = moderately agree
3 = equally agree and disagree
4 = moderately disagree
5 = completely disagree

5. Some people argue that the universe was created suddenly. Other people say that it evolved over a long period of time. I think that:

(a) We'll never know what happened a million years ago. So whichever of these viewpoints you choose is arbitrary. -- ________ **SKE**

(b) A careful analysis of what really happened will make the answer clear. ------- ________ **OBJ1**

(c) When people argue about things like this they don't have the facts straight. It is quite clear which point of view is right. --------------------------------------- ________ **OBJ2**

(d) It is possible for both theories to explain many of the facts about the origin of the universe. -- ________ **RAT**

WHICH STATEMENT EXPRESSES YOUR OWN VIEWPOINT BEST?

CIRCLE ONE: (a) (b) (c) (d)

Figure 2.3 A sample question from the EDQ (Hallett, 2000, p.55)

Hofer and Pintrich (1997) proposed four-factor structure for the dimensionality of personal epistemology (see Section 2.1.3) by excluding learning aspect (quick learning and innate ability). These were including certainty of knowledge, simplicity of knowledge, source of knowledge and justification for knowing. In order to assess dimensionality and differences across domains, Hofer (2000) developed the discipline-focused epistemological beliefs questionnaire (DEBQ) with a team of researchers in the field. The instrument was an adaptation of preexisting instruments such as CLEV, MER, and EBQ. The DEBQ is a likert-type scale including 27 items. Each item points out a field, subject matter or reference such as "In this field, knowledge is certain." (p.388). Factor analysis revealed similar results as in Qian and Alvermann's (1995) study that certain and simple knowledge dimensions were loaded as one factor. The factors relied on DEBQ were determined as (a) certainty/simplicity of knowledge, (b) justification for knowing: personal, (c) source of knowledge: authority, (d) Attainability of truth. However, justification for knowing and source of knowledge factors were not represented as hypothesized according to items loaded in factors. For instance, justification of knowing was limited to justification by individual rather than assessment of external knowledge such as evidence, or expert opinion.

After development of MPEX, a second version (MPEX-II) of the survey released by Elby, McCaskey, Lippmann and Redish (2001). In this version, MPEX and EBAPS items were reexamined and Hammer's (1994) framework (see Figure 2.2) was adopted as theoretical background. MPEX-II consists of 32 items in total: 25 likert-type items (5 point rating scale), three multiple choice, and four debate questions. Clusters in MPEX-II and sample items are given in Table 2.5. One item in the survey (#19: "A significant problem in this course will be being able to memorize all the information I need to know.") was integrated into coherence and concepts clusters. Even though epistemological dimension are probed with several items, the survey aims to collect information about students' views and expectations in physics learning.

Table 2.5 Dimensions of MPEX-II (Elby *et al*., 2001)

Clusters	Sample items	N of items
Coherence (math, reality, other)	"The extent to which the student sees physics knowledge as coherent and sensible as opposed to a bunch of disconnected pieces."	12
Concepts	"The extent to which students see concepts as the substance of physics -- as opposed to thinking of them as mere cues for which formulas to use."	9
Independence (epistemology, personal)	"The extent to which the student sees learning physics as a matter of constructing her own understanding rather than absorbing knowledge from authority."	12

On the purpose of creating domain-specific instrument, Buehl, Alexander, & Murphy (2002) developed the Domain-Specific Belief Questionnaire (DBSQ) parallel to four-dimensional EBQ. Mathematics and history were selected as domains. Initial version of DBSQ consisted of 82 items created for four-factor structure as in Schommer's (1990). However, two-factor model yielded from factor analysis results that researchers pointed out sample size could cause such a result (Buehl *et al.*, 2002, p.426). By reducing the number of items and increasing number of participants, they conducted another validation study. Exploratory factor analysis revealed a four-factor solution for 22-item version of DBSQ as shown in Table 2.6. Factors are distinguished in instrument according to mathematics and history domains.

Table 2.6 Factors of DBSQ (Buehl *et al.*, 2002, p.436)

Factors	Sample items	N of items	Cronbach's α
Need for effort in mathematics	"Even if it takes a long time to learn a math concept, it is best to keep trying."	5	.68
Integration of information and problem solving in math	"It is a waste of time to work on math problems that have no precise answers."	6	.70
Need for effort in history	"Even if it takes a long time to learn a history concept, it is best to keep trying."	5	.61
Integration of information and problem solving in history	"It is a good use of time to work in history questions that have no precise answers."	6	.75

An alternative to physics related domain specific instrument, a group of researcher in University of Colorado designed the Colorado Learning Attitudes about Science Survey (CLASS) (Adams, Perkins, Podolefsky, Dubson, Finkelstein, & Wieman, 2006). There are 42 items in the survey for physics course. Researchers proposed eight categories for the CLASS, however there are six items uncategorized. Categories are: real world connection, personal interest, sense making/effort, conceptual connections, applied conceptual understanding, problem solving general, problem solving confidence and problem solving sophistication. It should be noted that some items are put into more than one category or two categories. For example, sixth item “Knowledge in physics consists of many disconnected topics.” is related with conceptual connections and applied conceptual understanding by researchers. It is difficult to find out how these two categories differ. In addition, there are some items that concerns attitude toward problem solving in physics such as “I enjoy solving physics problems.” Researchers included very few items on students’ views about physics knowledge. Understanding physics is mostly recognized being able to solve physics problems as in 29th item: “To learn physics, I only need to memorize solutions to sample problems.”

Stahl and Bromme (2007) selected a different approach to measure domain-specific epistemological beliefs. They suggested distinguishing denotative (students’ “explicit beliefs about the philosophy of science that effects their concrete image of nature of knowledge”) and connotative (“evaluative associations”) aspects in order to obtain deeper understanding about students’ epistemological beliefs. In the Connotative Aspects of Epistemological Beliefs (CAEB) questionnaire, semantic differential technique was used. Hypothetical structure of CAEB was based on three factors: simplicity of knowledge, certainty of knowledge, and source of knowledge. Researchers created adjective pairs related to each factor and these were analyzed in terms of relevance and appropriateness by four raters. Initial version of CAEB consisted of 24 items in total. For instance, “simple-complex” or “connected-divided” adjective pairs were included in simplicity of knowledge factor whereas “stable-unstable”, “flexible-inflexible” in certainty of knowledge, and “refutable-irrefutable”, “constructed-preexisting” in source of knowledge factor. Each adjective pair was rated on a 7 point-scale.

In order to test whether CAEB assesses domain specific differences, it was administered in three different subject areas (i.e. plant identification, genetics and physics.) Researchers identified two-factor structure based on factor analysis result (including 17 items) as shown in Table 2.7. Stahl and Bromme (2007) coded these factors differently from previous studies. Texture factor can be associated with structure of knowledge and variability with certainty of knowledge. Moreover, they confirmed that CAEB distinguished students' epistemological beliefs across three academic domains (p.780).

Table 2.7 Factors of CAEB (Stahl & Bromme, 2007, p. 778-9)

Factors	Explanations	Sample Adjective Pairs	N of items	Cronbach's α
Texture	refers to "beliefs about structure and accuracy of knowledge"	"sorted-unsorted" "confirmable-unconfirmable" "objective-subjective"	10	Plants: .78 Genetics: .75 Physics: .83
Variability	refers to "beliefs about stability and dynamics of knowledge"	"completed-uncompleted" "stable-unstable" "dynamic-static"	7	Plants:.75 Genetics: .73 Physics: .76

Stathopoulou and Vosniadou (2007) developed the Greek Epistemological Beliefs Evaluation instrument for Physics (GEBEP) to assess students' beliefs about nature of knowledge as well as process of obtaining knowledge in physics. In spite of existing domain-specific instruments, researchers aimed to construct "an instrument more akin to general cultural and education context within which the learning of physics takes place in Greek secondary schools" (p.262).The instrument focuses on four hypothetical dimensions of students' physics-related epistemological beliefs mentioned in Section 2.1.3 as shown in Table 2.8. Four-factor model for GEBEP yielded from factor analysis which was different than the proposed model.

Justification of knowing factor did not appear even though researchers hypothesized that dimension as core beliefs about process of knowing.

Table 2.8 Factors of GEBEP (Stathopoulou & Vosnidaou, 2007, p.265-7)

Factors	Sample Items	N of Items	Cronbach's α
Structure of knowledge	"It is useful to check whether and how new physics knowledge is related with what you already know."	10 statement items	.67
Construction and stability of knowledge	"Physics textbooks present theories that have been confirmed by scientists and are not going to change."	7 statement items	.56
Attainability of absolute truth	"Sooner or later scientists will reveal all the secrets of nature."	4 statement items	.66
Source of knowing	"How much physics knowledge we get from school mostly depends on the quality of our teachers."	2 statement and 2 debate items	Not reported

Bråten and Strømsø (2009) proposed an alternative instrument to domain-specific level questionnaires. Their aim was to measure topic-specific level epistemological beliefs on climate change. Theoretical framework of the Topic-Specific Epistemic Belief Questionnaire (TSEBQ) was based on Hofer and Pintrich's (1997) model (see Section 2.1.3). Preliminarily, 49 items were written for hypothetical four-factor structures. Each item was rated on a 10 point-scale (1: strongly disagree; 10: strongly agree). Factor analysis yielded four-factor solution with 24 items in total (as given in Table 2.9). However, Bråten and Strømsø (2009) considered certainty and simplicity of knowledge factors as core dimensions within personal epistemology and did not use source and justification components in their study without giving any reasonable explanation.

Table 2.9 Factors of TSEBQ (Bråten & Strømsø, 2009, p.14)

Factors	Sample Items	N of Items	Cronbach's α
Certainty of knowledge about climate change	"What is considered to be certain knowledge about climate today, may be considered to be false tomorrow." "Theories about climate can be disproved at any time."	6	.70
Simplicity of knowledge about climate change	"With respect to knowledge about climate, there are seldom connections among different issues." "Within climate research, various theories about the same will make things unnecessary complicated."	6	.60
Source of knowledge about climate change	No sample item	5	Not reported
Justification for knowing about climate change	No sample item	7	Not reported

2.3. Intervention Studies on Personal Epistemology in Education Research

The studies on personal epistemology heavily rely on relational studies which explore relationships between epistemological beliefs and other measures such as domain/discipline (e.g. Schommer & Walker, 1995; Hofer, 2000), gender (e.g. Baxter Magolda, 1987), academic achievement (e.g. Schommer, Calvert, Garglietti, & Bajaj, 1997), learning orientations (e.g. Tsai, 1998; Tsai, 2007), conceptions about teaching and learning (e.g. Chan & Elliot, 2004), and so on. Based on the findings of previous associational research, some researchers began to conduct intervention studies on developing personal epistemologies in educational context (e.g. Conley *et* *al*., 2004; Valanides & Angeli, 2005; Rosenberg *et al*., 2006; Ryu & Sandoval, 2012; Yerdelen-Damar, 2013; Yaman, 2013). Intervention studies are discussed in this section.

2.3.1. Implicit Interventions to Tap Students' Personal Epistemologies in Education Research

Based on findings of educational research that relates epistemological sophistication with academic achievement, Elby (2001) designed a course to promote epistemological development. Course was given to two different samples including high school students at different academic years. California sample consisted of 27 high school students in San Francisco. The other sample consisted of 55 physics students from gifted and talented students in Virginia. He administered two epistemological surveys in the study. The Maryland Physics Expectations Survey (MPEX) was developed by Redish, Saul and Steinberg (1998). The survey was constructed from six dimensions: independence, coherence, concepts, reality link, math link and effort. The Epistemological Beliefs Assessment for Physical Science (EBAPS) was developed by White *et al*. (1999). The EBAPS was constructed from five non-orthogonal dimensions: structure of scientific knowledge, nature of knowing and learning, real-life applicability, evolving knowledge and source of ability to learn. California sample took EBAPS as pretest and posttest. However, Virginia sample took both tests at the beginning and at the end of the academic year. MPEX results of Virginia sample showed that students' gains were statistically significant for each dimension in the survey. When EBAPS scores were considered, Virginia students' gains were statistically significant for overall survey. However, findings revealed that course was not effective on changing students' views on evolving knowledge and source of ability to learn dimensions. Similar to Virginia sample, California students' gains were statistically significant for overall survey. Students' views were changed significantly on two dimensions out of five except real-life applicability, evolving knowledge and source of ability to learn dimensions.

Elby (2001) discussed that epistemology-focused course might influence students' epistemological views about structure of knowledge (coherent and conceptual structure of physics) and constructive nature of learning dimensions for both average and gifted students (p.S57). In spite of improvement of students' epistemological views, there are some issues related with research design. Absence of control group is a weakness of study to attain success to course itself. For instance, maturation of students throughout an academic year might be a potential source for change in epistemological views. Another issue was comparison of two unique samples. Virginia students were all talented and gifted students. Lastly, researcher's position as instructor might be potential threat for internal validity of the study.

Conley *et al*. (2004) conducted research to examine how epistemological beliefs of elementary school students change over time. 187 fifth graders from 12 elementary schools were participated in the study. Self-reports as measurement instruments were used for data collection before starting and after the completion of a science unit. The instrument consists of 26-item to measure epistemological beliefs along four dimensions. Instruction on the chemical properties of substances was constant in every classroom in the sample. Science process skills and also ability to perform scientific investigation were emphasized in the unit. Teachers encouraged their students to explore the introduced facts and make their own investigations during the class. Next, teachers were expected to start discussion depending on a guideline with suggestions given before the instruction. In general, instruction was formed by three phases. Firstly, teacher reminded of the previous activity and the main concepts and introduces new hands-on activity while giving instructions on what students are expected to record on their notebooks. In second phase, students work in small groups for hands-on activity in the guidance of teacher. And in third phase, whole class discusses the activity at the end of the lecture. Researchers reported zero-order correlations achievement and epistemological beliefs in science. Correlations between first and last measures of the same belief ranged from r= .44 to .76, which suggests both change and stability over time. The results of the analysis show that students who had higher levels of achievement also held more sophisticated beliefs. It is questionable to indicate the changes within the subdimensions of epistemological beliefs (source, certainty, development and justification) over time. In addition, mean score differences across the subdimensions are very small (about .30) to indicate any improvement within those dimensions.

Another intervention study targeting teacher education program was conducted by Gill, Ashton and Algina (2004). Participants of the study were 161 preservice elementary teachers. 90 percent of the students were female. Participants were randomly assigned to experimental and control groups. In experimental group, augmented activation message and refutational texts were used to stimulate particular epistemological beliefs. Augmented activation message presents information that direct students' attention to conflicting ideas with their own. Meanwhile, students have chance to examine different views by this technique. After this instructional text, students read refutational text. The aim of using refutational text is to create dissatisfaction on students' existing beliefs by presenting scientific evidence. In control group, students completed word scramble while experimental group reading augment message. Later, they read an expository text presents information about constructivist epistemology and teaching practices in mathematics without challenging ideas as in refutational text. To assess pre-service teachers' explicit epistemological beliefs, first and third subscales of Cognitively Guided Instruction Belief Survey (CGI) were used. First subscale is about how children learn mathematics and third subscale concerns about teachers' beliefs about methods to teach addition and subtraction. Moreover, eight teaching scenarios on mathematics were developed to get deeper understanding about students' implicit epistemological mathematics beliefs. Students' general epistemological beliefs were measured by Schommer's (1990) Epistemological Beliefs Questionnaire. Researchers used thought-listing task in order to assess degree of students' systematic processing of refutational and expository texts. Pretest (including 30 CGI items, 11 epistemological questions and eight scenarios) administered before students were introduced with constructivism subject. One week later, students were exposed to treatment and posttests. Short time gap between pre and posttest administration is one of the possible threat to internal validity of findings. Simultaneous equation model (path analysis method) was used to find out effect of intervention on epistemological change. Statistically significant difference was found between experimental and control groups on preservice teachers' implicit epistemological beliefs on mathematics due to standardized direct effect of constructivist scenario intervention (SDE = .18, Cohen's d = .36, z = 2.75, $p < .01$), due to standardized direct effect of systematic processing (SDE = .15, z = 2.29, $p < .025$) and due to standardized direct effect of procedural scenarios intervention (SDE = -.14, Cohen's d = -.27, z = -1.86, $p < .05$). Moreover, there was statistically significant difference between experimental and control groups on preservice teachers' explicit epistemological beliefs on mathematics due to standardized direct effect of treatment (SDE=.16, Cohen's d = .31, z = 2.46, $p < .01$). Findings revealed that intervention of augmented activation message and refutational text resulted with more improvement in preservice teachers' epistemological beliefs when compared to standard expository text. However, it should be noted that effect sizes were found small. Also, duration of intervention was too short that it is difficult to underestimate novelty effect.

Valanides and Angeli's (2005) research on effectiveness of teaching critical thinking principles to change university students' epistemological beliefs are an example of intervention studies. 108 undergraduate college students are participated in the study. These participants are randomly assigned to three different intervention session. In first session students are introduced with an ill-defined problem. Students read and summarized the article. In second session, three different methods are used separately in three groups. (1) General teaching intervention consists of reading and outlining task. (2) Infusion teaching intervention consists of discussion, preparation of outline, reflection of ideas, lecturing, and completion of outline for the task. (3) Immersion teaching intervention is implemented starting with discussion and continued with preparation of outline, reflection of ideas, Socratic questioning, and completion of outline for the task. And third session was same with the first session. The data collection is done by Epistemic Belief Questionnaire Form A and Form B adapted from King and Kitchener's (1994) interview questions. Researchers reported correlation between pre and post measures of epistemological beliefs were significantly correlated, either as .05 or .01. The findings indicated that posttest scores were higher than pretest scores for each teaching session. Repeated measures of ANOVA was used as a statistical analysis that results show that posttest performance is significantly higher than pretest performance (F (2, 105) = 19.769, p = .00), and the main effect related to the between subjects independent variable was significant (F (2, 105) = 3.995, p = .021). The interaction effect between treatment and epistemological beliefs was not found to be significant (F (2, 105) = .933, p= .397).

Finkelstein and Pollock (2005) investigated the effectiveness of "Tutorials in Introductory Physics" on university students' conceptual understanding. These tutorials were designed to assists classical calculus based physics instruction by modification of recitation hours. Meanwhile, they explored if there would be any change in students' beliefs about physics and physics learning by administering CLASS. Researchers claimed that the course implicitly conveys "metamessages" about "how, why and by whom science is learned" (p. 010101-4). Force Concept Inventory (FCI) and Force Motion Conceptual Evaluation (FMCE) were used to measure students' conceptual gains after tutorials. Although normalized gain was calculated as 0.67 which indicates high-gain for conceptual scores, the results of CLASS revealed no significant change in students' beliefs about learning. In addition, researchers reported low but statistically significant correlations between CLASS score and pre and post FMCE scores (.24 and .34 respectively). They concluded that students' belief about learning may be affected by learning experience by referring to correlations.

To investigate coherency of the cognitive structure accounted for students' personal epistemologies, Rosenberg *et al*. (2006) conducted a case study on eight graders. Researchers advocated that variability of the cognitive structure in a particular domain will indicate a complex model rather than a coherent system of beliefs. The purpose of this case study was to observe nature and role of epistemology in classroom context instead of using interviews or surveys. Source of data were students' statements and argumentations during the discussion. The focus was not on nature of knowledge. Twenty-two eighth graders in a suburban middle school were participants of the study. Students were expected to read a worksheet about "How are rocks formed?" In first discussion segment after reading worksheet, students discussed the question. Authors stated that students are not very productive in discussion where they even misused the technical words. In second segment, teacher started the discussion with a statement "start from what you know". Based on teacher's intervention, students were expected to focus on one way to engage with the epistemic activity. In third segment, students seemed to be more flexible about forming their knowledge. Because they did not feel themselves dependent on the text (as source of knowledge) that they became the source of making meaning. And in last segment, students are expected to discuss "where does it get heat and pressure?" question. Students tried to find casual evidence based on already formed knowledge and they began to find discrepancies in the story and the information they need to answer this question. Authors explained these changing situations as shifts in students' epistemologies.

Kienhues, Bromme and Stahl (2008) studied with 58 university students from different departments (e.g. psychology, education) in a German university. They conducted a short-term intervention study to explore to what extent individuals change their epistemological beliefs by the refutational epistemological instruction. They gave "pure information" to comparison group by informational instruction (p.549). Researchers pointed out that these instructions might affect different existing epistemological beliefs. It should be also noted that instruction refers to reading task in this study. Research design was 2x2 factorial pretest and posttest design to examine effect of instruction type (refutational epistemological instruction vs. informational instruction) and students' epistemological profiles (naive vs. sophisticated). Students' epistemological beliefs were measured by two instruments: (a) German version of Hofer's (2000) Discipline-Focused Epistemological Beliefs Questionnaire (DBEQ), and (b) Stahl and Bromme's (2007) Connotative Aspects of Epistemological Beliefs (CAEB). These two instruments are not necessarily measures same aspects of the epistemological beliefs. In addition to epistemological measures, researchers collected more data for control variables such as students' need for cognition, verbal intelligence and knowledge of genetics. For epistemological instruction, the subject was selected as research on DNA fingerprinting. In comparison group the reading task was written as in traditional textbooks to convey information about fingerprinting without controversial ideas. In treatment group, refutational text begins with "DNA fingerprinting is a safe method". This part introduced knowledge on DNA fingerprinting as known and certain. Then, "the uncertainties and difficulties in DNA fingerprinting" was discussed in text. Epistemologically, certainty of knowledge dimension was stimulated in this group. Participants reached out these texts on-line. MANOVA for repeated measures was performed to assess effectiveness of instruction, prior epistemological beliefs and interaction effect. Main effect of instruction type and interaction between instruction type and prior epistemological beliefs were found non-significant. However, main effect of prior epistemological beliefs was found significant (F (6, 49) = 32.91, p < .01, partial eta squared = .80). There was statistically and practically significant difference between pre and post measurements regarding to stability factor (F (1, 54) = 9.55, p < .01, partial eta squared = .15) and simplicity and certainty factor in DEBQ (F (1, 54) = 21.19, p < .01, partial eta squared = .28). Researchers reported that they failed to promote significant changes in naïve refutational group as expected. Meanwhile, results of CAEB provided evidence for change in epistemological beliefs due to instruction type. Only naïve and sophisticated refutational group displayed significant changes between pre and posttest measures. Naive group improved their scores but sophisticated group views became more naïve.

Redish and Hammer (2009) conducted a project to transform introductory algebra-based course by examining the components of the curricula. They designed a physics course for biologist based on their needs to stimulate students' productive conceptual and epistemological resources. In the course, epistemological integration was explicit and these integrations were categorized as shopping for ideas, sense making, seeking coherence, restricting the scope, etc. They adapted Peer Instruction into classes which start with clicker questions. Lectures illustrated with interactive lecture demonstrations. Researchers used variety of data collection tools, such as videotaping tutorials, laboratory activities, courses, students' responses to clicker question in peer instruction, quizzes, homework and exams, semi-structured interviews with volunteer students, conceptual surveys (FCI) and FMCE), epistemological surveys (MPEX-II). MPEX-II was prepared by researchers by using items from MPEX and EBAPS. It consists of 32 items (25 statements and seven multiple choice items). Results on concept learning showed that average gains in treatment class were between 0.44 and 0.47 which indicated moderate improvement. In reformed laboratories, students spent more time (about %20) on sense-making when compared to a traditional laboratory session. On the other hand, epistemological survey results (MPEX-II) indicated strong gains in class. These strong gains were calculated for concepts and coherence categories. Researchers noted that they were able to improve reality category from 66 percent to 73 percent favorable response. However, non-significant gain was found for independence category. In accordance with the results, researchers concluded that reforming instructional environment with well-known practices in science education promoted higher improvement in concept learning despite of little change in expectations and attitudes about course.

From a different perspective, Ryu and Sandoval (2012) investigated the effect of scientific argumentation on students' personal epistemological understanding. More specifically, they focused on whether argumentation improves practical use of "epistemic criteria for scientific arguments" (p.489) such as use of coherency of causal claims and justification of knowledge with appropriate evidence. In detail, four epistemic criteria were determined: (a) causal structure, (b) causal coherence, (c) citation of evidence, and (d) evidentiary justification. For the study, sample was selected from third and fourth grade classrooms. In total, 21 students participated in the study including nine third grader and 12 fourth graders. In classrooms, scientific content was integrated with different student activity like epistemological activity, guided activity, open-ended group experiment, planning presentation and final presentation. The teacher often directed epistemic questions such as "how do we know what we know?" and "How can a hospital administrator convince others that longer visiting hours are good?" (p.496). Researchers developed "an argument construction task" (p.499) for assessment. Students encountered with scientific questions and they were expected to provide claims by using available information. Later, students' written arguments are evaluated by using a rubric concerning epistemic criteria. Results of the study showed that students performed better after implementation (pretest: M = 3.19, SD = 0.75; posttest M = 3.90, SD = 0.39; $t(20) = 5.08$, $p < .001$) (p.503). They also noted that children demonstrated better performance to comprehend causal structure, evidence citation and explicit justification. However, they performed worse at causal coherence which might be difficult task for that age group.

Muis and Duffy (2013) designed an instruction in order to foster changes in s students' beliefs, learning strategies and to improve their achievement. The intervention was applied to a graduate-level statistics class that students displayed less constructivist beliefs in the subject-domain, students' learning strategies were primarily rote memorization and they had low motivation level. There were 63 graduate university students (46 female, 17 male) enrolled in graduate programs in education, nursing, health promotion, psychology, etc. 32 participants were in control group class and 31 were in intervention group. Research design was multiple time testing and control group design. To assess students' epistemic beliefs, Hofer's (2000) Discipline-Focused Epistemic Beliefs Questionnaire (DFEBQ) was used in the study. In order to assess critical thinking skills, Motivated Strategies for Learning Questionnaire (MSLQ) was administered to participants. And for achievement, students' scores on exams and assignments including final grade they get from statistics course were used. Intervention in instruction was done in four epistemological dimensions. Certainty and simplicity of knowledge dimensions were stimulated by a question asked by instructor. In small groups, students studied together to give answer and presented their results in class. Furthermore, these presentations led to new discussions. Also instructors introduced different evolving statistical approaches and debates about them during the course. For source dimension, students were encouraged to interact with their peers and study collaboratively. The aim was to give message about knowledge is constructed by personal learning and interaction with others. Justification dimension was pointed out by the professor "relying on logic and reason to justify why approaches and solutions to problems were correct" (p.218). In other words, intervention class focused on justification of knowledge by the process and product of inquiry, self opinions and individual experiences. The uniqueness of the study was based on five time measurement (week 2, 4, 8, 12, 15) in the semester. Researchers were able to examine whether epistemological dimensions started to change between consecutive weeks. Main effect of time was only found significant for attainability of truth dimension (F (4, 58) = 2.50, p < .01, partial eta squared = .15). Main effect of the instructional group was significant for justification of knowledge (F (1, 61) = 4.97, p < .01, partial eta squared = .06), attainability of truth (F (1, 61) = 8.86, p < .01, partial eta squared = .13), certainty and simplicity of knowledge dimensions (F (4, 61) = 11.75, p < .001, partial eta squared =. 16). These results also practically large effect sizes when partial eta squared values are considered. Researchers reported significant interactions between time and instructional group in each epistemological dimension. In accordance with the results, intervention method was effective to promote epistemological change in students' beliefs. In fact, these changes in beliefs did not occur quickly bur gradually.

Another doctoral study (Yaman, 2013) completed in same year was also investigated the effects of instructions based on conceptual change strategies (i.e. cognitive bridging and cognitive conflict) on students' conceptual understanding, epistemological beliefs and self-efficacy. Researcher hypothesized that different conceptual change strategies has distinct potential to effect students' with different personal epistemologies. 206 ninth grade high school students from two different schools participated in the study. Within this sample, one control and two treatment groups were selected from each school. The duration of implementation including pre and post testing process took six weeks in total. Researcher used translated version of EBAPS (White *et al*., 1999) by himself to measure students' epistemological beliefs. Validation process was not reported in detail except content validity and face validity. Construct validity was not the concern. Reliability of the test, Cronbach's alpha, reported as .43. According to results, no significant difference was observed between two groups treated with different conceptual change strategies in terms of epistemological beliefs at the end of the treatment.

2.3.2. Explicit Interventions to Tap Students' Personal Epistemologies in Education Research

Brownlee, Purdie and Boulton-Lewis (2001) explored the influence of an enhanced teaching program on pre-service teachers' epistemological beliefs at the Queensland University of Technology in Australia. This study was the first phase (Phase 1) of a longitudinal project. They selected two groups: research group (RG) and comparison group (CG). Participants of the RG were selected purposively from who enrolled into enhanced teaching program (29 Graduate Diploma in Education students). These students had already undergraduate degrees (i.e. business, social science, psychology, etc.). And they enrolled in this one year long teaching program to obtain diploma to teach in primary schools. The CG was formed by 25 students. Main difference between RG and CG was that RG students were expected to make reflections on the content by establishing link with epistemological beliefs literature and their personal epistemologies. These students kept personal journal to record their reflections explicitly. Reflections on the journal and the feedback given on these reflections were used in interviews with students. Then emergent constructions were shared and discussed with next interviewee. Later in a whole group discussion, all constructions were represented and new discussions were prompted. Schommers' (1990) Epistemological Beliefs Questionnaire was administered both RG and CG for twice (Time 1 and Time 2) in order to collect quantitative data. Qualitative data was collected by 35-60 minutes interviews from RG for twice. In CG, qualitative data was collected by a task "to complete written statement about their beliefs about knowing" (p.255). This task was given at the beginning and at the end of the year. Results of the repeated measures ANOVA showed that there were significant differences between two groups in two dimensions: quick learning (calculated Cohen's d= .61, medium effect size) and certain knowledge (calculated Cohen's d= .12, small effect size). Students in CG revealed more responses close to learning should be quick while number of students in RG decreased in terms of quick learning. On the other hand, RG students displayed progress toward relativistic view of truth while CG students did not change their views over time in terms of certain knowledge. Researchers had extended five dimensions in epistemological beliefs questionnaire into 12 dimensions. Accordingly, they found out difference between RG and CG for two more sub-dimensions: (a) "Cannot learn how to learn" in innate ability dimension, and (b) "Depend on authority" in omniscient authority dimension. Number of students in RG increased who responded as ability to learn is changeable whereas less number of students in the group responded that individual should depend on authority. Qualitative data analysis was also supported the quantitative analysis that more students in RG gave sophisticated answers than students in CG at Time 2. Results of the study showed that explicit reflections on epistemological beliefs promoted development in students' epistemologies. However, it should be noted that practical significance of the finding was medium for quick learning and small for certain knowledge. And number of participants was small to make generalizations from results of the study.

In Phase 2, Stacey, Brownlee, Thorpe and Reeves (2005) examined the effect of explicit reflection in a research method course on early childhood pre-service teachers' personal epistemologies. 65 pre-service teachers (60 female and 5 male) participated into the study. It is worth to note that participants were also co-researchers in current study and they were expected to write an empirical report for assessment. In order to stimulate personal epistemologies, students interviewed their critical friends on their beliefs and critical friends interviewed these students in return. They were expected to write interview result as a report in terms of personal epistemology literature. In the course, students engaged with multiple research methods and they tried to make associations with epistemology literature. To assess epistemological beliefs, online version of Schommer's (1998) EBQ was used as pre and post tests. They reused 12 subscales in Phase 2 emerged from Schommer's scale in Phase 1. Repeated measures t-test was performed to evaluate change in epistemological beliefs. Results showed that there were significant changes occurred in students' epistemological beliefs after intervention especially in Innate Ability scale ($t(51) = 2.62$, p = .012). Significant changes observed in following subscales: "Avoid Integration" ($t(52) = 2.84$, p = .006), "Knowledge is Certain" ($t(53) = 2.09$, p = .041), "Don't Criticize Authority"($t(53) = 2.77$, $p = .008$), "Ability to Learn is Innate"(t (51) = 2.04, $p = .046$) and "Success Unrelated to Hard Work" (t (51) = 2.62, $p < .001$). These changes indicated movements from naïve beliefs to sophisticated beliefs. There are limitations of study that no control group was formed for comparison. Therefore only pre and posttest results of sample were compared. Gender bias due to selection of department also restricts generalization of results. As participants were co-researchers, they were aware of the research questions that may also cause researcher bias.

Brownlee, Petriwskyj, Thorpe, Stacey and Gibson (2011) kept on exploring effects of explicit reflections in integrated teaching program on students' personal epistemologies as Phase 3 study. The program was adopted social constructivist approach to foster epistemological change through implicit and explicit reflections on epistemology. In this program students were engaged with themes such as evidence-based thinking and practice, multiplicity in ways of knowing, etc. Four units in the program were selected for the current study. Research in Early Childhood Education lecture was the last lesson in which students shared their thoughts emanated from at the end of the program. In this lecture, students were expected to submit a short research project in order to make explicit reflection on their personal epistemologies. Research design was mixed-method design including quantitative and qualitative data collection processes. To assess changes in student epistemologies, Kardash and Wood's (2000) the Epistemological Beliefs Survey (EBS) was used. 73 students were responded to the survey. Qualitative data was gathered from open-ended questions on the EBS (N=25) and students' journal reflections (N=51). According to results of quantitative analysis, there was significant positive change in students' epistemological beliefs at the end of the program (for "structure and integration of knowledge" $t(23) = -4.07$, $p < .001$, Calculated Cohen's $d = 0.42$; for "speed of knowledge acquisition" $t(23) = -3.28$, $p = .003$, Calculated Cohen's $d = 0.57$; for "knowledge as the construction of personal meaning" $t(23) = -2.16$, $p = .041$, Calculated Cohen's $d = 0.31$; and "view of student success as based on innate ability" $t(23) = -2.16$, $p = .042$, Calculated Cohen's $d = 0.30$). It should be noted that even though statistical significance was found for these subscales, practically small effect sizes for each subscale were observed except speed of knowledge acquisition (moderate effect). Results of qualitative analysis revealed that as students acquired more or "increased knowledge", they made more explicit associations between different units (p.486).

A study on epistemological understanding in physics was conducted by Yerdelen-Damar (2013) as a doctoral thesis in Turkey. Her study focused on the effect of epistemologically and metacognitively stimulated 7E learning cycle (EM-7ELC) method on students' physics achievement and epistemological understanding. 107 tenth grade students in an Anatolian Teacher Training High School (ATTHS) were participated in the study. Each component of the learning cycle was enhanced by different epistemic activities. For example, "elicit phase" was illustrated by concept mapping, "group discussion led by metacognitive and epistemological prompts" (p.64). The aim of such activities was to make aware of students about their own knowledge, their intuitive knowledge and their classmates' knowledge. In "extend phase", refinement diagrams and implication games were embedded to assist students' to refine their own knowledge. To assess students' achievement two different tests were used: the force and motion test-I and II. The Turkish Physics Expectation Survey was administered to assess students' epistemological understanding in physics. This test was adapted by Yerdelen-Damar, Elby and Eryilmaz (2012) from the Maryland Physics Expectations Survey-II (MPEX-II). Internal consistency coefficient was reported as .64 for pretest and .72 for the posttest scores. Results of the study showed that EM-7ELC was an effective method to develop students' epistemological understanding when compared to traditional instruction (F (1, 100) = 19.97, $p < .001$, partial eta squared = 0.17).

2.4. Summary of the Literature Review

Initial research recognized that individuals' perspectives about knowledge and knowing were influential on their learning process. Emanating from this point, researchers argued about how students' perspectives, in other words, personal epistemologies change over time. Perry (1968) was pioneer of developmental view of personal epistemology in the field and Belenky *et al*. (1986) and Baxter Magolda (1987) conducted comprehensive works on this view. In general, early studies suggested individual's personal epistemology develops through stages ranges between unsophisticated (e.g. absolutist, dualist, etc.) and sophisticated epistemologies (e.g. relativist). Another common feature of this view was adopting unitary structure of personal epistemology which was independent of content and context. Research focusing on relationship between text comprehension and personal epistemologies indicated discrepancies about existing models (e.g. Ryan, 1982). Accordingly, Schommer (1990) proposed a multidimensional structure that each dimension was independent from each other which also suggests different progression can be observed across dimensions over time. In her studies, Schommer (1990, 1993) used the five hypothetical dimensions in her model (and in EBQ) that inspired further research to investigate which epistemological elements compose personal epistemology (e.g. Hofer, 2001). In the current study, multidimensional perspective on personal epistemology was adopted instead of unitary structure suggested by earlier studies. The literature on personal epistemology brought out various hypothetical dimensions suggested by educational psychology researchers. There are similarities as well as differences in these dimensions. In order to get benefit from each perspective (such as epistemological theories or epistemological resources approach), there is a need for more elaborated structure which defines personal epistemology.

In previous studies, there are examples of intervention studies based on different conceptual frameworks related to personal epistemology. Despite of very limited information provided in most of the studies about what had been done in actual classrooms, there are two different approaches followed by the researchers: implicit versus explicit. The implicit approach in intervention studies (e.g. Finkelstein & Pollock, 2005) did not make intended contribution for fostering students' personal epistemologies when compared to explicit approaches (e.g. Elby, 2001; Redish & Hammer, 2009; Yerdelen-Damar, 2013). In Turkish settings, there is only one unique example of explicit approach (Yerdelen-Damar, 2013) that researcher developed a specific instruction to foster students' personal epistemologies and achievement in force and motion unit. Results of the study indicated that epistemologically and metacognitively enhanced learning cycle instruction fostered both students' epistemological understanding as well as conceptual understanding in physics.

Intervention studies on personal epistemology were conducted mostly on undergraduates (e.g. Elby, 2001; Valanides & Angeli, 2005; Kienhues *et al.*, 2008; Redish & Hammer, 2009), post-graduates (e.g. Muis & Duffy, 2013) and pre-service teachers (e.g. Brownlee *et al.,* 2001; Gill *et al*., 2004; Stacey *et al*., 2005; Brownlee *et al*., 2011). In recent research studies, elementary and middle school students' (e.g. Conley *et al*., 2004; Rosenberg *et al.*, 2006; Ryu & Sandoval, 2012) and high school students' personal epistemologies (e.g. Yerdelen-Damar, 2013; Yaman, 2013; Yerdelen-Damar & Eryilmaz, 2016) were also recognized as essential component in science learning. Therefore, recognition of personal epistemology in early ages may help students to be more successful in science courses. For this purpose, more intervention studies on younger students should be conducted to grasp idea about how to design more efficient instruction to convey epistemic messages.

CHAPTER 3

METHOD

This chapter provides detailed information about the methodology of the research used in the study. In the first section, population and sample of the study are presented. The variables of the study and the instruments used for data collection are introduced in the following sections. In the fourth section, instructional materials developed for the treatment groups are presented. Research design of the study, procedures used for controlling internal validity threats, the procedure followed for the implementation of treatments and the issues about treatment fidelity, treatment verification, statistical analysis of the data, power analysis, assumptions and limitations of the study are discussed in the following sections.

3.1. Population and Sample

The target population was all ninth (9^{th}) grade students in Anatolian teacher training high schools (ATTHS) in Ankara. There were 10 ATTHSs in Ankara between 2013-2014 years. In total, 1362 ninth graders were enrolled in these schools. The accessible population of this study is defined as all ninth grade students at Anatolian teacher training high schools in Çankaya district of Ankara, Turkey. Sample of the study was selected from two ATTHSs in accessible population. There were 440 students in these two schools. Purposive sampling was used as the sampling method because two conditions were required to conduct the research effectively. The first condition was that teachers with at least three classes were needed to control possible teacher effects and the second condition was the availability of physics laboratory facilities for the implementation of treatments.

Only one of the two ATTHSs in Çankaya with six classes met the required conditions to be included in the study. This sample included 186 students which corresponded to 42 percent of the accessible population and 14 percent of the target population. Therefore, treatment and control groups were randomly assigned to the already-existing classes. Two out of them were instructed on explicit epistemologically enhanced instruction (EEEI) while implicit epistemologically enhanced instruction (IEEI) was implemented in another two classes Latter two classes were instructed based on conventional instruction (CI). All of the classes were taught by the same teacher. The sample of the study was consisted of 186 students. This sample size was also larger than the value of 69.3 obtained using Cohen's tables for power analysis (Cohen, Cohen, West & Aiken, 2003), which will be discussed later in power analysis section in this chapter. Detailed demographic information about students' distribution in different groups is presented in Table 3.1.

Table 3.1 Sample of the study in terms of instructional grouping, age and gender

		Gender					
		Female		Male		Total	
Group	Age	N	%	N	%	N	%
EEEI	14	6	3.22	2	1.08	8	4.30
	15	30	16.12	18	9.68	48	25.80
	16	1	0.54	5	2.69	6	3.23
subtotal		37	19.88	25	13.45	62	33.33
IEEI	14	4	2.15	4	2.15	8	4.30
	15	29	15.60	18	9.67	47	25.27
	16	6	3.23	3	1.61	9	4.84
subtotal		39	20.98	25	13.43	64	34.41
CI	14	3	1.61	8	4.30	11	5.91
	15	30	16.13	19	10.21	49	26.34
	16	0	0.00	0	0.00	0	0.00
subtotal		33	17.74	27	14.51	60	32.25
Total		109	58.60	77	41.40	186	100

As can be seen from Table 3.1, percentage of female students (% 58.60) is higher than male students (% 41.40). But for each group type, number of students (in terms of gender) was almost homogeneously distributed (which was done by the school administration at the beginning of the school year). In addition, students' age average was about 15 (~14.94). Older students at age 16 were mostly found in IEEI groups. Moreover, data of students' achievements in physics course in the first semester was directly provided by the physics teacher. Achievement means for each class of experimental and control groups were given in Table 3.2. Due to differences among groups in terms of age, gender and previous semester physics course grade (out of 100), these variables can be used as potential covariates in the current study.

Table 3.2 Class averages of previous semester physics course grades (out of 100)

	Treatment Groups		Control Groups
	EEEI	IEEI	CI
Class	Mean	Mean	Mean
9A	-	72.39	-
9B	-	73.13	-
9C	-	-	70.33
9D	-	-	74.19
9E	75.65	-	-
9F	72.00	-	-

In the school, there were two physics teachers and only one of them was responsible from six ninth grade physics classrooms. Therefore, one teacher involved in this study. The teacher was female and has almost 20-year experience in the field. She had been participated another thesis study about physics related epistemological beliefs which was held 2 years ago. She was familiar with the purpose and conceptual framework of the study.

3.2. Variables

In this study, there are six independent variables (IVs). These are the students' gender, age, type of instruction (METHOD), previous semester physics course grade (PPHYSCG), pretest scores on Heat and Temperature Achievement Test (PREHTAT) and the pretest scores on Physics Related Personal Epistemology Questionnaire (PREPPEQ).

PPHYSCG, PREHTAT, PREPPEQ, and age are continuous variables. Gender and METHOD are categorical variables. METHOD has three different levels: explicit epistemologically enhanced instruction, implicit epistemologically enhanced instruction, and conventional instruction in this study.

There are two dependent variables (DVs) which are the posttest scores on the Heat and Temperature Achievement Test (POSTHTAT) and the posttest scores on the Physics related Personal Epistemology Questionnaire (POSTPPEQ). These are continuous variables, which are measured on interval scale. The list of variables included in the study is given in Table 3.3.

Table 3.3 List of variables used in the study

Name	**Type**	**Nature**	**Scale**
GENDER	IV	Categorical	Nominal
INSTRUCTION	IV	Categorical	Nominal
AGE	IV	Continuous	Interval
PPHYSCG	IV	Continuous	Interval
PREHTAT	IV	Continuous	Interval
PREPPEQ	IV	Continuous	Interval
POSTHTAT	DV	Continuous	Interval
POSTPPEQ	DV	Continuous	Interval

3.3. Research Design

Due to mandatory situation took place in Turkish school system; it was not possible to form new classes by random selection. For this reason, intact groups in the school were randomly assigned to control and treatment groups. In addition, these groups were statistically controlled on some related variables by using covariance analysis. As a result, the study adopts quasi-experimental design; more specifically pretest-posttest control group design was employed (Fraenkel & Wallen, 2006).

As shown in Table 3.4, firstly all groups took pretests of the PPEQ and the HTAT two weeks before the treatments. Treatments were started at the first week of April, 2014. After administration of pretests, one of the treatment groups was instructed by the EEEI while other treatment groups by IEEI and control group was taught by conventional instruction until the end of May. At the end of the treatments, the first of week of June, the PPEQ and the HTAT were administered again as posttests.

Table 3.4 The research design of the study

Group	**Pretest**	**Matching**	**Treatment**	**Posttest**
EEEI group (Treatment 1)	PPEQ HTAT	Statistical matching	Instruction based on explicit epistemologically enhanced instruction	PPEQ HTAT
IEEI group (Treatment 2)	PPEQ HTAT	Statistical matching	Instruction based on implicit epistemologically enhanced instruction	PPEQ HTAT
CI group (Control)	PPEQ HTAT	Statistical matching	Instruction based on conventional instruction	PPEQ HTAT

3.4. Instruments

Two measurement instruments were used in this study: the Heat and Temperature Achievement Test (HTAT) and the Physics related Personal Epistemology Questionnaire (PPEQ). For treatment verification, the classroom observation checklist was used. In the following sections, further information about these instruments is given.

3.4.1. The Heat and Temperature Achievement Test (HTAT)

The HTAT was developed by the researcher by considering objective list presented in 2013 high school physics curriculum published by the Ministry of National Education. This test aims to assess ninth grade students' academic achievement in heat and temperature unit. Prior to construction of the HTAT, the objective list of the heat and temperature unit in ninth grade level was examined. The table of test specification was prepared based on these objectives (see Appendix A). First version of the HTAT is given in Appendix B. At least one question for each objective was written by the researcher or adopted from other resources such as textbooks and internet.

For the construct and content validity of the HTAT, the expert opinion checklist was developed by the researcher (see Appendix C). The checklist was used for assessing the compatibility of objective levels and objectives as well as the compatibility of objectives and test items. In total, six experts including one associate professor and four assistant professors (PhD in physics education) and one high school physics teacher (four-year experience in teaching) reviewed the test and completed the checklist. They evaluated the answer key and the scoring rubric as well as appropriate use of language for each item.

According to experts' feedbacks and suggestions, the test was modified (revised version of the HTAT in Appendix E and answer key in Appendix F). Individual analysis of objectives showed that objectives ranged between remembering and analyzing levels according to Bloom's revised taxonomy (see Appendix D). First version of HTAT was administered to three high school students. Observations during implementation of the test gave hints about testing time and student's opinions were taken after completion of the test. Students gave feedback mostly about clarity of expressions in the test. Due to experts' opinion and researcher's observation results, final version of the test was prepared. The feedbacks provided by different sources and the revisions made by the researcher can be summarized as follows:

- *Compatibility of objective levels and objectives:* Some of the objectives coded as remembering and understanding were revised according to the feedback provided by the experts.
- *Compatibility of objectives and test items:* All experts agreed that test items are compatible with the table of test specification prepared according to the objectives and cognitive level of each objective.
- *Testing time:* Students had difficulty to complete the test in 45 minutes because of the open-ended questions. There were four open ended questions and none of the students were able to answer two of the questions (question 34 and 36) in the first version of the test. After discussion with experts, researcher decided to delete those items because there were other items measuring the same objectives.
- *Readability of the test:* Students did not find any difficulty while reading the text and related graphs of the test items. Experts and high school teacher were also agreed with the readability of texts.
- *Compatibility of the expressions (e.g. vocabulary, length of sentences etc.) in the test with students' level:* As aforementioned, both questions 34 and 36

were found problematic in the first version by both students and experts. The length of the question seemed to be inappropriate for students to comprehend. Other test items were found appropriate for students' level by experts and high school physics teacher.

Revised version of the test was consisted of five parts and 34 questions in total. These parts included: (a) 10 true-false (TF), (b) 10 short answer (SA), (c) seven matching, (d) six multiple-choice (MC), and (e) one structured open-ended questions respectively. Students' responses to test items in the Post-HTAT were analyzed by using SPSS to examine item statistics in terms of item difficulty (p-value) and item discrimination index (point-biserial correlation). Item difficulty indicates the proportion of individuals answered the item correctly (Crocker & Algina, 1986). It ranges between 0.00 and 1.00. Hambleton, Swaminathan and Rogers (1991) suggested that item difficulty indices may vary between .20 and .80 for a classroom achievement test. As the value gets closer to 1.00, it indicates that difficulty of item is easy.

Another statistics, item discrimination, indicates whether an item can differentiate between low and high achievers. Item discrimination index ranges between -1.00 and +1.00. Higher positive item discrimination index shows that the item was correctly answered mostly by high achievers within group (Crocker & Algina, 1986). Internal reliability coefficient for the post-HTAT was found as .841. However, the coefficient was found as .858 when essay questions were excluded. The difference may emanate from the low response rate for the essay type question. In Table 3.5, internal reliability coefficients of post-HTAT are presented for each item type. Reliability of selective type items (i.e. TF, matching, and MC) are higher than written response items (i.e. SA). Interestingly, students were not willing to write a sentence or a phrase for short answer and essay type questions.

Table 3.5 Internal reliability coefficients of item types

Item type	Cronbach's alpha coefficient
TF	0.835
SA	0.626
Matching	0.821
MC	0.674
Overall	0.858

For True/False questions, internal reliability coefficient was .835. Table 3.6 presents corrected item-total correlation values (point-biserial correlation) and p-values (item difficulty). Difficulty level ranged between .075 (difficult) and .866 (very easy). The most challenging question in this part for the sample was TF04. The question was related with the misconception "matters do not contain heat." Similarly, when researcher asked "we cannot talk about heat of a substance" in TF08, most of the students did not answer the item correctly. Even though questions are in remembering and comprehension level, the students found the test difficult.

Table 3.6 Item statistics for TF questions in Post-HTAT

	Corrected Item-Total Correlation	p-value		Corrected Item-Total Correlation	p-value
TF01	.758	.866	TF06	.347	.242
TF02	.389	.247	TF07	.779	.709
TF03	.764	.839	TF08	.439	.156
TF04	.257	.075	TF09	.713	.629
TF05	.370	.457	TF10	.392	.296

Short answer items were found a little bit problematic according to students' responses (see Table 3.7). None of the students responded to SA13 (related to rate of energy transfer in comprehension level) and SA14 (related to heat insulation). Lower rates of responses were reflected to the item statistics as shown in below. When the researcher revisited experts' opinion, these questions were found as appropriate for students' grade level and content. In order to provide content validity, any of these items from the students' data was excluded.

Table 3.7 Item statistics for SA questions in Post-HTAT

	Corrected Item-Total Correlation	p-value		Corrected Item-Total Correlation	p-value
SA11	.479	.419	SA16C	.362	.005
SA12	.364	.468	SA17A	.303	.156
SA13	.000	-	SA17B	.312	.194
SA14	.000	-	SA17C	.284	.129
SA15	.429	.333	SA18	.471	.419
SA16A	.391	.156	SA19	.198	.005
SA16B	.340	.005	SA20	.277	.021

Internal reliability coefficient for matching items was .821. Item difficulty ranges between .167 (difficult) and .667 (moderately easy). Result of item statistics for matching items are given in Table 3.8. Recommended point-biserial value for an item between .15 and .25 indicates a good item. Matching26 item has the lowest point-biserial value of .205. This is probably because in ways of energy transfer topic, students examined various situations in daily life and concluded that there may be more than one way of energy transfer occurring simultaneously.

Table 3.8 Item statistics for matching items in Post-HTAT

	Corrected Item-Total Correlation	p-value		Corrected Item-Total Correlation	p-value
Matching21	.478	.489	Matching25	.243	.167
Matching22	.503	.559	Matching26	.205	.280
Matching23	.580	.667	Matching27	.332	.290
Matching24	.640	.667			

In matching type items dominant ways of energy transfer in a particular situation were asked. Students' selections are shown in Table 3.9. Students encountered difficulty to distinguish between convection and radiation for fireplace in 25th item. From a closer distance, radiation is the dominant way of energy transfer due to burnt coal and wood. Majority of the students chose convection as a way of energy transfer, most probably because of existence of air between fireplace and oneself. Similar responses are observed for 26th item.

Table 3.9 Students' responses in matching part in Post-HTAT

Item No.	A: Conduction	B: Convection	C: Radiation
Matching21	33 (% 18.1)	*91 (% 50.0)	58 (% 31.9)
Matching22	*104 (% 57.1)	20 (% 11.0)	58 (% 31.9)
Matching23	10 (% 5.5)	50 (% 27.5)	*122 (% 67.0)
Matching24	*124 (% 68.1)	12 (% 6.6)	46 (% 25.3)
Matching25	30 (% 16.5)	121 (% 66.5)	*31 (% 17.0)
Matching26	38 (% 20.9)	92 (% 50.6)	*52 (% 28.5)
Matching27	128 (% 70.3)	*54 (% 29.7)	0 (% 0)

* Correct answer

Internal reliability coefficient for multiple-choice questions was found .674. Item discrimination index of each MC item is higher than the acceptable value of .25 (see Table 3.10). P-values ranged between .203 (difficult) and .727 (easy) which indicates that MC questions varied in difficulty level.

Table 3.10 Item statistics for MC questions in Post-HTAT

	Corrected Item-Total Correlation	p-value		Corrected Item-Total Correlation	p-value
MC28	.494	.203	MC31	.592	.522
MC29	.252	.727	MC32	.596	.411
MC30	.409	.627	MC33	.326	.647

The most difficult MC question for the sample appears to be MC28. Actually, MC28 requires only a simple calculation to make conversion between Fahrenheit to Celsius temperature scales. This question is the only question that student needs to make computation. The discrimination index is high for this item that high scoring students were able to give correct response more than low achievers. Distracter analyses for MC questions are presented in Table 3.11. Alternatives in MC part worked quite well except for a few items (i.e., E option for MC29 and B for MC30). When these distracters were examined, they are meaningful (possible) distracters that students may select. Therefore, we include all MC questions in the calculation of Post-HTAT scores.

Table 3.11 Distracter analysis for MC questions in Post-HTAT

Item No.	A	B	C	D	E
MC28	18 (%10.14)	26 (%14.49)	55 (% 30.43)	45 (% 24.64)	*37 (% 20.29)
MC29	10 (% 5.47)	16 (% 8.59)	23 (% 12.50)	*132 (% 72.66)	1 (% 0.78)
MC30	19 (% 10.45)	7 (% 3.73)	31 (% 17.16)	11 (% 5.97)	*114 (% 62.69)
MC31	29 (% 15.67)	10 (% 5.22)	26 (% 14.18)	23 (% 12.69)	*95 (% 52.24)
MC32	17 (% 9.30)	*75 (% 41.09)	21 (% 11.63)	30 (% 16.28)	40 (% 21.71)
MC33	4 (% 2.26)	16 (% 9.02)	19 (% 10.53)	*118 (% 64.66)	25 (% 13.53)

*Correct answer

A simple analytic rubric was formed to score structured essay type items as shown in Table 3.12. Firstly, we examined all students' responses to the items. Meaningful partial answers including using formula, half correct calculations, or line drawing in graphs were all coded in order to give possible scores. For instance if student does not write down any calculation but writes a random number (it may be the correct answer), it is coded as CODE A for Essay34a, 34b and 34c. If student writes appropriate formula for the calculation but does not make any numerical calculation, it is coded as CODE B. Moreover, CODE C indicates that student is able to do further calculation but does not complete the whole solution. And CODE D refers to the correct answer with the required solution steps. For Essay34d, these codes are arranged according to the requirements of the question, which is related to drawing graphs. We did not focus on the scale of the graph while scoring. Instead, the important criterion for this question was choosing appropriate values for x- and y-axis and line drawing. Accordingly, we categorized the given responses and coded them as shown in Table 3.12.

Table 3.12 Coding and scoring rubric for structured essay type items in Post-HTAT

Item	Code	Numerical Code	Explanation	Score
Essay34a	A	1	Empty, no calculation	0
	B	2	Figure out formula	1
	C	3	Figure out formula and calculation	2
	D	4	Correct answer	3
Essay34b	A	1	Empty, no calculation	0
	B	2	Figure out formula	1
	C	3	Figure out formula and calculation	2
	D	4	Correct answer	4
Essay34c	A	1	Empty, no calculation	0
	B	2	Figure out formula	1
	C	3	Figure out formula and half of the calculation	3
	D	4	Correct answer	5
Essay34d	A	1	Empty, no drawing	0
	B	2	Correct numbers on axis without line drawing	2
	C	3	Line drawing without correct numbers on axis	2
	D	4	Correct numbers on axis with partial correct lines	4
	E	5	Correct numbers on axis with correct lines	6

Students' responses are presented in Table 3.13. When we look at CODE A column, low number of responses are obvious. Few students attempted to answer the essay type questions. Only for Essay 34a, more than 20 percent of students were able to give correct answer. And this ratio decreased for other questions, especially for drawing graph.

Table 3.13 Students' responses to structured essay type item

Item No.	A	B	C	D	E
Essay34a	128 (%70.33)	8 (% 4.40)	4 (%2.20)	42 (% 23.07)	-
Essay34b	145 (%79.67)	6 (% 3.29)	5 (% 2.75)	26 (% 14.29)	-
Essay34c	150 (% 82.42)	13 (% 7.14)	4 (% 2.20)	15 (% 8.24)	-
Essay34d	161 (%88.46)	4 (% 2.20)	2 (% 1.10)	6 (% 3.29)	9 (% 4.95)

3.4.2. The Physics Related Personal Epistemology Questionnaire (PPEQ)

As mentioned in Section 2.2.1, researchers developed various domain-general and domain-specific instruments to assess epistemological beliefs. Firstly, relevant studies showed that there are differences in epistemological beliefs on different academic domain or discipline. Domain-specific epistemological beliefs questionnaire, especially related with physics, were scrutinized in terms of appropriateness for the current study. The EBAPS, VASS (physics version), MPEX, MPEX-II and GEBEP were the questionnaires included statements directly related with physics knowledge.

Secondly, content and construct validity of questionnaires were taken into account. For EBAPS, VASS, MPEX and MPEX-II, researchers did not report any analysis for construct validity of the surveys such as factor analysis. Additionally, students' expectations about physics course are related but do not refer to students' epistemological beliefs theoretically. In these surveys, researchers integrated different dimensions of personal epistemology from the research on students' expectations about how to improve achievements in physics courses. Analysis of students' views about physics knowledge was performed through items related with problem-solving and use of mathematical formulation (e.g. MPEX- Item26: "When I solve most exam or homework problems, I explicitly think about the concepts that underlie the problem.”). Nonetheless, dimensions of these questionnaires do not include multidimensional model of personal epistemology adopted for this study. On the other hand, physics version of VASS included statements about scientific epistemology besides epistemological beliefs (e.g. VASS-Item32: I attempt to solve homework problems: (a) before they are solved in class (b) after they are solved in class.”). In this study, researcher only focused on personal epistemology that using VASS by omitting those items would create problems for validity and reliability. For the GEBEP, the internal reliability coefficient was reported as .72 and four-factor structure (explaining %26 of variance) was proposed according to factor analysis results. The items in “structure of knowledge” and “construction and stability of knowledge” dimensions were directly posing statements about not personal physics knowledge but scientists’ endeavors (e.g. “Scientists use their imagination to understand what they cannot directly observe.”, “Scientists get to their discoveries by meticulously following some well known prescribed steps.”).

Thirdly, adequacy of questionnaires for target age group in Turkish context was examined. MPEX-II was developed for assessing epistemological beliefs of high school students and university students. Turkish version of MPEX-II was developed by Yerdelen-Damar, Elby and Eryilmaz (2012). They conducted exploratory and confirmatory factor analysis for MPEX-II which suggested three factor solution for the survey including, “coherence”, “concepts” and “independence” dimensions. The overall survey was reliable (α=.80) but not in two dimensions (α=.51 for “coherence”; α=.52 for “independence”). Researchers claimed that “From the beliefs perspective, the survey is therefore of only limited use.” (p. 010104-6).

Issues associated with validity (measuring intended dimensions of personal epistemology) and reliability of the instruments also directed our attention to study on a new instrument which should be appropriate for high school students in their early years in Turkish educational setting. Our concern was to use a valid instrument to make more effective judgments about students' physics related personal epistemologies. Researcher inspired from aforementioned instruments while constructing the PPEQ.

First version of the test was developed considering six factors originated from personal epistemology models in literature and from researcher's personal experiences in physics learning and teaching. These factors are (a) SK: structure of knowledge (coherent structure, link between concepts, and hierarchical structure), (b) JK: justification of knowledge and knowing, (c) CK: changeability of knowledge, (d) EQ: equations in physics, (e) Source: source of knowledge (self-constructive knowledge, authority), and (f) QL: quick learning.

In the first version of PPEQ (see Appendix H), 42 short statement items were written for six hypothesized factors in total: 10 statements on SK, 8 statements on JK, 6 statements on CK, 5 statements on EQ, 6 statements on QL, and 7 statements on source of knowledge. For each statement, "I" language (individual and internal expressions) was used rather than "E" language (external) as long as "personal epistemology" was main concern of the study. An example from the PPEQ is "*Fizik dersinde yeni bilgileri sahip olduğum bilgilerle ilişkilendirerek öğrenirim*." (In physics lecture, I do learn by establishing link between my previous/past knowledge and new knowledge). The PPEQ was constructed as a likert type scale that participants scored each statement 1 to 5 (strongly disagree to strongly agree). Initial version of the PPEQ was delivered to three experts who have a doctoral degree in science education and have been conducting studies on epistemological beliefs. They gave feedback about the clarity of items and consistency between factors and related items. By considering experts' opinion, first version of the PPEQ was formed. Explanations related with factors and sample items for each factor are given in Table 3.14.

Table 3.14 Hypothetical dimensions in the PPEQ

Factors	**Explanation**	**Examples**
Structure of knowledge (SK)	This factor questions whether self-knowledge is formed by establishing link between previous and new physics knowledge, has a coherent vs. incoherent structure, and hierarchical vs. fragmented structure.	**A02.** Fizik dersinde yeni bilgileri sahip olduğum bilgilerle ilişkilendirerek öğrenirim. **A09.** Fizik dersinde verilen bilgilerle önceden öğrendiğim bilgiler uyumlu olmalıdır.
Justification of knowledge (JK)	This factor questions whether one justifies his/her physics knowledge by use of mental processes (i.e. logical reasoning), use of evidence from experimentation, inquiry emanated from conflicts between previous experiences and novel situations.	**B02.**Fizik dersinde öğrendiğim bilgilerle günlük hayattaki tecrübelerim çelişirse sorgulamadan derste verilen bilgileri doğru kabul ederim. **B04.** Fizik dersinde verilen bilgilerin doğruluğunu yapabileceğim deneylerle test ederim.
Changeability of knowledge (CK)	This factor questions whether self-knowledge is subject to change or fixed (unchangeable).	**C02.** Fizik dersinde öğrendiğim bilgiler hiçbir zaman değişmeyecek fiziksel gerçeklerdir; bu yüzden kendi bilgilerim de değişmeyecektir. **C04.** Mantıklı açıklamalarla desteklenen yeni bilgiler sunulursa önceki fizik bilgilerimi değiştiririm.

Table 3.14 (Continued)

Factors	**Explanation**	**Examples**
Equations in physics (EQ)	This factor questions whether memorizing mathematical formulas is sufficient enough to “know physics” or equations only show mathematical relations between physical concepts to “understand physics”.	**D01.** Fizik dersinde verilen formülleri bilmem konuyu anlamam için yeterlidir; bu yüzden konuyla ilgili başka bir şey öğrenmem gerekmez. **D04.** Fizik dersinde verilen formüller, konuyla ilgili kavramların arasındaki ilişkileri gösterir.
Quick learning (QL)	This factor questions whether one takes time to construct physics knowledge (a gradual process of meaning making) or one adopts knowledge very quickly.	**E03.** Fizikte anlayamadığım bir konu üzerinde tekrar tekrar düşünsem de konunun mantığını anlayamam. **E06.** Fizik dersinde verilen bilgileri ilk seferde anlamayabilirim, bu fiziği anlamayacağım anlamına gelmez.
Source of knowledge (Source)	This factor questions whether knowledge is constructed by individual or accepted directly from authority (i.e. textbooks, teachers, scientists). Note that even authoritative knowledge can be reconstructed after checking validity of information by mental processing.	**F02.** Fizik dersinde öğrendiğim bilgiler bilim insanları tarafından kabul edilmiş gerçeklerdir, bu bilgileri sorgulamam gerekmez. **F04.** Fiziği anlamamın sebebi fizik bilgisini doğrudan anlatan bir ders kitabına sahip olmamdır.

To assure construct validity of the PPEQ, a two-staged pilot study was conducted before the current study. In order to investigate relationship between observed variables and latent variables (factors), researchers frequently use factor analysis (FA) (Byrne, 2010). FA provides information about covariance among the set of observed variables which are assumed to be related with a latent variable. There are two types of FA for different purposes; (a) exploratory factor analysis (EFA) and (b) confirmatory factor analysis (CFA). EFA is conducted when the relation between observed variables and factors are unknown. EFA designed to illustrate how observed variables and latent variables are linked. On the other hand, CFA is performed when we have knowledge about observed variables and underlying factors depending on a theory, etc.

At the first-stage, the questionnaire was administered to 362 ninth grade students in three Anatolian high schools in Çankaya district, in March 2014. Administration of test was completed about 15 to 20 minutes of a lecture hour. According to EFA results of first-stage of the pilot study, the questionnaire was revised and later administered to a different sample. Number of participants in second-stage for validation of the instrument was 350 ninth graders. There were 190 female and 160 male students. Lastly, CFA was performed to examine whether the hypothesized model works. The factor analyses results are presented in next two sections.

3.4.2.1. Exploratory Factor Analysis of PPEQ

After collection of data, exploratory factor analysis was conducted to identify factors underlying the personal epistemology construct. By considering the related literature and the results of FA, factors were identified for CFA. The collected data from PPEQ were analyzed by IBM SPSS Statistics 21. The data was analyzed in order to satisfy the conditions to conduct FA. Patterns in responses were examined and deleted. 345 students' data remained out of 362. In other words, 4.7 percent of data was excluded from the analysis. Statistical analyses, such as EFA, could be affected by the missing values. In order to examine these values, missing data analyses was performed by SPSS (see Table 3.15).

Table 3.15 Missing value analysis for each variable in the PPEQ

		Missing				Missing	
	N	Count	Percent		N	Count	Percent
ITEMA01	344	1	.3	ITEMC04	344	1	.3
ITEMA02	344	1	.3	ITEMC05	342	3	.9
ITEMA03	343	2	.6	ITEMC06	344	1	.3
ITEMA04	344	1	.3	ITEMD01	343	2	.6
ITEMA05	341	4	1.2	ITEMD02	343	2	.6
ITEMA06	342	3	.9	ITEMD03	343	2	.6
ITEMA07	342	3	.9	ITEMD04	342	3	.9
ITEMA08	343	2	.6	ITEMD05	342	3	.9
ITEMA09	340	5	1.4	ITEME01	343	2	.6
ITEMA10	342	3	.9	ITEME02	343	2	.6
ITEMB01	345	0	0	ITEME03	341	4	1.2
ITEMB02	344	1	.3	ITEME04	342	3	.9
ITEMB03	344	1	.3	ITEME05	341	4	1.2
ITEMB04	344	1	.3	ITEME06	343	2	.6
ITEMB05	345	0	0	ITEMF01	343	2	.6
ITEMB06	343	2	.6	ITEMF02	343	2	.6
ITEMB07	342	3	.9	ITEMF03	343	2	.6
ITEMB08	343	2	.6	ITEMF04	343	2	.6
ITEMC01	344	1	.3	ITEMF05	343	2	.6
ITEMC02	343	2	.6	ITEMF06	343	2	.6
ITEMC03	343	2	.6	ITEMF07	343	2	.6

When the percentages were examined, 1.4 % was the highest value in the study which is in an acceptable range (Pallant, 2007). Before performing factor analysis, it is important to check univariate normality of items in order to gather information about multivariate normality. Skewness and kurtosis values of each item were examined for this purpose (see Table 3.16).

Table 3.16 Descriptive statistics for the PPEQ items in pilot study

	Skewness		Kurtosis			Skewness		Kurtosis	
	Statistic	S.E.	Statistic	S.E.		Statistic	S.E.	Statistic	S.E.
ITEMA01	-0.661	.131	-0.329	.262	ITEMC04	-1.027	.131	0.833	.262
ITEMA02	-0.935	.131	0.700	.262	ITEMC05	-0.545	.132	-0.341	.263
ITEMA03	-1.853	.132	2.719	.263	ITEMC06	-1.438	.131	2.175	.262
ITEMA04	-1.158	.131	0.589	.262	ITEMD01	-1.198	.132	0.715	.263
ITEMA05	-0.455	.132	-0.397	.263	ITEMD02	0.227	.132	-1.125	.263
ITEMA06	-1.779	.132	2.775	.263	ITEMD03	0.416	.132	-0.911	.263
ITEMA07	-1.598	.132	2.194	.263	ITEMD04	-0.952	.132	0.479	.263
ITEMA08	-0.956	.132	0.728	.263	ITEMD05	-0.122	.132	-1.049	.263
ITEMA09	-1.177	.132	1.077	.264	ITEME01	-1.315	.132	1.019	.263
ITEMA10	-0.590	.132	-0.782	.263	ITEME02	-0.268	.132	-0.619	.263
ITEMB01	-1.454	.131	1.653	.262	ITEME03	-0.775	.132	0.050	.263
ITEMB02	-0.908	.131	-0.015	.262	ITEME04	-0.994	.132	0.606	.263
ITEMB03	-0.534	.131	-0.323	.262	ITEME05	-1.287	.132	1.554	.263
ITEMB04	-0.130	.131	-0.778	.262	ITEME06	-1.454	.132	1.411	.263
ITEMB05	-1.561	.131	1.753	.262	ITEMF01	-0.882	.132	0.264	.263
ITEMB06	-0.860	.132	0.043	.263	ITEMF02	-0.881	.132	0.059	.263
ITEMB07	-1.021	.132	0.733	.263	ITEMF03	0.264	.132	-0.819	.263
ITEMB08	-0.687	.132	-0.131	.263	ITEMF04	-0.441	.132	-0.741	.263
ITEMC01	-0.341	.131	-0.578	.262	ITEMF05	-0.897	.132	0.130	.263
ITEMC02	-0.763	.132	-0.016	.263	ITEMF06	-0.850	.132	0.248	.263
ITEMC03	-0.869	.132	0.248	.263	ITEMF07	-0.427	.132	-0.695	.263

Statistical research asserts that skewness is influential on test means meanwhile kurtosis is effective on test of variances and covariance (Byrne, 2010). As can be seen from Table 3.16, skewness and kurtosis values for each item were located between ± 3. DeCarlo (1997) stated that "[t]henormal distribution has a kurtosis of 3" (p.292). As a result, no item was found kurtotic. Firstly, Kaiser-Meyer-Olkin Measures of Sampling Adequacy (KMO) and Bartlett's test of sphericity (BTS) values were analyzed in order to make valid interpretations from EFA results.

Tabachnick and Fidell (2001) recommended that the KMO value should be bigger than .60. Here, the KMO value was calculated as .894 which was relatively large. Bartlett's test was found statistically significant (BTS= 5645.099, $p<0.001$). The anti-image correlations ranged between .502 and .945 that should be greater than .50. The results showed that it was possible to investigate underlying structure of the PPEQ.

The first version of PPEQ including 42 items was analyzed to examine the number of factors underlying the latent variable. 11 factors were loaded which have eigenvalues greater than 1 and all factor loadings were bigger than .30 threshold value. When the factor loadings were examined, some factors did not fit well with theoretical base which means that loaded items did not create a meaningful factor. Following 10 items were deleted because of loading more than one factor with coefficient more than .30; ITEMA10 (SK), ITEMB02 (JK), ITEMB03 (JK), ITEMB04 (JK), ITEMC01 (CK), ITEME02 (QL), ITEME05 (QL), ITEMF03 (Source), ITEMF04 (Source), ITEMF07 (Source). And EQ factor was not loaded as expected according to the EFA results. In total 15 items were deleted from the questionnaire. When remaining 27 items were reanalyzed, KMO and BTS values were found better than the first analysis and adequate to continue EFA (see Table 3.17).As the factor EQ was omitted from the questionnaire, there were five factors remained in PPEQ.

Table 3.17 SPSS Output of KMO and Bartlett's Test for PPEQ Items

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.913
Bartlett's Test of Sphericity	Approx. Chi-Square	3731.148
	df	351
	Sig.	.000

For EFA, communality value of the items should be equal to or greater than .50. Table 3.18 presents the SPSS output for communalities of items. All items have sufficient communality value. Moreover, these items had high factor loadings (more than .30) and created six-factor structural model for PPEQ. This model explained 60.183 % of cumulative variance in ninth grade students' physics related personal epistemology.

Table 3.18 SPSS Output of Item Communalities

Communalities		
Item	Initial	Extraction
ITEMA01SK	1.000	.565
ITEMA02SK	1.000	.576
ITEMA03SK	1.000	.635
ITEMA04SK	1.000	.570
ITEMA05SK	1.000	.594
ITEMA06SK	1.000	.686
ITEMA07SK	1.000	.602
ITEMA08SK	1.000	.597
ITEMA09SK	1.000	.597
ITEMB01JK	1.000	.594
ITEMB05JK	1.000	.576
ITEMB06JK	1.000	.547
ITEMB07JK	1.000	.660
ITEMB08JK	1.000	.638
ITEMC02CK	1.000	.554
ITEMC03CK	1.000	.616
ITEMC04CK	1.000	.561
ITEMC05CK	1.000	.504
ITEMC06CK	1.000	.586
ITEME01QL	1.000	.662
ITEME03QL	1.000	.508
ITEME04QL	1.000	.506
ITEME06QL	1.000	.633
ITEMF01Source	1.000	.719
ITEMF02Source	1.000	.733
ITEMF05Source	1.000	.708
ITEMF06Source	1.000	.552

Extraction Method: Principal Component Analysis.

Factor loadings are shown in Table 3.19. When factor loadings were examined, SK factor was divided into two different factors. These are reported as SK_1 and SK_2 because of SK items are loaded under these factors.

Table 3.19 EFA results of PPEQ (Pattern Matrix)

	Factors					
	JK	Source	CK	QL	SK_1	SK_2
ITEMB08JK	.808					
ITEMB07JK	.765					
ITEMB01JK	.602					
ITEMB05JK	.556					
ITEMB06JK	.552					
ITEMF01Source		.819				
ITEMF05Source		.779				
ITEMF02Source		.759				
ITEMF06Source		.434				
ITEMC03CK			.669			
ITEMC05CK			.656			
ITEMC04CK			.584			
ITEMC02CK			.546			
ITEMC06CK			.505			
ITEME06QL				.774		
ITEME01QL				.762		
ITEME03QL				.624		
ITEME04QL				.542		
ITEMA06SK					.770	
ITEMA09SK					.689	
ITEMA07SK					.685	
ITEMA04SK					.676	
ITEMA03SK					.656	
ITEMA01SK						.712
ITEMA05SK						.657
ITEMA02SK						.527
ITEMA08SK						.483

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

The items loaded in SK_1 and SK_2 factors can be seen from Table 3.20. Even though statements in newly emerged factors were interrelated, there was a unique difference. In SK_1 factor, coherency and consistency related items were loaded mostly. On the other hand, SK_2 factor was consisted of items (or views) underlying new knowledge should be linked with previous knowledge which can be called as hierarchical structure. Thus, it would be practical to rename SK_1 and SK_2 factors as SK Coherence (SKC) and SK Hierarchical (SKH) factors respectively. To sum up, EFA results showed six-factor structure associated with the PPEQ which is a little bit different from the prior model. JK, CK, QL and Source factors were remained and items related with SK factor loaded into two different factors.

Table 3.20 Two emerged factors from SK factor in PPEQ

	Item	PPEQ Statement
SK_1 Factor (Coherent, consistent structure of physics knowledge)	ITEMA03	Fizik dersinde bir konuyu anlayabilmem için konuyla ilgili temel kavramları anlamam gerekir.
	ITEMA04	Fizik dersinde öğrendiğim bilgiler birbiriyle tutarlı (uyumlu) olmak zorunda değil.
	ITEMA06	Fizik dersinde karmaşık ya da üst düzey konuları anlayabilmem için temel kavramları anlamam gerekir.
	ITEMA07	Fizik dersinde bir konuyu anlayabilmem için önceden öğrendiğim bilgilere ihtiyacım yok.
	ITEMA09	Fizik dersinde verilen bilgilerle önceden öğrendiğim bilgiler uyumlu olmalıdır.
SK_2 Factor (Hierarchical structure of physics knowledge)	ITEMA01	Fizik dersindeki farklı konularda öğrendiğim bilgilerin birbirleriyle ilişkisini kurmam.
	ITEMA02	Fizik dersinde yeni bilgileri sahip olduğum bilgilerle ilişkilendirerek öğrenirim.
	ITEMA05	Fizik dersinde bir konuyu önceden öğrendiğim bilgiler sayesinde anlarım.
	ITEMA08	Fizik dersinde yeni konuyla ilgili kavramları bildiklerimle ilişkilendirerek anlamlandırırım.

As a measure of internal consistency, Cronbach's Alpha coefficients were calculated for each factor and for the scores obtained from the questionnaire as shown in Table 3.21. Reliability coefficients for the PPEQ factors ranged between .701 and .833. In social science research, the acceptable value should be .70 or higher for an instrument to be used (Fraenkel & Wallen, 2006). The reliability coefficient of the overall PPEQ was found .918 for 27 items which is relatively high value.

Table 3.21 Reliability coefficients for the PPEQ scores and factors

Factor	Cronbach's Alpha Coefficient	Number of Item
Source	.833	4
JK	.821	5
SKC	.813	5
CK	.751	5
QL	.749	4
SKH	.701	4
Overall Test	.918	27

3.4.2.2. Confirmatory Factor Analysis of PPEQ

By considering EFA result of the initial version, revised version of PPEQ was prepared with 27 items considered appropriate for validation study (see Appendix I). Before data analysis, items were re-coded due to changes in the model (see Appendix J). In order to test construct validity of proposed model for PPEQ, CFA was performed by using IBM SPSS AMOS 24 program. In the analysis, *Physics Related Personal Epistemology* was the latent variable with six underlying factors (JK, Source, QL, CK, SKC, SKH) and 27 items in PPEQ were included as observed variables as shown in Figure 3.1.

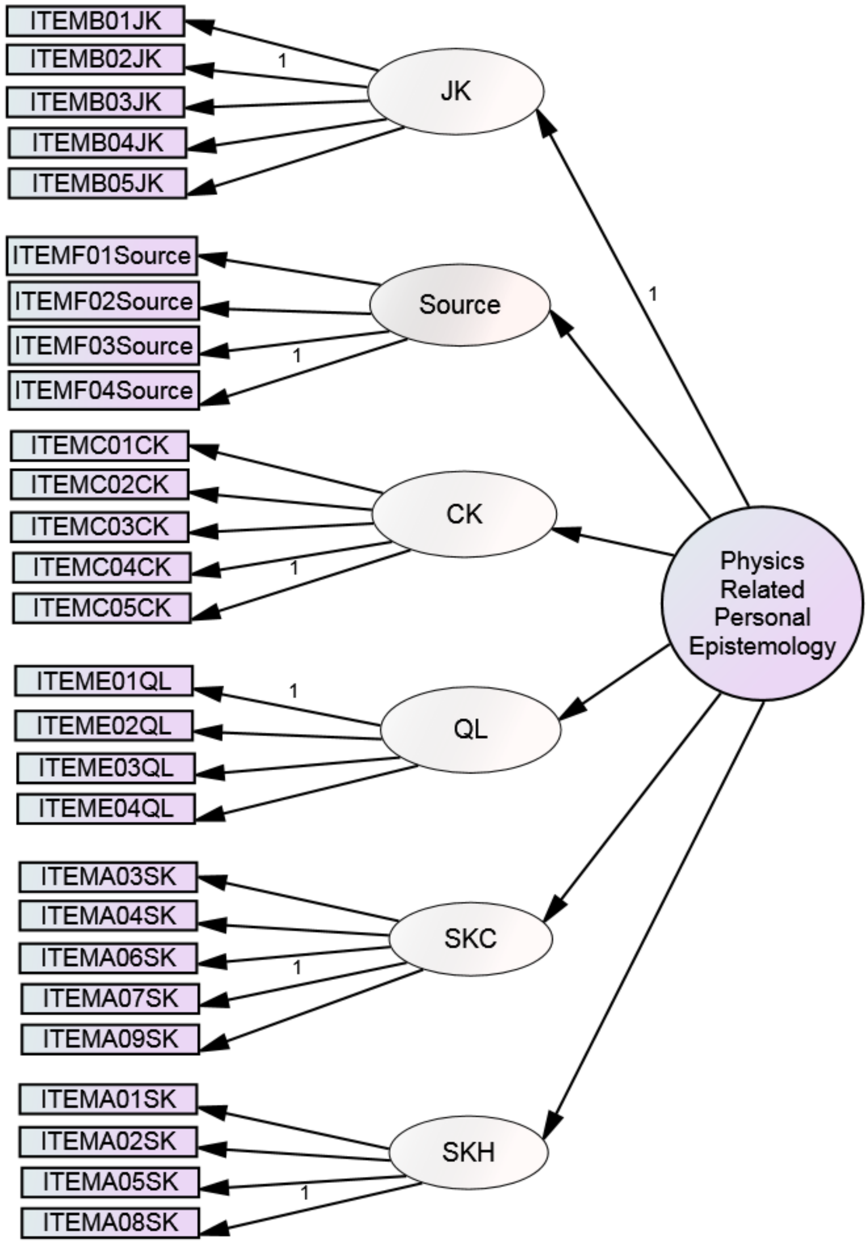


Figure 3.1 Hypothesized six-factor CFA model of the PPEQ

Regression weights (or regression coefficient) of factor loadings are presented in Table 3.22. These values show the relation between latent variables and observed variables. Higher values indicate relative effectiveness of a variable in a group on independent variable. Estimated regression weights, standard error (S.E.), critical ratio (C.R.) and probability values (P) are listed in Table 3.22.

Table 3.22 AMOS output for hypothesized six-factor CFA model: Regression weights (*probability < .00)

			Estimate	S.E.	C.R.	P
JK	<---	PPE	1.000			
QL	<---	PPE	.950	.099	9.549	*
SKH	<---	PPE	.909	.086	10.522	*
Source	<---	PPE	.843	.089	9.449	*
SKC	<---	PPE	.834	.090	9.276	*
CK	<---	PPE	.822	.084	9.757	*
ITEMB02	<---	JK	1.000			
ITEMB01	<---	JK	.964	.081	11.954	*
ITEMB03	<---	JK	.878	.094	9.307	*
ITEMB04	<---	JK	.841	.079	10.685	*
ITEMB05	<---	JK	.767	.083	9.193	*
ITEMD04	<---	Source	1.000			
ITEMD02	<---	Source	.997	.108	9.244	*
ITEMD03	<---	Source	.944	.095	9.885	*
ITEMD01	<---	Source	.768	.098	7.844	*
ITEMC05	<---	CK	1.000			
ITEMC03	<---	CK	.920	.097	9.534	*
ITEMC02	<---	CK	.892	.099	8.990	*
ITEMC01	<---	CK	.659	.108	6.089	*
ITEMC04	<---	CK	.619	.108	5.756	*
ITEME01	<---	QL	1.000			
ITEME02	<---	QL	.821	.091	9.073	*
ITEME03	<---	QL	.880	.095	9.220	*
ITEME04	<---	QL	.866	.091	9.551	*
ITEMA07	<---	SKC	1.000			
ITEMA03	<---	SKC	.980	.108	9.089	*
ITEMA06	<---	SKC	.936	.097	9.609	*
ITEMA04	<---	SKC	.914	.104	8.745	*
ITEMA09	<---	SKC	.885	.100	8.885	*
ITEMA08	<---	SKH	1.000			
ITEMA02	<---	SKH	.871	.080	10.918	*
ITEMA05	<---	SKH	.660	.091	7.283	*
ITEMA01	<---	SKH	.560	.099	5.686	*

The unstandardized solution shows that all estimates are statistically significant and acceptable and standard errors are in good range. For better illustration of factor loadings, standardized regression weights can be examined. These values indicate how well observable variables predict the latent variable and also show the location of an item in a particular group (factor). In Table 3.23, standardized regression weights are presented.

Table 3.23 AMOS output for standardized regression weights

Standardized Regression Weights			
ITEMB01	<---	JK	.643
ITEMB02	<---	JK	.657
ITEMB03	<---	JK	.574
ITEMB04	<---	JK	.591
ITEMB05	<---	JK	.510
ITEMD01	<---	Source	.432
ITEMD02	<---	Source	.535
ITEMD03	<---	Source	.520
ITEMD04	<---	Source	.584
ITEMC01	<---	CK	.348
ITEMC02	<---	CK	.493
ITEMC03	<---	CK	.525
ITEMC04	<---	CK	.324
ITEMC05	<---	CK	.606
ITEME01	<---	QL	.594
ITEME02	<---	QL	.504
ITEME03	<---	QL	.589
ITEME04	<---	QL	.526
ITEMA03	<---	SKC	.536
ITEMA04	<---	SKC	.485
ITEMA06	<---	SKC	.545
ITEMA07	<---	SKC	.573
ITEMA09	<---	SKC	.532
ITEMA01	<---	SKH	.318
ITEMA02	<---	SKH	.590
ITEMA05	<---	SKH	.401
ITEMA08	<---	SKH	.664

Standardized regression weights ranged between .318 and .664. Three items (ITEMC01, ITEMC04, and ITEMA01) have lower weights (<.40) comparing to other items in PPEQ. In order to reexamine the effect of these items on CFA results, researcher deleted one of the items per time. Only deletion of ITEMC01 was created impact on goodness-of-fit indices even though standardized regression weight was higher than other items. Deletion of ITEMC04 or ITEMA01 at once brought out no better solution. Therefore, only ITEMC01 was deleted. Standardized regression weight estimates of the modified PPEQ model is illustrated in Figure 3.2.

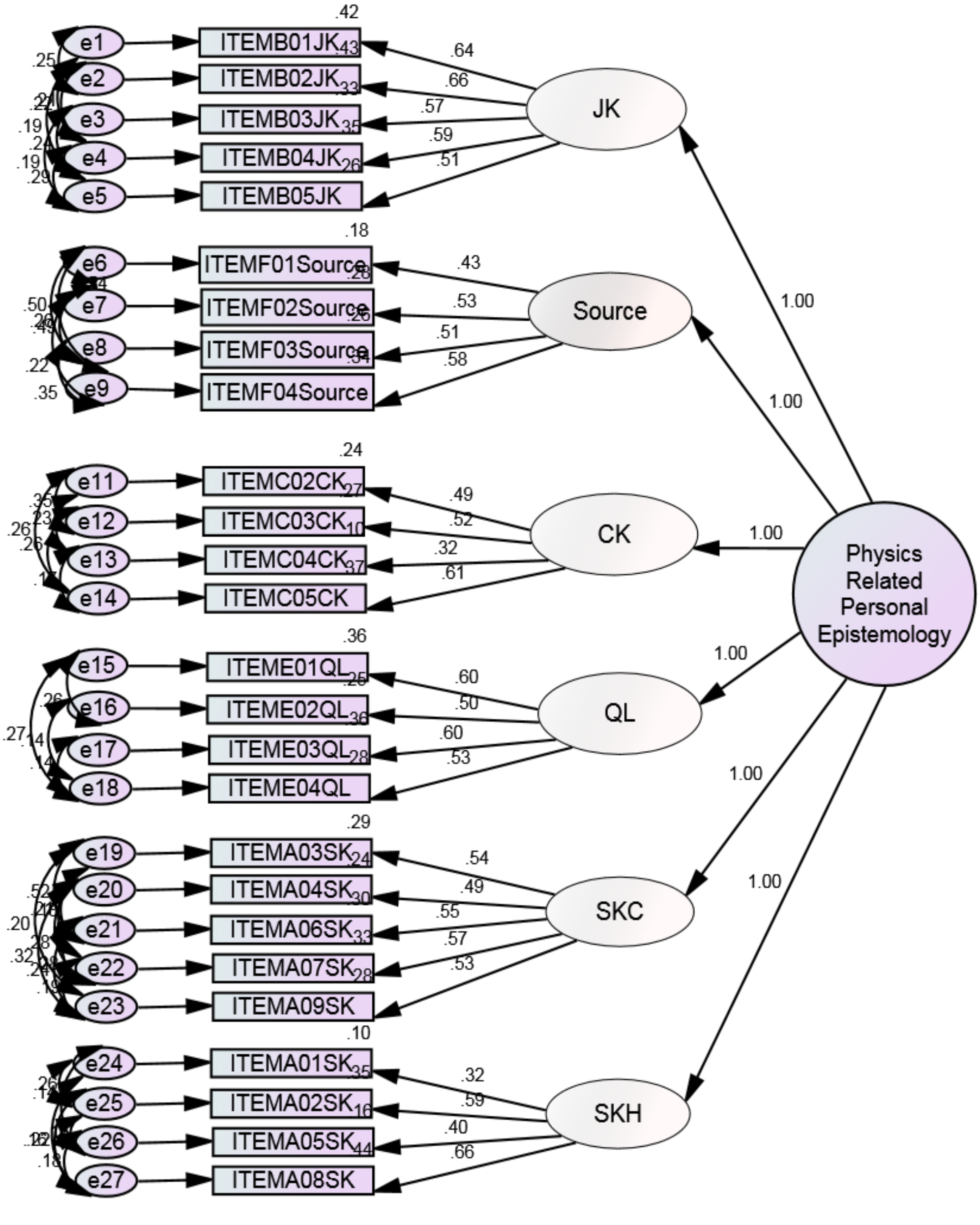


Figure 3.2 Standardized parameter estimates of the modified the PPEQ Model

After revision due to modification indices suggested by AMOS, the fit indices of the model were found as follows: AGFI of .882, GFI of .912, RMSEA of .45, NNFI of .935, CFI of .947, RMR of .049, and S-RMR of .0435. The summary of goodness-of-fit statistics for the six-factor CFA model of PPEQ is presented in Appendix K. The acceptable range for goodness-of-fit indices and obtained values from the CFA are given in Table 3.24.

Table 3.24 Criterion for fit indices and values obtained from model of PPEQ

Fit Index	Criterion	Value
Chi-Square (χ^2)	Non-significant	Significant
Chi-Square (χ^2)/ Degrees of Freedom (df) (CMIN/df)	Ratio of χ^2 to df <2	=1.694
Root Mean Square Residual (RMR)	<.050	=.049
Standardized Root Mean Square Residual (S-RMR)	<.050	=.0435
Root Mean Square Error of Approximation (RMSEA)	<.050	=.045
Parsimony Goodness of Fit Index (PGFI)	higher the better	=.681
Parsimony Normed Fit Index (PNFI)	higher the better	=.711
Normed Fit Index (NFI)	>.90	=.883
Non-normed Fit Index (NNFI)	>.90	=.935
Comparative Fit Index (CFI)	>.90	=.947
Incremental Fit Index (IFI)	>.90	=.948
Relative Fit Index (RFI)	>.90	=.854
Tucker-Lewis Index (TLI)	>.90	=.935
Goodness-of-Fit Index (GFI)	close to 1.0	=.912
Adjusted Goodness of Fit Index (AGFI)	close to 1.0	=.882

Likelihood Ratio Test (test of χ^2 statistic) was found significant that suggesting the fit of the data to the hypothesized model was inadequate. It should be noted that

Likelihood Ratio test is highly sensitive to sample size and the result was not unexpected for the current analysis (Bryne, 2010). Referring to sample size problem, Tabachnick and Fidell (2001) recommended a rough rule that "a good-fitting model may be indicated when the ratio of the χ^2 to the degrees of freedom is less than 2" (p.698). This value is presented as CMIN/df in AMOS output and the value (1.694) was smaller than 2 for current data.

To obtain more evidence for model fit, other fit indices were also examined. RMR and S-RMR values were less than .05 which refers to a good fit (Kline, 2005). RMSEA value was found .045 that also indicated good model data fit (Bryne, 2010). NFI makes estimation by comparing χ^2 values for hypothesized model and independence model (Tabachnick & Fidell, 2001). Values higher than .90 indicates to good fit. For the current analysis, it was found .883. Similar to Likelihood Ratio Test, interpretation of NFI may be problematic because of sample size. Another fit index suggested for smaller samples, non-normed fit index (NNFI), was calculated in order to check model fit. The value was calculated as .935. The IFI of .948 and CFI of .948 indicated good model fit as well as NNFI. The GFI and AGFI values can be interpreted as moderate fit that values closer to 1.0 are much better.

To sum up, goodness of fit indices provided evidence that the hypothesized model displays good fit with the observed data. In other words, the physics related personal epistemology construct has a structure of six factors and the PPEQ assesses these six factors due to good fit between hypothesized model and observed data. Additionally, internal reliability coefficients of pre-PPEQ was found α=.879 and α= .860 for post-PPEQ in the main study.

3.4.3. The Classroom Observation Checklist

To verify that treatment groups and control groups were received the intended instructions, a classroom observation checklist was developed by the researcher. The checklist is available in Appendix G and its results are presented in Section 4.5 which was used for treatment verification. The classroom observation checklist used in this study includes 26 items. There are specific items written for explicit epistemologically enhanced instruction (i.e. item no. 5, 6, 8, 12, 15, 19, 21, 22, 24, 25 and 26). These items were written in bold in the checklist. These action statements were characterizing the explicit instruction and assisting observer to distinguish EEEI from implicit instruction (IEEI). Other items were written for both implicit and explicit instruction. There are only two alternatives in the checklist: yes and no.

The data collection technique, non-participant observation, was used during classroom observations. The researcher observed the classroom discourse and implementations without taking an active part in classroom setting. In order to handle Hawthorne effect, the situation that the people may act or behave differently while being observed, the researcher observed each class for few number of lecture hours before the current study. Therefore, observation during implementation was not a novel event for the students.

The researcher sat on an empty seat behind the classroom and took notes of live observations besides completing the classroom observation checklist. The researcher attended and observed each class in treatment and control groups. Each classroom observation took two lecture hours (90 minutes) for each class. The *Heat and Temperature* unit was completed in seven weeks which corresponds to 14 lecture-hours for each group. In total, 84 lecture hours were observed.

For the validation of observations, another observer was invited to make observations in randomly selected classes for 12 lecture hours (%14 of whole study). This observer was a doctoral student in the department of Secondary Science and Mathematics Education at METU. Correlation between observations by different observers was calculated (for the CI groups r=.92, for the IEEI groups r=.87; for the EEEI groups r=.87). These correlations refer to acceptable level of agreement among raters (the researcher and the observer). Results of the classroom observation checklist are presented in Section 4.5.

3.5. Instructional Materials and Treatments

Instructional materials that were used in treatment groups are introduced in the following section. These materials included teacher guidebook and lesson plans. Thereafter, detailed information about the instructions in treatment and control groups is presented.

3.5.1. Teacher Guide Book and Lesson Plans for Treatment Groups

Before implementations, a guidebook was developed for the teacher to support her instructional practices for treatment groups. Teacher guidebook is important to ensure treatment fidelity. This guidebook includes core materials about subject matter knowledge on heat and temperature unit, the epistemological discussion questions before and after lecturing, and all other directions which should be followed step by step during instruction. Also, teacher and students' roles in the class defined clearly (See Appendix N for each lesson plan). Additionally, researcher prepared PowerPoint presentations for each lesson in IEEI and EEEI. These presentations were quite helpful for teacher to follow sequence of the instruction.

3.5.2. Treatments

There are two types of instruction implemented in the study: (1) explicit epistemologically enhanced instruction, and (2) implicit epistemologically enhanced instruction. For the sake of integrating epistemic dimensions into instruction, firstly the researcher adopted a framework of personal epistemology which included five interrelated dimensions. These are structure of physics knowledge, justification of physics knowledge, changeability of physics knowledge, source of knowledge, and lastly fixed ability to learn physics knowledge. While developing instructional plan, firstly sequence of the physics content was rearranged differently from ninth grade physics program as shown in Figure 3.3.

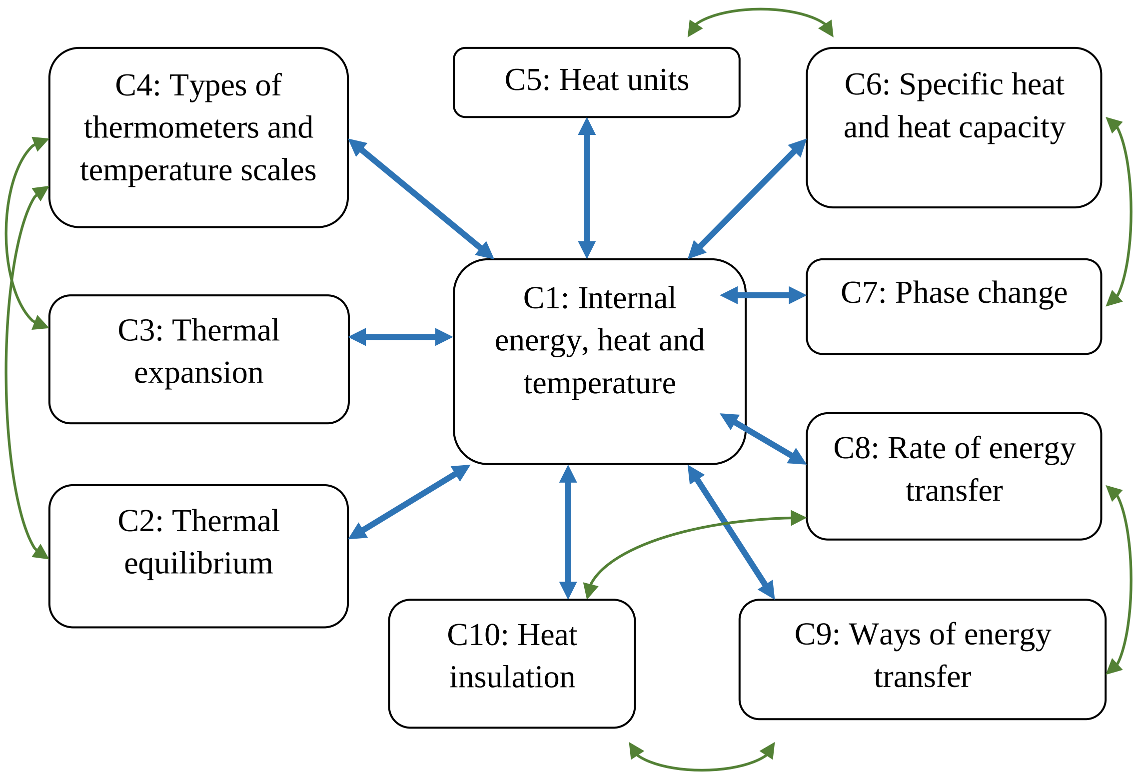


Figure 3.3 Sequence of physics content in EEEI and IEEI classes

3.5.2.1. Explicit Epistemologically Enhanced Instruction (EEEI)

Widely known teaching strategies and methods that are used in physics instructions are determined to probe specific personal epistemology dimensions. These are presented in Table 3.25

Table 3.25 Instructional activities to probe dimensions of personal epistemology

Instructional Activities	Dimension of personal epistemology
Discussions based on retrieval of students' previous knowledge - Reflection Papers: "What do I know?"	*Hierarchical structure of knowledge *Source of knowledge
Making connections between previous and new learning experiences - Reflection Papers: "What did I learn?"	*Hierarchical structure of knowledge *Coherent structure of knowledge *Source of knowledge
Conceptual change strategies Checking inconsistency in previous and new learning experiences	*Coherent structure of knowledge *Changeability of knowledge
Checking inconsistency in an animation	*Coherent structure of knowledge *Source of knowledge
Predict-Observe-Explain(via classroom demonstrations) Laboratory experiments and explorations (inquiry strategies)	* Justification of knowledge * Source of knowledge
Solving quantitative physics questions (simple to complex)	* Quick learning
Presentation/Discussion of historical examples to illustrate how knowledge change	* Changeability of knowledge

(a) Epistemological Dimension 1: Structure of Physics Knowledge

Motto: I make connections between my personal knowledge and new scientific knowledge (Connection)

Students bring their prior knowledge from earlier science classrooms. In this probe, we build bridges to connect their prior knowledge and new scientific knowledge. This connection will be helpful for two aims: (1) we make sense of knowledge by making links with our previous learning, and (2) if we are able to connect them meaningfully, this indicates that there should be a coherent structure. In other words, there should be no contradiction or dissatisfaction in our knowledge system. The probe also deals with the naïve view that individual's scientific knowledge is a collection of different bits of knowledge. Dividing physics into different chapters and dealing with them one by one without establishing links between concepts may be one of the sources for creating such views. To overcome aforementioned view, each concept was presented by establishing links with the new concept. It should be clarified that main focus is on student's own knowledge. New scientific knowledge also indicates how student make sense of new knowledge in his/her own knowledge system. Therefore, aim of instruction was to help students to establish links between their previous knowledge and new learning. For this sake, researcher focused on previous knowledge from primary school including 4th to 8th grade science and technology classes and prior subjects to "Heat and Temperature" in 9th grade physics curriculum. Teacher will emphasize how useful to make connections between past and present learning. Researcher assumed that students would be able to transfer coherency from conceptual to epistemological coherency with teacher's talk and class discussions.

Purpose of the EEEI was to enable students to build up coherent conceptualization about heat and temperature unit and to motivate students to take responsibility while constructing their own knowledge. Previous subject matter was energy unit. Students' understanding about energy was activated to build up a perspective on heat, temperature, internal and thermal energy concepts. In these classes, lectures started with small discussion sessions. Students were asked to make connections with macro world and micro world in terms of energy as shown in Figure 3.4. For this, teacher asked conceptually bridging questions to associate previous knowledge with new ones. Iteratively, students were expected to make connections with main concepts of the unit and new mathematical models introduced during classes.

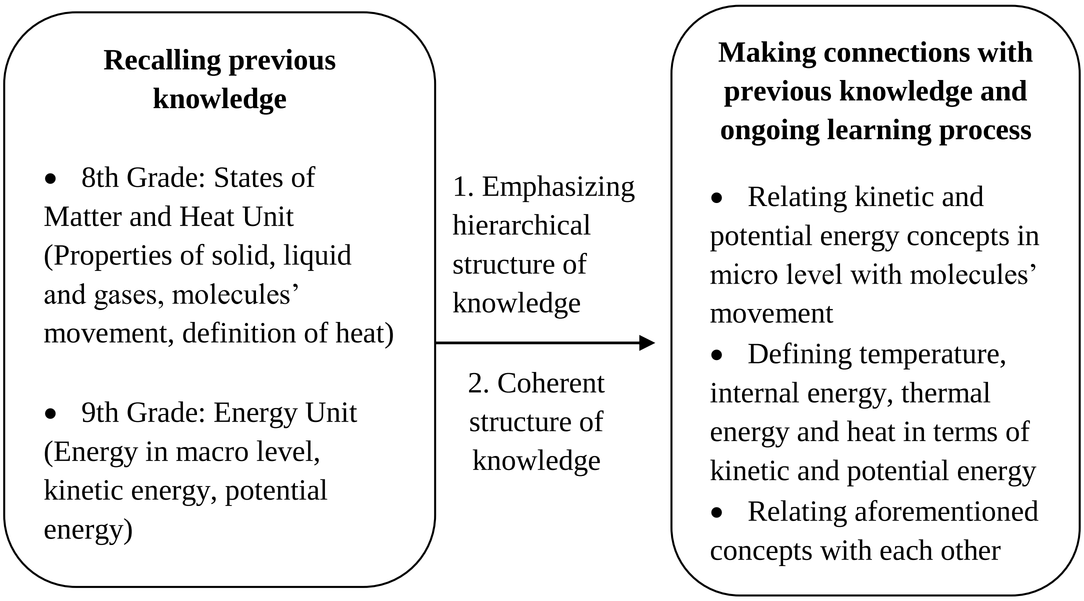


Figure 3.4 Epistemological emphases on coherent structure of knowledge

At the end of each lecture, teacher showed concepts such as internal energy, temperature and heat and asked students whether these concepts are related with each other. To sum up, teacher showed slides making conceptual links as shown in Figure 3.5.

Figure 3.5 Connecting internal energy concept with temperature and heat concepts

Later, teacher encouraged students to realize how past learning experiences are efficient in learning process. For structure of knowledge dimension, some discussion questions were posed as follow:

- "Are there any new concepts that you learnt today? Try to define new concepts by using previous ones."
- "Did you get benefit from your previous knowledge during today's lecture? How?"
- "Are there any difference between daily usage of temperature and heat words and definition of these concepts in physics? If yes, does it make sense?"

(b) Epistemological Dimension 2: Justification of Knowledge and Knowing

Motto: I justify knowledge by using my reasoning tools to integrate into my personal understanding (Justification)

Students are the major actors of their learning. To make sense of new knowledge, students should be able to develop reasoning tool such as determining criteria for consistency, seeking for evidence, using mathematical relationships to judge reliability of findings considering uncertainty. Adopting knowledge provided by the authority (i.e. scientists or teachers) without justification is accepted as an indication for unsophisticated epistemology. In the following activity, students were encouraged to think about how they decide on the reliability of a knowledge claim (see Figure 3.6).

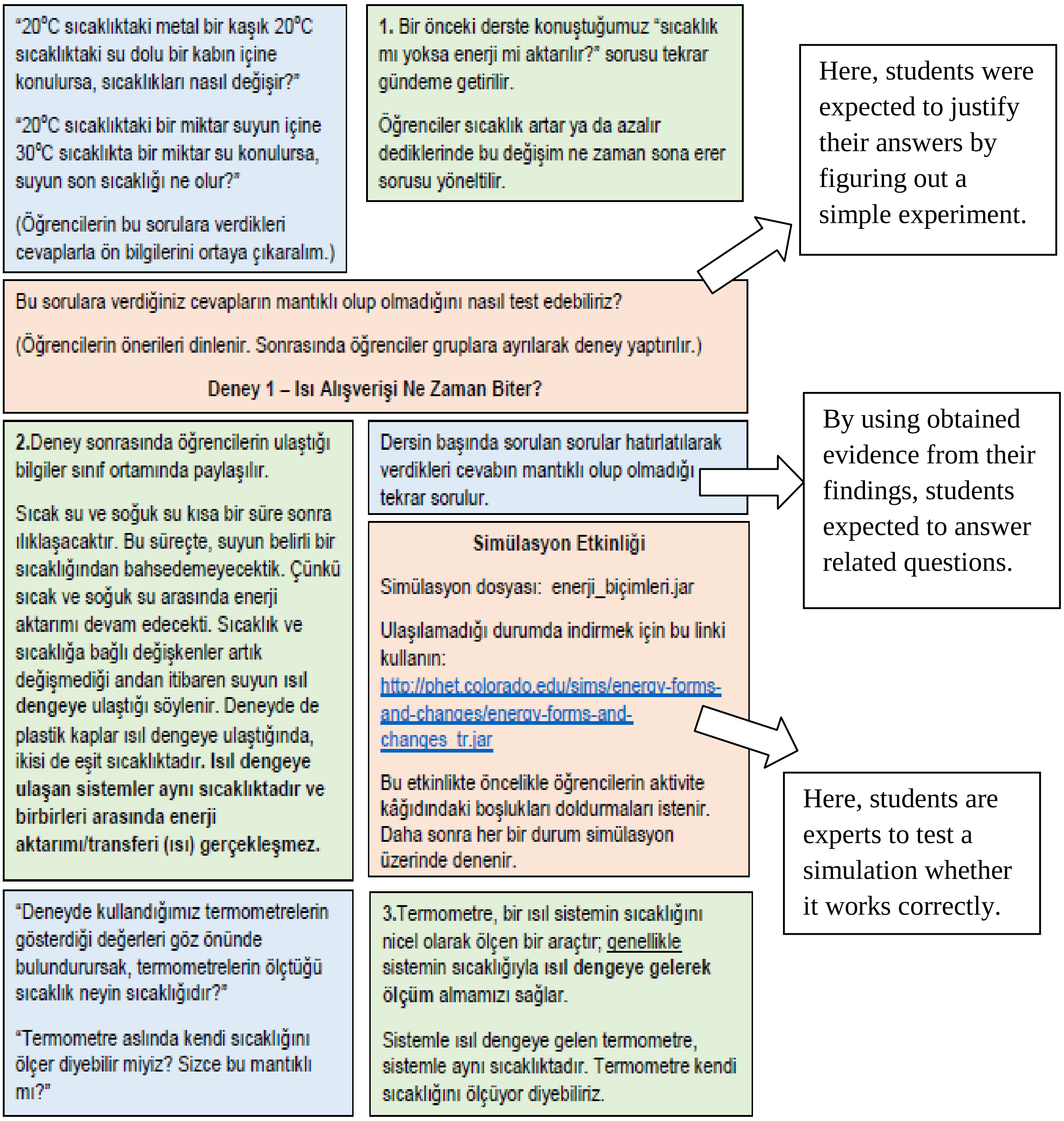


Figure 3.6 Engagement activities to provoke justification probe

As an epistemological probe, simple inquiry activities were conducted (see Figure 3.7). Students worked in groups in these activities. They generated and tested their hypotheses for given issue. Their own interpretations of findings would help students to realize that they are the actor of their learning process. The goal was to encourage students to be aware of and continue to use their own reasoning tools.

Deney 1(B): Farklı maddeler için Isı-Sıcaklık Değişimi Oranı Aynı Mıdır?

Araç gereçler

- Terazi
- Su
- Alkol
- Sıvı yağ
- Üç adet termometre
- Cam beher
- Üç adet özdeş deney tüpü
- Kronometre

Deneyin yapılışı

1. Cam beheri sıcak su ile dolduralım.
2. Deney tüplerine eşit kütle ve sıcaklıkta su, alkol ve sıvı yağ koyalım.
3. Deney tüplerini dik olacak şekilde behere bantla tutturalım.
4. Tüplerdeki sıvılara termometre koyalım ve sıvıların ilk sıcaklık değerlerini ölçelim.
5. Belirli sürelerde termometre ile yaptığımız ölçümleri tabloya kaydedelim.

Sıcaklık (°C)	Su	Etil Alkol	Sıvı Yağ
İlk sıcaklık			
1. Ölçüm			
2. Ölçüm			
3. Ölçüm			

Sonuca Ulaşalım

1. Tahminleriniz ve gözlem sonuçlarınız tutarlı mı? Farklılık varsa sebepleri ne(ler) olabilir?
2. Süre ilerledikçe sıvıların sıcakları nasıl değişti?
3. Sıvıları, sıcaklık artış miktarlarına göre büyükten küçüğe doğru sıralayınız.
4. Aynı grafik üzerinde su, etil alkol ve yağın sıcaklık–zaman grafiğini çizelim.

Figure 3.7 Experimenting to provoke justification probe

For instance, in the objective 9.5.1.3.b students were expected to explain why different temperature and heat units were emerged. For this objective, teacher discussed and presented comprehensive amount of historical elements to illustrate how scientists constructed temperature and heat concepts for two different lecture hours. Short version of the lesson plan was provided to show how teacher stimulated justification (see Figure 3.8). How temperature was measured by using instruments in history was presented in the lecture. By time, scientists developed more reliable instruments. As they searched more about materials' physical properties (e.g. thermal expansion coefficients) and enhanced conceptualization of scales by considering "fixed points" (e.g. water's boiling point) allowed us to measure temperature. Accordingly, students were expected to build their own thermometers by using simple items and scale their thermometers to observe changes due to temperature changes.

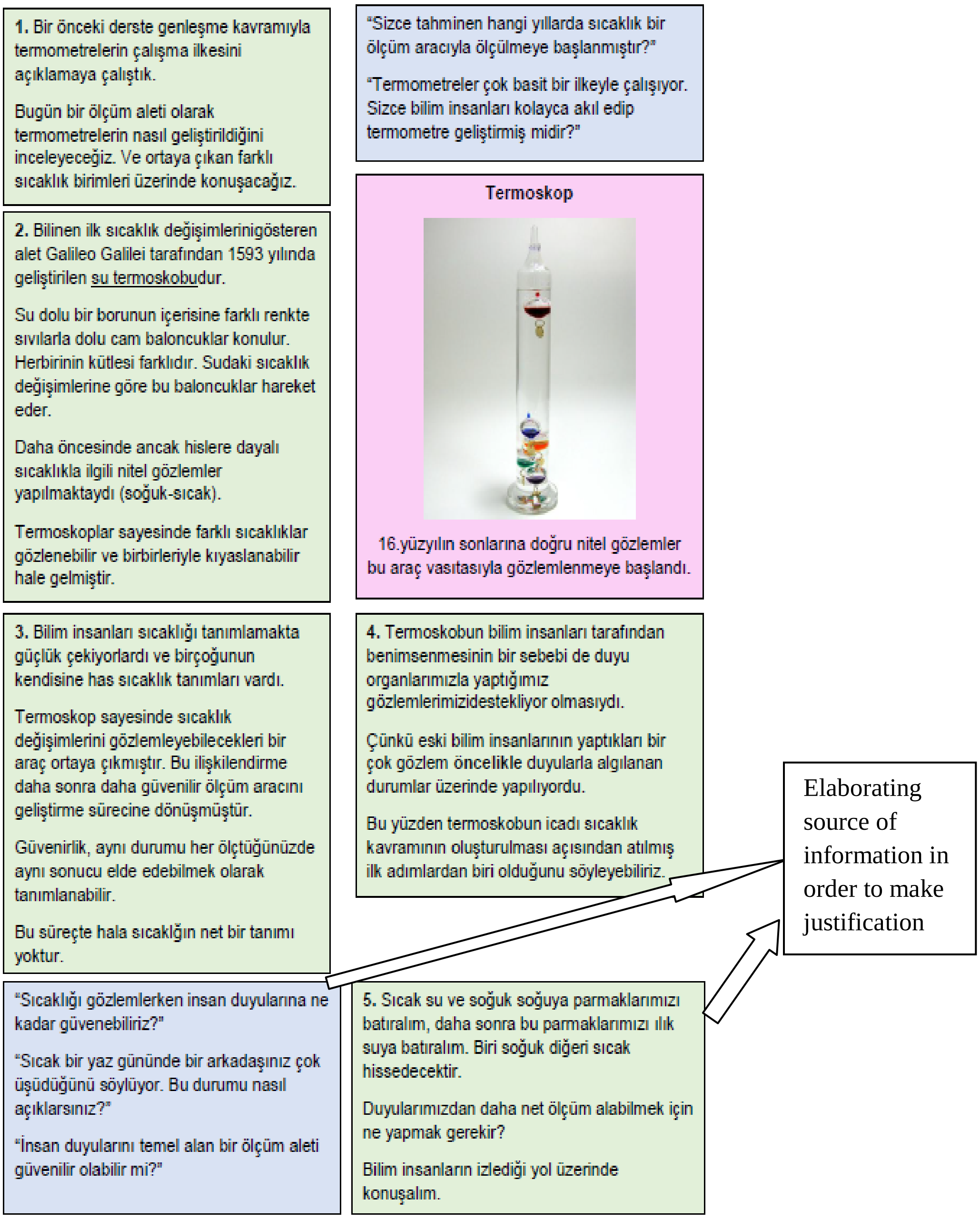


Figure 3.8 Inquiries for source of information in justification probe

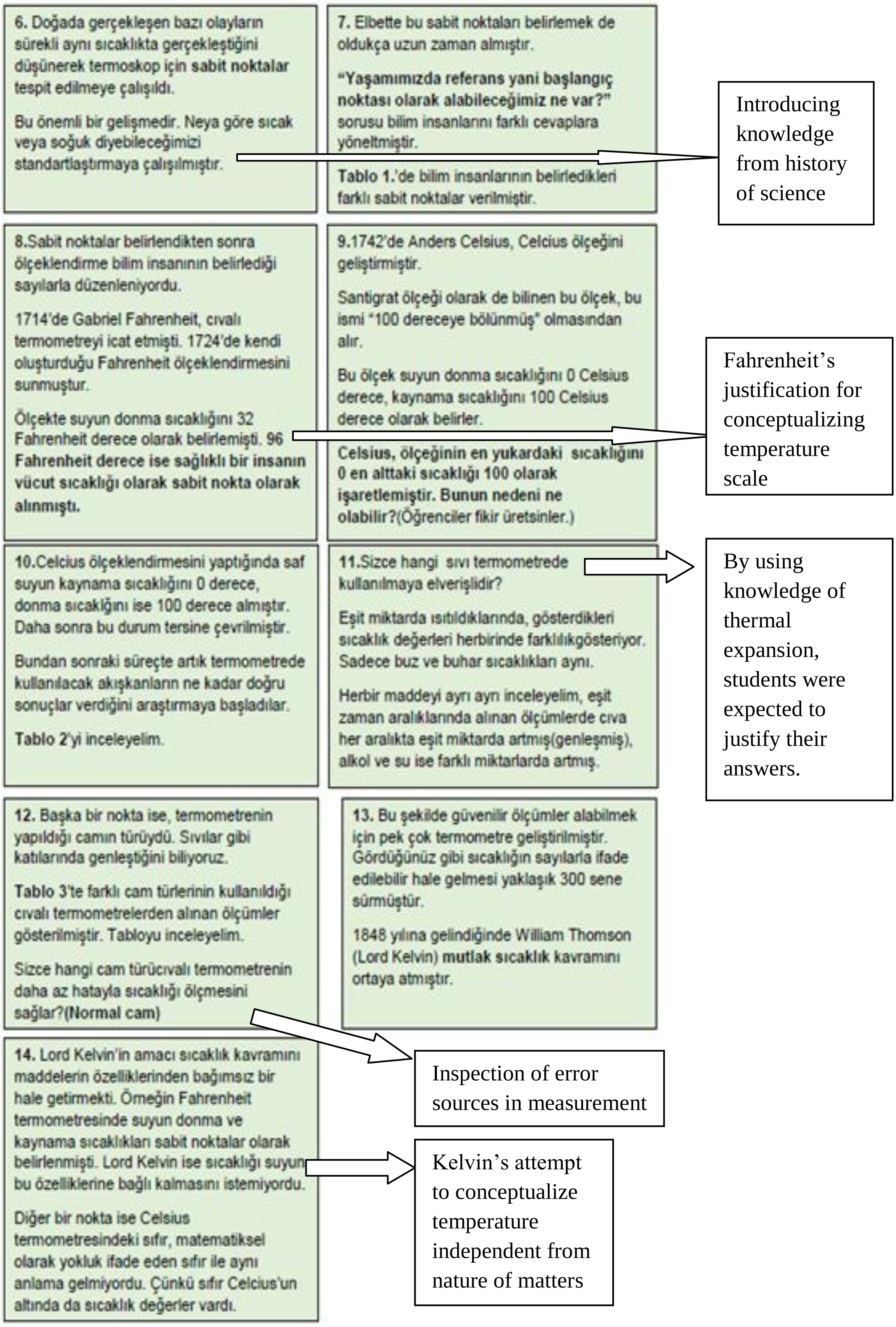
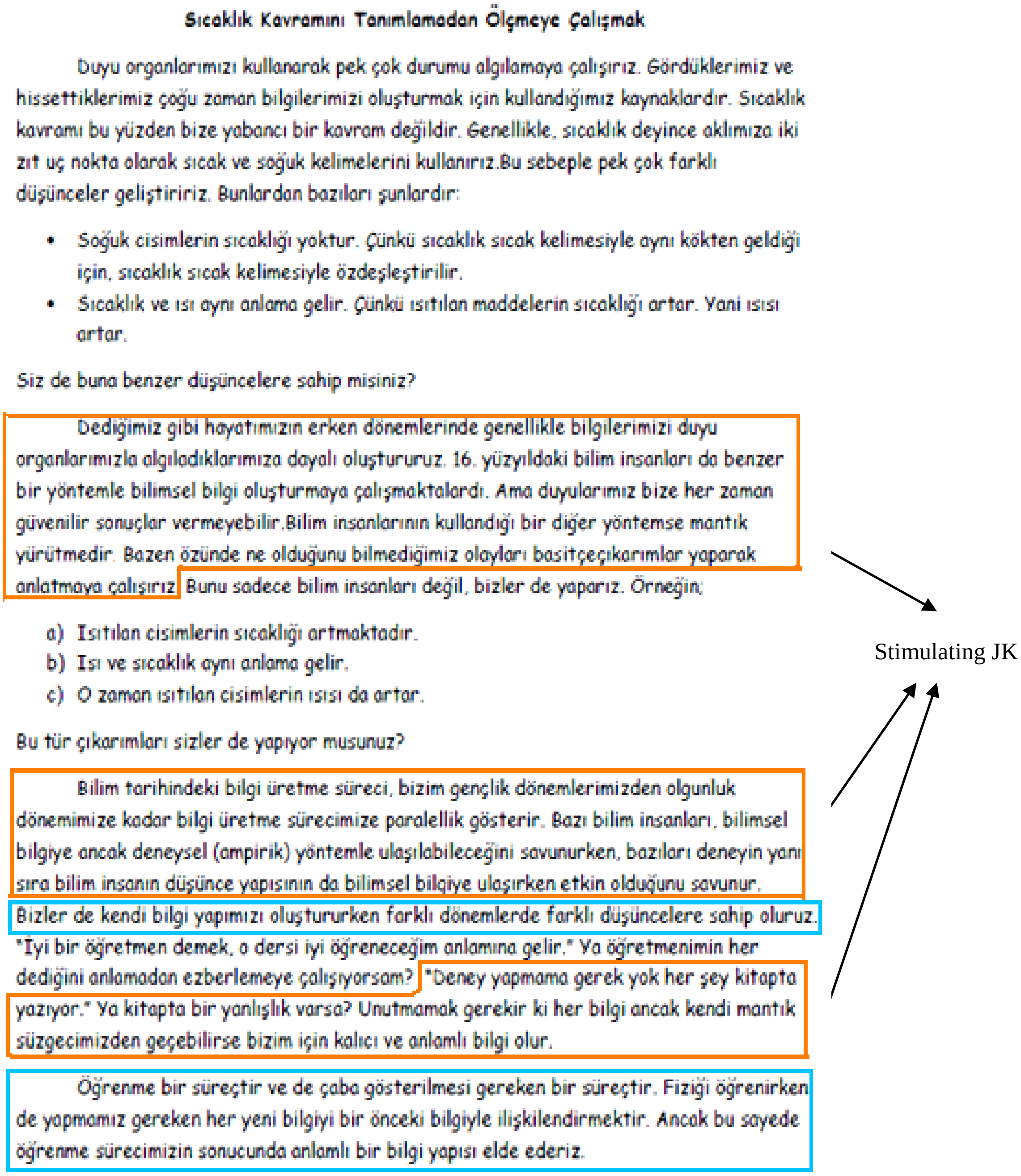


Figure 3.8 (continued)

After completion of subject matter, teacher delivered a paper (see Figure 3.9) to start new epistemological discussion. Even though the text is pointing out more than one epistemological dimension, it emphasizes mental processing of human being to justify the knowledge claims.



Sıcaklık Kavramını Tanımlamadan Ölçmeye Çalışmak

Duyu organlarımızı kullanarak pek çok durumu algılamaya çalışırız. Gördüklerimiz ve hissettiklerimiz çoğu zaman bilgilerimizi oluşturmak için kullandığımız kaynaklardır. Sıcaklık kavramı bu yüzden bize yabancı bir kavram değildir. Genellikle, sıcaklık deyince aklımıza iki zıt uç nokta olarak sıcak ve soğuk kelimelerini kullanırız.Bu sebeple pek çok farklı düşünceler geliştiririz. Bunlardan bazıları şunlardır:

- Soğuk cisimlerin sıcaklığı yoktur. Çünkü sıcaklık sıcak kelimesiyle aynı kökten geldiği için, sıcaklık sıcak kelimesiyle özdeşleştirilir.
- Sıcaklık ve ısı aynı anlama gelir. Çünkü ısıtılan maddelerin sıcaklığı artar. Yani ısısı artar.

Siz de buna benzer düşüncelere sahip misiniz?

Dediğimiz gibi hayatımızın erken dönemlerinde genellikle bilgilerimizi duyu organlarımızla algıladıklarımıza dayalı oluştururuz. 16. yüzyıldaki bilim insanları da benzer bir yöntemle bilimsel bilgi oluşturmaya çalışmaktalardı. Ama duyularımız bize her zaman güvenilir sonuçlar vermeyebilir.Bilim insanlarının kullandığı bir diğer yöntemse mantık yürütmedir. Bazen özünde ne olduğunu bilmediğimiz olayları basitçeçıkarımlar yaparak anlatmaya çalışırız. Bunu sadece bilim insanları değil, bizler de yaparız. Örneğin;

a) Isıtılan cisimlerin sıcaklığı artmaktadır.
b) Isı ve sıcaklık aynı anlama gelir.
c) O zaman ısıtılan cisimlerin ısısı da artar.

Bu tür çıkarımları sizler de yapıyor musunuz?

Bilim tarihindeki bilgi üretme süreci, bizim gençlik dönemlerimizden olgunluk dönemimize kadar bilgi üretme sürecimize paralellik gösterir. Bazı bilim insanları, bilimsel bilgiye ancak deneysel (ampirik) yöntemle ulaşılabileceğini savunurken, bazıları deneyin yanı sıra bilim insanın düşünce yapısının da bilimsel bilgiye ulaşırken etkin olduğunu savunur. Bizler de kendi bilgi yapımızı oluştururken farklı dönemlerde farklı düşüncelere sahip oluruz. "İyi bir öğretmen demek, o dersi iyi öğreneceğim anlamına gelir." Ya öğretmenimin her dediğini anlamadan ezberlemeye çalışıyorsam? "Deney yapmama gerek yok her şey kitapta yazıyor." Ya kitapta bir yanlışlık varsa? Unutmamak gerekir ki her bilgi ancak kendi mantık süzgecimizden geçebilirse bizim için kalıcı ve anlamlı bilgi olur.

Öğrenme bir süreçtir ve de çaba gösterilmesi gereken bir süreçtir. Fiziği öğrenirken de yapmamız gereken her yeni bilgiyi bir önceki bilgiyle ilişkilendirmektir. Ancak bu sayede öğrenme sürecimizin sonucunda anlamlı bir bilgi yapısı elde ederiz.

Figure 3.9 Reading task to provoke justification probe

(c) Epistemological Dimension 3: Changeability of Physics Knowledge

Motto: My physics knowledge may transform or change by new evidence (Transformation or Modification)

Conceptual change literature shed light upon understanding changeability of knowledge. Some ideas that students formed in science classes or from daily life observations may create difficulty in learning physics. In this probe, the focus is on students' tendency to change their own ideas. Cognitive conflict situations were created by introducing misconception questions. Discussions about prevailed ideas were important for this probe. Defense of individual ideas by students also allow us to detect which reasoning tools are activated, and why students resist changing their ideas. History of science elements was also integrated for achieving the goal of this probe (see Figure 3.10). Construction of scientific knowledge can inspire students that any idea can be proposed in terms of explaining a phenomenon unless they are refutable. Students were not expected to change their ideas quickly, but to form principles/reasoning tools to judge their own knowledge and accordingly transform or modify their knowledge.

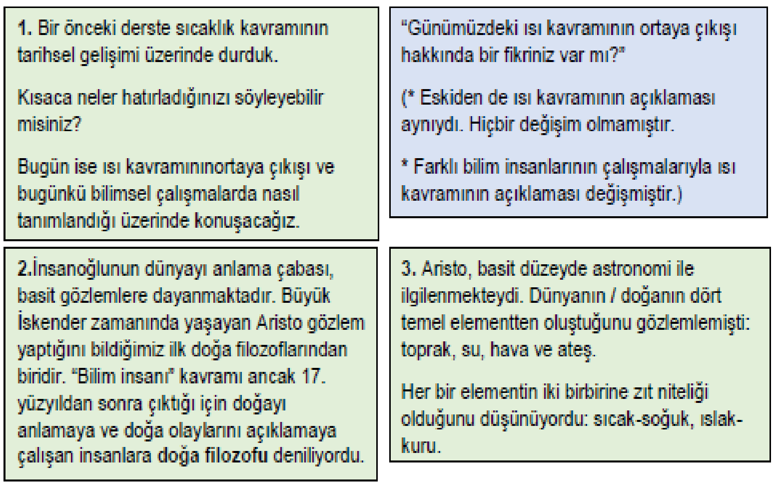


Figure 3.10 Introducing how heat concept changed by time to provoke changeability of knowledge probe

4. Toprak: soğuk ve kuru
Su: soğuk ve ıslak
Hava: sıcak ve ıslak
Ateş: sıcak ve kuru

Bu elementler birbirleriyle etkileşerek birbirlerinin niteliklerini alabilirlerdi. Su kaynarsa, sıcak ve kuru ateş soğukla birleşir, ıslak su sıcak ve ıslak hava üretir. Aristo'ya ve pek çok orta çağ filozofuna göre ısı (ve soğuk) maddesel dünyanın en temel niteliğiydi.

"Aristo'ya göre dört elementin özellikleri nasıl sınıflandırılmışolabilir?" (Öğrencileri derse entegre etmek için sorulabilir)

Inspecting possible ontological misconceptions about heat

5. Ortaya çıkan iki temel ısı tanımını şu şekilde özetleyebiliriz:
a. Isı temel elementlerden "ateş" ile aynı maddeydi. Maddenin yoğunluğu ne kadar fazla ise, o kadar fazla ısısı vardır.
Diğer görüş ise:
b. Isı, basit bir maddenin parçacıklarının hızlı hareketinin bir sonucudur. Bu hareket ne kadar etkin/enerjik ise o kadar çok ısı anlamına geliyordu.

"Bu açıklamalardan sizin ısı tanımınıza uyan bir ifade var mı?"

"Hangi açıdan benzerlikler/farklılıklar var?"

Conceptualization of heat in 18th century

6. Birinci görüşü benimseyenler maddesel düşünürken, ikinci görüşü benimseyenler ise dinamik (hareketli) bir ısı kavramı ortaya atmışlardır.

Gözlemler ve akıl yürütmeler sonucunda oluşan alt yapı, yeni doğa filozoflarını yeni araştırma metotlarına yöneltti. Aletle ölçüm almak gibi

Geçen derste üzerinde konuştuğumuz termometrelerin yapımı 17. yüzyılın ortalarına rastlar. Bu yüzyılın sonunda varlığını devam ettiren sıcaklık ölçekleri Fahrenheit, Celsius'dur. *(Reumorda bunlar arasındadır.)*

7. 18. yüzyıla girilmesiyle birlikte bilim insanlarının görüşleri ısının maddesel bir kavram olduğu teorisine doğru kayar.

Isı, göze çarpmayan/kolayca fark edilemeyen bir akışkan olarak görülmeye başlanmıştır. Bu akışkana "kalorik" madde denildi. (1740lar)

Enerji birimi kalori de buradan türetilmiştir.

8. Fransız bilim insanları Lavosier ve Laplace ise kimyasal olarak kalorik maddeyi ele almışlardı.Kalorik maddenin hissedilebilir olduğunu (örneğin termometrede sıcaklık değişimini görebiliriz), ağırlığı olan bir maddeye bağlanırsa tespit edilemez olduğunu savunuyordu.

Bilimsel açıdan ısrarla savunulan kalorik teori, 19. yüzyılın başlarında etkisini yitirmeye başladı. Çünkü kalorik teoriyi çürütebilecek bilimsel deliller ortaya çıkmaya başlamıştı.

"Bilim insanlarının ısrarla savunduğu ısıyı madde olarak gören kalorik teori neden değiştirilmek istenmiştir?"

Bilimde bir tanımın değişmesi için ne gereklidir?

(somut deliller, akıl yürütme sonucu ulaşılan farklılık yaratacak mantıklı sonuçlar)

Evidence required for refutation of existing conceptualization

Figure 3.10 (continued)

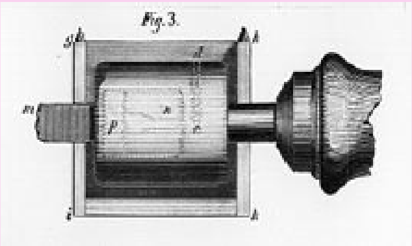
9. Farkında olmadan kalorik teoriyi çürütecek delil bulan **Kont Rumford** oldu. Onu Benjamin Thomson olarak tanıyoruz (atom teorileri).

Kont Rumford, Münih'te bir bombardıman silahı olan topun üretildiği bir askeri üstte görevliydi. Topun fırlatıldığı boruyu delmek için yapılan uygulamaları seyrederken delme işlemi esnasında sürtünmeden dolayı ısı açığa çıktığını fark etti.

10. Demir delginin pirinç üzerinde sürtünmesiyle ısı açığa çıkmıştı.

Rumford delme sonucu çıkan artık kısımları dikkatle inceledi. Bu artıklar birebir silindirle aynı olan metalden olduğu, dolayısıyla kendilerinden hiçbir şey kaybetmediklerini düşündü.

Yani ısı ortaya çıktığında maddesel bir kayıp yoktu.



Şekil 1 Rumford'ın yaptığı deney mekanizması

11. Kont Rumford, ısıca yalıtılmış bir kutunun içinden pirinçten yapılmış içi dolu silindir geçirir. Ve kutuyu suyla doldurur. Pirinç silindir ortasından delinirken, silindir kendi etrafında döndürülmektedir.
Şu gözlemleri yapar:
*Silindir dakikada 32 tur dönmekte. Kısa süre döndükten sonra silindirin ısındığını, aynı zamanda suyunda ısındığını gözlemler.

12. "Bir saatin sonunda, termometreyi suya koyduğumda, şimdiki sıcaklığının Fahrenheit ölçeğine göre 107 dereceye ulaştığını, yani sıcaklığının 47 derece daha yükseldiğini gördüm... İki saatin sonunda, suyun sıcaklığının 178 °F'a yükseldiğini buldum. 2 saat 20 dakikada sıcaklığın 200 °F olduğunu ve iki buçuk saat sonra suyun kaynadığını gördüm."

Data collection in order to understand nature of phenomenon

"Fahrenheit ölçeğindeki sıcaklığı nasıl Celsius'a çeviriyorduk?"

107-32=85/1.8 = 47,22 °C

178-32=146/1.8= 81,11 °C

200-32=168/1.8 = 93,33 °C

"Kont Rumford'ın bulguları ısının maddesel olmadığına sizi ikna etti mi?"

(Neden ve hangi açıdan ikna edici olup olmadığını soralım.)

"Kont Rumford'ın bulguları sizce bilim insanlarını ikna edebilmiş midir?"

13. Rumford, sürtünmeden dolayı ısınmanın gerçekleştiğini söylemiş; ısıca yalıtılmış bir ortamda dışardan bir şeyin yani "kalorik maddenin" geldiğini söylemenin manasız olduğunu savunmuştur. Isınmanın sebebinin bir tür hareket olduğunu söylemiştir.

Rumford'ın söyledikleri bilim çevrelerince kabul görmemiştir. Henüz açıkça yeni bir teori getirilmediği ve kalorik teoriyi savunanların hala etkin olması sebebiyle kalorik teoriden vazgeçilmemiştir.

Resistance of scientific community

14. (Dönemle ilgili bilgiler) 18. yüzyıla gelindiğinde hala "enerji"nin tanımı yapılamıyordu. "İş" kavramı da net değildi. İş kavramının tanımı özellikle Fransız mühendislerin çalışmaları sonucunda netlik kazanmıştır.

İngiliz mühendisler ise "güç" kavramıyla ilgileniyorlardı. İnsangücü, beygirgücü kavramlarının bu dönemde çıktığını söyleyebiliriz. Makinenin birim zamanda iş yapabilme kapasitesini bir insan ya da bir beygirin iş yapabilme kapasitesiyle orantılıyorlardı.

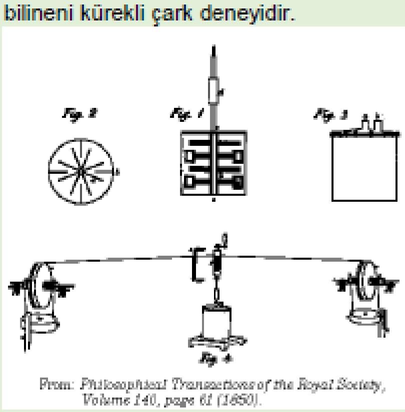
Figure 3.10 (continued)

15. Günümüzdeki enerji, kinetik ve potansiyel enerji kavramları 19. yüzyılın ilk yarısında anlaşılır hale gelmişti.

Bu dönemde ilgi elektrik ve manyetizma konularına doğru kaymıştı. Bu alanda yapılan çalışmalar bazı bilim insanlarının ısıyı daha iyi anlamasına yardımcı oldu.

Bunlardan biri James Joule'dür. Elektrik ve manyetizma üzerin çalışan Joule, deneylerinde kullandığı üreteçlerin elektrik akımı üretmesi sonucu tellerde meydana gelen ısınmayı kalorik teoriyle açıklamaya çalışmıştı. Üreteçteki kalorik madde direnci yani tele aktarılıyor bu sayede tel ısınıyordu.

16. Joule uzun süre çalışmaları esnasında farklı deneyler yapmıştır. Bunlardan en çok bilineni kürekli çark deneyidir.



17. Enerji ünitesinde yapılan işin harcanan enerjiyle olan bağlantısı üzerinde konuşmuştuk.

Joule'ün deneyi de bu bağlantıyı ortaya çıkartmıştır.
1. Yalıtılmış bir silindirin içine çark yerleştirilir ve içi su doldurulur.
2. Çarkın döndürülmesiyle suda gerçekleşek ısınma, çarkı döndürmek için yapılan iş ile denkleştirilip ısı miktarı hesaplanabilecekti.

Justifiable evidence to refute caloric view of heat

18. James Joule bilim adına büyük bir adım atmıştır. Binlerce yıldır tanımı netleştirilemeyen ve hesaplanamayan "ısı" kavramı bu sayede netlik kazanmıştır.

Deneysel ve matematiksel kanıtlar bilim çevrelerini ikna etmişti. Kalorik teoriden daha fazla işe yarayan yeni bir teorinin ortaya çıkmasına neden olmuştu.

Günümüzde artık enerji birimi olarak Joule kullanılmakta ve kalori birimi kullanma geleneği terk edilmektedir.

Bu iki enerji birimi arasındaki ilişki ise şu bağıntıyla verilmektedir:
1 Kalori = 4,18 Joule
1 cal= 4,18 J

Figure 3.10 (continued)

(d) Epistemological Dimension 4: Source of Knowledge

Motto: Source of information can be external (not necessarily) but we reconstruct the knowledge

Source of knowledge dimension is closely related with justification dimension. However, "good" physics teachers and "good" textbooks are perceived as primary sources of knowledge in our educational system. In order to make shift from external source of knowledge to the role of internal processes, teacher emphasized that individual's mental processing is essential to create one's own knowledge system. Content of teacher's talk was accordingly planned to discuss several issues as follows. Physics knowledge can be obtained from authority (physics teachers or textbook authors) or from nature (experimenting or making observation on nature). However, learning takes place when individuals make sense from obtained information. Therefore, we reconstruct the external information and integrate them into our knowledge system by testing coherency and consistency.

(e) Epistemological Dimension 5: Fixed Ability and Quick Leaning

Motto: Everybody have potential to learn physics (Potential for Learning Physics)

By little steps and little efforts, and cumulative effect of both would be helpful for students to diminish negative image of learning physics. Especially providing examples from observable nature, less mathematical focus and more conceptual discussions might be useful for changing beliefs. Construction of hierarchical structure of knowledge view might support the belief that everybody has the potential for learning physics. Throughout the instructions, students were constantly reminded that their previous learning is vital for their future learning and students studied on problems with varying difficulty levels beginning from simple to complicated. In addition, teacher's verbal reinforcement was used to encourage students and show their progress throughout instructions.

3.5.2.2. Implicit Epistemologically Enhanced Instruction (IEEI)

In this instructional method, content of the instruction was exactly same with EEEI. Epistemological discussions and students' reflections after the lecture were excluded in this method. Again, connections within the subject matter knowledge were done as shown in Figure 3.3. Teacher avoided explicit emphasis on epistemological dimensions. Instead, she spent more time on content knowledge.

3.6. Instruction in the Control Groups: Conventional Instruction

In control groups, students were taught based on teacher's conventional instruction. The instruction mostly based on lectures. The teacher presented the related physics content knowledge from textbook and solved questions parallel to university entrance exam questions. In some parts of the lecture, there were student-teacher interactions to stimulate students engage in the subject matter knowledge with real-life situations.

In general, the sequence of the lecture was determined by the textbook followed by the teacher. There was not any specific effort to make connections between students' previously learnt concepts. Teacher tend to ask simple questions to students about daily life situations, but these interactions did not lead to any further discussion. After introducing main concepts and related mathematical equations, teacher solved one or two questions on the board. These questions were taken from textbook directly. If time left, teacher allowed students to solve a few more questions on the board.

Teacher's lectures were mainly relied on textbook content rather than objectives in the 9th grade physics program. Even though conceptualization of heat and temperature unit was the first objective in the program, she preferred her students to be able to solve more questions requiring mathematical calculations than conceptual understanding. The main reason behind this situation was the term exams. She reported that she preferred calculation problems mostly in examinations. She avoided essay or short answer type questions because of students' incompetence on verbal performance. Interestingly, students also leave open ended questions empty without even reading them. Therefore, teacher was willing to spend more time on solving quantitative problems.

Students' roles in the CI class were active listeners during lecturing and active participants during question solving. Students were asked to recall specific piece of knowledge from previous lectures, such as defining heat or temperature or recalling formula of transferred energy $Q = m\ c\ \Delta T$. In order to give more insight about the teacher's convention of teaching, an excerpt from teacher's discourse and writings on board in a CI session was provided from field reports. An example of classroom discourse was as follows:

> *Teacher:* Let's remember. How do we use the energy given out or taken in?
> *Student A:* If a matter gives off energy, it gets colder. But temperature will increase in environment.
> *Student B:* By giving energy, we can also melt down an ice for example.
> *Teacher:* As the kinetic energy does not change, the temperature of a matter will not change during phase change. Now, please write on your notebook. "During phase change, the energy required to melt down 1 gram of matter is called latent heat of fusion.
> *Student C:* Is the latent heat of fusion same with specific heat?
> *Teacher:* No. Specific heat is the energy required for 1 gram of matter to change its temperature by 1^{o}C degree. For latent heat, we did not talk about temperature change.
> *Teacher's writing on board:*
> "Melting – opposite to freezing"
> "Latent heat of fusion (melting) = Latent heat of fusion (freezing)"
> *Teacher:* When we pour salt on ice, melting point of ice will decrease. If volume of a matter increases by melting, melting point of these matters will increase by external pressure. Bismuth (Bi) and antimony (Sb) are examples to these matters.

When ice melts down, its volume will decrease. With external pressure, its melting point will decrease.

Student D: M'am, the snow on the high mountains does not melt down for so long. It is because of external pressure, right?

Teacher: External pressure is different than atmospheric pressure. Do not mix them. Now, let's continue with the boiling point. Now, write on your notebooks. "When external pressure and internal vapor pressure becomes equal, it is the temperature which matters start to boil. It is called boiling point. Boiling point differs for every matter." What is the difference between boiling and vaporization?

Student E: For boiling, matter should reach higher temperature.

Teacher: Vaporization occurs at every temperature. However, water boils at 100^{o}C. Another example, you can dry out your clothes in either winter or summer because of vaporization. Only rate of vaporization changes due to season. Vaporization takes place on the surface. We can increase the number of examples. When liquids take "heat" from environment, environment cools down. Cologne is a good example. When your body temperature rises, you can cool down by applying wet cloth on your forehead. Moreover, moisture refers to water vapor in air. The rate of vaporization decreases with moisture.

Teacher's writing on the board:

$$Pressure\ \frac{1}{\alpha}\ Rate\ of\ vaporization$$

Teacher: In a windy day, atmospheric pressure decreases. Therefore rate of vaporization will increase. They are inversely proportional.

Teacher's writing on the board:

"Latent heat of vaporization = Latent heat of condensation"

"Type of matter" (affects boiling point)

"Purity of matter" → (affects boiling point) Salty water boils at 105^{o}C.

"Pressure" → (affects boiling point) In Ankara, water boils at 96^{o}C.

3.7. Procedure

Firstly, the research problem of the study was determined while articulating related literature review about personal epistemology. After determining research problem, intense and detailed literature review was conducted by using key words given in Appendix P. By using these keywords and their combinations, systematical analysis of resources took place. ProQuest (UMI) Dissertations and Theses, the Middle East Technical University (METU) Library Theses and Dissertations Archive, METUnique search, Web of Science, EKUAL and Google Scholar were used as general resources. In addition, MS and PhD thesis studies in Turkey were searched from Turkish Council of Higher Education National Thesis Center database.

Collected papers related to the current study were classified and summarized in literature review chapter. Based on the literature review, treatments were started to be developed in the form of detailed lesson plans. Then, the treatments were reviewed by the supervisor and some revisions were made. A year before the study, the researcher had already begun to develop PPEQ instrument. Two staged data collection was conducted by the researcher in terms of pilot and validation of the test. Meanwhile, The HTAT was developed, validated and administered for pilot study. Following the item analysis and required permission from the Directorate of National Education in Ankara, in the fall semester of 2013-2014 academic year, the treatments were implemented in a school (see Appendix L).

Next step was to determine sample and population of the study and accordingly the related physics unit was determined. Before implementation of treatment, researcher and teacher made meetings to check out lesson plans and instructional materials (reflection papers, experiment handouts). Two weeks before implementation, pretests were implemented by taking permission from school administration and teachers. Treatments lasted for seven weeks. One week later posttests were delivered. Later, raw data were entered to electronic format in MS Excel and SPSS programs. By using PASW Statistics 18, the data was analyzed.

3.8. Treatment Fidelity and Verification

Treatment fidelity can be described as “the extent to which core components of interventions are delivered as intended by protocols” (Gearing, El-Bassel, Ghesquiere, Baldwin, & Ngeow, 2007, p.79). Instructional materials for treatment groups were developed by the researcher and reviewed by the experts including the teacher participated in the study. In this process, the supervisor of the study gave feedback routinely after each produced material. According to feedbacks, materials were revised or enhanced. These instructional materials were also shared with thesis monitoring committee members for cross checking. Only one committee member had convenient time for planned meetings to take detailed feedbacks. Accordingly, the researcher reshaped the instructional materials.

In order to improve treatment fidelity, the treatment verification was done via the classroom observation checklist as mentioned in Section 3.4.3. After completion of development of the instructional materials, the key components of the explicit and implicit instruction were determined and the classroom observation checklist was constructed accordingly. This checklist was completed by the researcher for each lesson and by an observer for randomly selected lessons. By the way, the researcher always had chance to take immediate feedback from the classroom discourse and had time to make necessary changes for other lectures (e.g. when teacher did not mention particular content in the treatment groups, the content was integrated in the following session). For CI classrooms, instruction was always being checked that teacher did not use the same materials or examples given in the treatment groups.

3.9. Controlling Internal Validity Threats

Internal validity is an important issue that should be controlled in many aspects to minimize effects of undesired extraneous variables. For matching-only pretest-posttest control group research design, Fraenkel and Wallen (2008) asserted that there is some control over subject-characteristics, mortality, instrument decay, testing, history, maturation and regression threats and there is weak control over location, data collector characteristics and data collector bias, attitude of subjects and implementation threats (p.276). In order to improve internal validity of the current study, how threats for interpretable results were controlled is discussed in this section:

(a) Subject Characteristics: The study was conducted in purposively selected schools with intact classes. Students in the ninth grade classes could not have been randomly selected for two treatment groups and control groups. Instead, researcher randomly assigned classes to these groups. Data related to gender, age, physics achievement in first semester, pretest scores in HTAT and PPEQ were collected by the researcher in order to describe the common students' characteristics. These variables were considered as potential confounding variables based on literature review. Results of the descriptive analysis are presented in Chapter 4 that student groups displayed similar characteristics. Additionally, researcher used statistical matching by using covariates (pretest scores in HTAT and PPEQ) in data analysis in order to control effect of subject characteristics.

(b) Loss of subjects (Mortality): In order to reduce the possibility of this threat, administration of pretests and posttests were done in appropriate times decided with the teacher. The researcher was present in school during the test administration week that we could make rearrangements for implementations by considering number of absentees in a class. For absentees in pretests, researcher took permission from school administration and the teacher who had lecture in that hour to apply test. In spite of all cautions, there were still few students who did not take the tests at the end of the study. Missing data analysis is presented in Section 4.2. The percentage of missing data was about 3.2% of the sample that researcher assumed that it will not cause mortality effect.

(c) Location: Physics teacher did not have any interest to do laboratory session in her ninth grade classrooms. She claimed that classroom management was difficult in laboratory because of the classroom settings. However, experimental groups were required to attend lecture in laboratory class during implementation. This could be a possible threat for internal validity of this study that laboratory and classroom conditions are different than each other. In order to control location threat, the weeks that students in the IEEI and EEEI went to laboratory, the physics teacher instructed CI groups in laboratory also.

(d) Instrument Decay: This threat was controlled by using scoring rubrics for scoring one essay type item in HTAT (as shown in Table 3.12) which did not permit different interpretation of results.

(e) Data Collector Characteristics: Before implementations, researcher attended and observed classes in the sample during their physics lectures. As students got familiar with the researcher, researcher's existence became a routine of the classes. In order to control data collector characteristics, the researcher collected all data by herself.

(f) Data Collector Bias: For test administration, the researcher standardized the procedures for each class. During classroom observations, in order to eliminate data collector bias, another observer attended a sample of lectures. And she was not informed about which groups are treatment or control groups.

(g) Testing: In order to examine students' achievement levels and already existing personal epistemology, pretests were administered to all class in the sample. Pretesting might alert some students that would affect their performance on posttests. As all groups are exposed to pretests, the effect of testing is assumed to be in similar level.

(h) History: The researcher was always in contact with the physics teacher and most of the time she was present in the school. There was no specific or extraordinary event occurred during the treatment both in school and specifically in classrooms.

(i) Maturation: As the students in each groups displayed similar characteristics (such as age level, percentage of girls and boys in each class), the maturation was not a serious potential threat for the internal validity of the study.

(j) Attitude of Subjects: Students in each group received consent form at the beginning of the study including control group (available in Appendix M). By the way, researcher informed all students that they would be the subject of an experimental study and there would be only classroom observations during seven weeks. Students were unaware of how the experiment would be conducted in their physics classes. Researcher tried to equalize the number of class and laboratory sessions in each group. In CI groups, simple demonstrations were done by the teacher such as introducing thermometer and how it works. Additionally, researcher did not receive any different reaction (e.g. demoralization) or complaints from control group and experimental group students.

(k) Statistical Regression: Students' pretest scores and physics achievement in first semester were initially analyzed that there was no significant difference among groups.

(l) Implementer and Implementation: One teacher was assigned to all classes in the study. Before the treatment, researcher gave instructions about how the treatment would be integrated in lectures and provided guidebook and lesson plans. Before and after each class, researcher and teacher discussed the materials and researcher gave regular feedback about teacher's performance. the researcher observed every lesson both in treatment and control groups by filling the classroom observation checklist. It also helped researcher to control CI group to prevent usage of same activities in treatment groups.

In order to reduce the effect of unexpected events in school during test administration and implementation process, the researcher made an action plan at the beginning of the study as given in Table 3.26 by considering date of common examinations among ninth grades and national holidays.

Table 3.26 Action plan of the current study in school setting

Week	Dates	Research Event	Holiday(s) and common exams	Class will be affected
1	24 March – 28 March	Pretesting	-	All classes
2	31 March – 4 April	Recovery (for missing pretests)	4th April – I. Physics exam	All classes
3	07 April – 11 April	First lecture	-	-
4	14 April – 18 April	Second lecture	-	-
5	21 April – 25 April	Third lecture	23 April (Holiday)	9C
6	28 April – 02 May	Fourth lecture	29 April – Exam (4. lesson)	9E
			01 May (Holiday)	9A and 9B
7	05 May – 09 May	Fifth lecture	06 May – Exam (4. lesson)	9F
8	12 May – 16 May	Sixth lecture	-	-
9	19 May – 23 May	Seventh lecture	19 May (Holiday) 21 May – II. Physics Exam	All classes
10	26 May – 30 May	Recovery (for lectures)	30 May – Exam (4. lesson)	9F
11	02 June – 06 June	Post testing	03 June – Exam (3. lesson)	9E
12	09 June – 13 June	Recovery (for missing post tests)	-	-

In spite of planning the implementation and testing process, an unwanted situation took place in administration of posttests. Last physics exam of the ninth grades was held before administration of the post-HTAT. In spite of increase in post-HTAT scores, it was not as high as expected. It seems that students did not perform with full concentration during the posttests.

3.10. Analysis of Data

For the current study, type of instruction (INSTRCUTION) was identified as the independent variable. Students' pretest scores on the HTAT (PREHTAT), pretest scores on the PPEQ (PREPPEQ) and physics achievement in first semester (PPHYSCG), age and gender were identified as five potential covariates. Posttest scores on HTAT (POSTHTAT) and posttest scores on PPEQ (POSTPPEQ) were two dependent variables of the study.

In order to generalize results from sample to a population, Multivariate Analysis of Covariance (MANCOVA) was used as an inferential statistics analysis. MANCOVA was selected to be able to control effects of possible differences between treatment and control groups due to selecting samples from intact groups. Before conducting MANCOVA, assumptions of the statistical analysis were tested. The raw data is provided in Appendix O.

3.11. Power Analysis

The significance level of the study (α) was set to .05 which is commonly used value in education literature. Initially, minimum desired power value was set to .80 that was recommended by Hinkle, Wiersma and Jurs (2003). For the current study, estimated sample size for the desired power value was calculated by the following equation given by Cohen, Cohen, West and Aiken (2003, p.177):

$$n = \frac{L}{f^2} + k_A + k_B + 1$$

The "n" represents sample size in the equation. "k_A" refers to number of covariates. For this study, k_A was equal to five. And "k_B" refers to numbers of IVs (group membership variables). The number of IVs is obtained by "k_B=g-1", where g represents the number of levels of the group membership variables. In this study, group membership variable was teaching method that requires three levels. Therefore, k_B was equal to two. For computation by hand, value of "L" for the k_b by considering desired power and alpha level could be found from tables given in appendices by Cohen *et al*. (2003, p. 651). L value for the current study was determined as 9.64 using α=.05 and β=.80, and k_B=2. Preset index of effect size (f^2) was set by looking at the results of related studies. Unfortunately, there were only a few studies similar to current study to consider; therefore, the effect size was set to medium effect size of f^2=.06. Finally, the minimum sample size was calculated as 169 for the desired power by using the formula given before. In the current study, there were 186 students in the sample.

3.12. Unit of Analysis

For assumption of independence of observation, unit of analysis and experimental unit should have been same. Experimental unit can be defined as randomly assigned smallest unit of study in which units are allowed to give reaction independently (Burstein, 1980). In this study, the unit of analysis was each student and experimental unit was each intact classroom. Interactions among students in a classroom and between students of different classrooms were inevitably existed at some level because of the nature of educational settings. It is difficult to claim that independence of assumption was met sufficiently. However, during data collection, independence of observation was ensured by teacher by not allowing interaction among students who took tests.

3.13. Assumptions and Limitations

Assumptions of this study are:

- Students participated in this study responded every measurement tool seriously and honestly.
- Students of treatment groups did not interact with students in control groups.

Delimitations of this study are:

- The study is conducted in one school.
- Only one teacher participated into the study.
- Number of participants was limited to 186 ninth grade students.
- The results of this study were limited to ninth grade ATTHS students.
- The results of this study were limited to “heat and temperature unit” in ninth grade.
- Students’ physics related personal epistemology was relied on five sub-dimensions: structure of knowledge, justification of knowledge and knowing, changeability of knowledge, source of knowledge, and fixed ability and quick learning.
- The duration of the study was limited to seven weeks.

CHAPTER 4

RESULTS

Results of the current study will be introduced in this chapter. There are six sections: data cleaning, missing data analysis, descriptive statistics, inferential statistics, results of the classroom observation checklist and summary of the findings.

4.1. Data Cleaning

Before handling missing values, patterns in each variable were examined. The researcher detected specific patterns in students' responses such as coding all PPEQ tests items as 1 (or 5), responding all true/false questions as true (or false), or responding only half of the questions in PPEQ which were accepted as the signs of unattended responses. As a result, eight subjects (four subjects in CI and four in EEEI groups) were removed from the whole data set. Missing data analysis was continued with remaining 178 subjects.

4.2. Missing Data Analysis

To perform descriptive and inferential statistics, missing data analysis was conducted. Number of ninth grade students participated in the study was 186 in total. Demographic information about students including students' physics scores from previous semester were collected from teacher's records. Students' gender and age were gathered from the PPEQ. The pre-PPEQ was administered to 185 students and the pre-HTAT was taken by 181 students. On the other hand, three students were absent during the administration of post-PPEQ and four students did not take post-

HTAT. Within these absentees, one of the students did not take post-PPEQ and post-HTAT. These students were not reachable because of their early leave, before the end of the semester. For this reason, there were six missing values which were equivalent to 3.22 % of the sample. As Cohen and Cohen (1983) suggested that missing values in dependent variables might be excluded from the further analysis. Consequently, data analyses were conducted with data of 172 students. Missing values associated with each variable in each group are given in Table 4.1.

Table 4.1 Missing values of the variables in the study with respect to each instructional method

	CI		IEEI		EEEI		Total		
Variables	N	Missing	N	Missing	N	Missing	N	Missing	Missing %
Gender	60	0	64	0	62	0	186	0	0
Age	60	0	64	0	62	0	186	0	0
PPHYSCG	60	0	64	0	62	0	186	0	0
PREPPEQ	60	0	64	0	61	1	185	1	0.53
PREHTAT	59	1	63	1	59	3	181	5	2.67
POSTPPEQ	60	0	62	2	61	1	183	3	1.61
POSTHTAT	59	1	62	2	61	1	182	4	2.15

Subjects were deleted who did not take either one or both posttests and applied data replacement by means of series for missing subjects in pretests. As suggested by Tabachnick and Fidell (2001), missing values less than 5 % can be handled by replacing their missing values by the mean of the variable. There are 0.53 and 2.67 % missing values in pre-PPEQ and pre-HTAT, respectively that did not exceed the threshold value.

4.3. Descriptive Statistics

After handling missing values, 172 subjects' data (106 female (61.6%) and 66 male (38.4%) students), were included into data analysis. When students' PREACH scores are considered, sample mean was found 73.27 out of 100. Group means are close to sample mean which ranges between 71.86 and 74.10. For the PPEQ, subjects can get a possible minimum score of 26 and a maximum of 130. When pretest and posttest scores on PPEQ are considered, students scores ranged from 76 to 126. And for the HTAT, students can get scores between 0 and 100 as usual in achievement tests. In this study, students' scores ranged from 10 to 69. Pre-PPEQ and pre-HTAT results showed that control group (CI) has greater mean value than treatment groups but there is not much difference between the group means. The descriptive statistics of continuous IV and DVs for each teaching method are given in Table 4.2.

Table 4.2 Descriptive statistics of continuous IVs and DVs in the study

	N	Mean	Min.	Max.	S.D.	Skewness		Kurtosis	
						Stat.	S.E.	Stat.	S.E.
PPHYSCG									
CI	55	71.86	50.75	87.00	7.74	-0.461	.322	0.261	.322
IEEI	60	73.76	51.00	86.25	7.35	-0.718	.309	0.771	.309
EEEI	57	74.10	50.00	91.50	8.63	-0.313	.316	0.173	.316
Total	172	73.27	50.00	91.50	7.93	-0.437	.185	0.305	.368
PREPPEQ									
CI	55	102.75	78	125	8.84	-0.398	.322	0.301	.322
IEEI	60	102.95	78	121	8.43	-0.198	.309	0.296	.309
EEEI	57	101.57	78	123	10.4	-0.093	.316	-0.260	.316
Total	172	102.43	78	123	7.93	-0.239	.185	0.038	.368
PREHTAT									
CI	55	26.35	13	42	7.36	0.241	.322	-0.319	.322
IEEI	60	26.29	12	48	8.47	0.271	.309	-0.397	.309
EEEI	57	24.91	10	41	7.76	0.302	.316	-0.494	.316
Total	172	25.85	10	48	7.88	0.271	.185	-0.458	.368
POSTPPEQ									
CI	55	101.01	76	124	11.24	-0.156	.322	-0.607	.322
IEEI	60	104.86	83	122	9.79	-0.160	.309	-0.415	.309
EEEI	57	105.83	85	126	10.82	-0.301	.316	-0.626	.316
Total	172	103.95	76	126	10.75	-0.236	.185	-0.536	.368
POSTHTAT									
CI	55	29.14	16	43	7.69	0.031	.322	-0.788	.322
IEEI	60	38.44	12	59	9.71	-0.511	.309	0.084	.309
EEEI	57	42.98	17	69	10.70	-0.239	.316	-0.135	.316
Total	172	36.97	12	69	11.01	0.041	.185	-0.458	.368

When descriptive statistics of DVs are considered, mean differences between control group and treatment groups were observed. EEEI group performed better than other treatment group of IEEI and much better than CI on post-PPEQ. Same differences were observed for post-HTAT scores as well. Sample size of each group (55 for CI, 60 for IEEI and 57 for EEEI) is close to each other and greater than 20, which allow assuring normality assumption (Tabachnick & Fidell, 2001). In addition to the normality assumption, skewness and kurtosis values of each variable for each group are between -1 and +1. In other words, all distributions within sample are normal. Histograms with normal curves of IVs (PPHYSCG, PREHTAT and PREPPEQ) and DVs (POSTHTAT and POSTPPEQ) for CI, IEEI and EEEI groups are illustrated in Figure 4.1 and Figure 4.2 respectively.

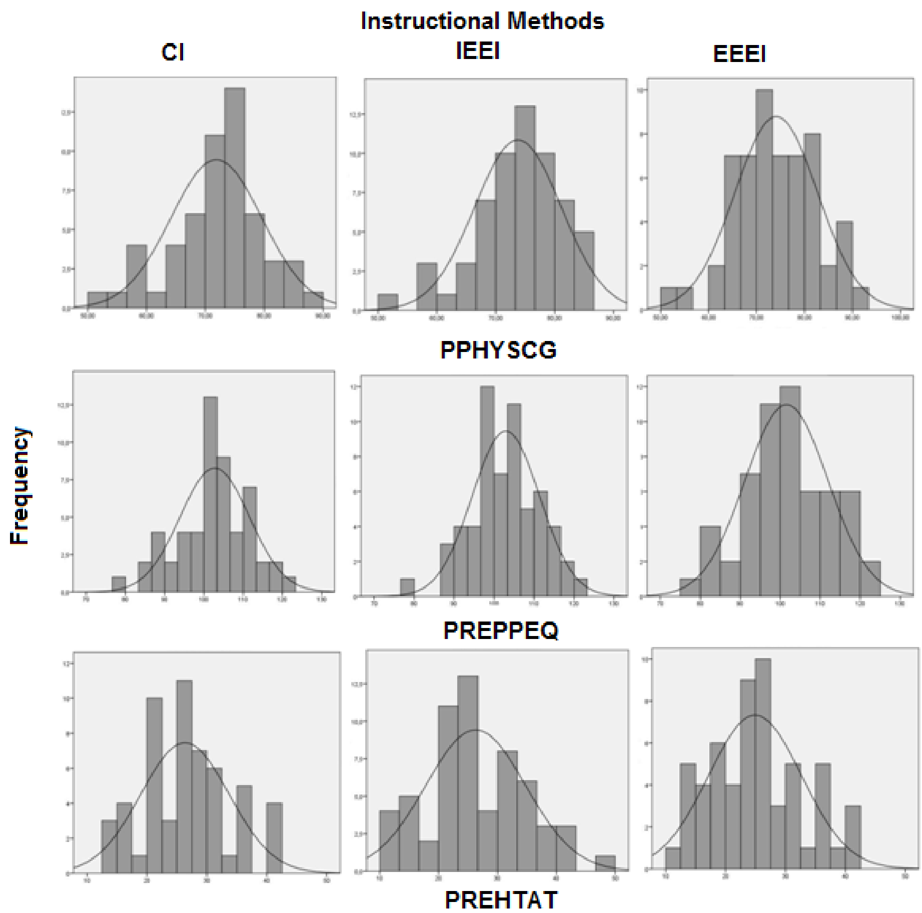


Figure 4.1 Histograms of PPHYSCG, PREHTAT and PREPPEQ scores for CI, IEEI and EEEI groups

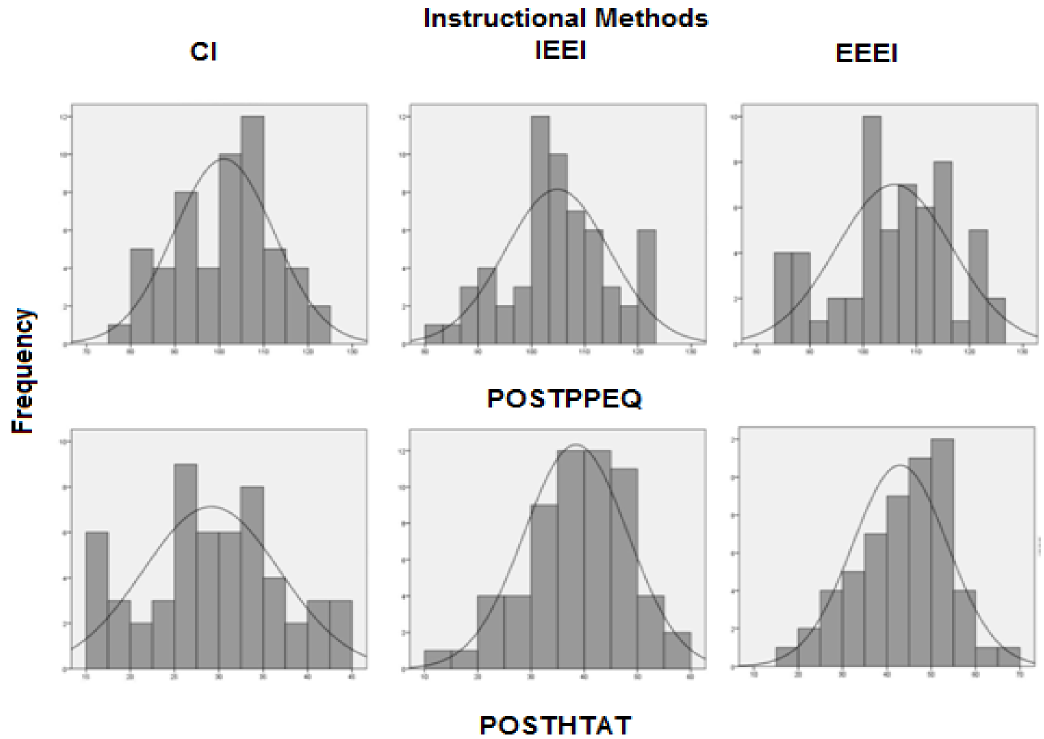


Figure 4.2 Histograms of POSTPPEQ and POSTHTAT scores for CI, IEEI and EEEI groups

4.3.1. Dimensional Analysis of PREPPEQ and POSTPPEQ

In order to examine dimensional changes between and within groups, students' responses in each dimension was summed up and new subscores for SKH, SKC, JK, CK, Source and QL dimensions were obtained. This summation was done for both PREPPEQ and POSTPPEQ scores. Subscores of each test with respect to teaching method are given in Table 4.3. When initial and final sum of the dimensions are compared, there is no drastic change occurred but some differences were observed within different groups. Only SKH subscores are increased besides decline in subscores of JK, CK, Source and QL dimensions in CI groups. In IEEI groups, subscores of SKH, SKC and CK are increased. However, their subscores on JK, Source and QL dimensions are decreased. For EEEI groups, some positive changes are observed in SKH, SKC, JK and Source dimensions with small increase in CK and QL dimensions.

Table 4.3 Subscores obtained from PREPPEQ and POSTPPEQ for each group

	PREPPEQ					POSTPPEQ			
	Min	Max	Mean	S. D.		Min	Max	Mean	S. D.
CI									
SUM_SKH	5	19	14.52	2.63	PSUM_SKH	10	20	15.29	2.55
SUM_SKC	10	25	20.74	3.27	PSUM_SKC	13	25	20.74	3.10
SUM_JK	13	25	20.23	2.94	PSUM_JK	12	25	19.34	3.35
SUM_CK	8	20	15.58	2.50	PSUM_CK	6	20	15.36	2.95
SUM_Source	6	20	15.12	3.43	PSUM_Source	7	20	14.76	3.23
SUM_QL	6	20	16.52	2.82	PSUM_QL	7	20	15.41	3.33
IEEI									
SUM_SKH	4	20	14.90	2.88	PSUM_SKH	4	20	15.63	2.68
SUM_SKC	9	25	20.68	3.08	PSUM_SKC	5	25	20.71	3.25
SUM_JK	14	25	19.73	2.74	PSUM_JK	9	25	19.71	3.36
SUM_CK	7	20	15.56	2.35	PSUM_CK	10	20	16.43	2.25
SUM_Source	9	20	15.78	2.62	PSUM_Source	4	20	15.66	3.68
SUM_QL	8	20	16.75	2.23	PSUM_QL	9	20	16.50	2.36
EEEI									
SUM_SKH	10	20	14.40	2.29	PSUM_SKH	11	20	16.21	2.34
SUM_SKC	8	25	20.05	3.63	PSUM_SKC	11	25	20.71	3.24
SUM_JK	12	25	20.10	2.98	PSUM_JK	12	25	20.43	3.24
SUM_CK	8	20	15.57	2.55	PSUM_CK	9	20	15.59	2.78
SUM_Source	8	20	15.54	2.75	PSUM_Source	8	20	16.21	3.02
SUM_QL	8	20	16.15	2.88	PSUM_QL	8	20	16.22	2.95

4.4. Inferential Statistics

Since there are two dependent variables and potential covariates in this study, Multivariate Analysis of Covariance (MANCOVA) was selected to perform data analysis. Firstly, covariates were determined and then assumptions of MANCOVA were checked. MANCOVA results were presented and discussed with follow-up analysis of covariance (ANCOVA) tests.

4.4.1. Determination of Covariates

In order to determine covariates among five independent variables, correlations between all variables are examined. As can be seen from Table 4.4, either gender or age variables are not correlated with any IVs and DVs in the study. These variables will be excluded from further inferential tests.

Table 4.4 Correlations among independent and dependent variables in the study

Variables	AGE	PPHYSCG	PREPPEQ	PREHTAT	POSTPPEQ	POSTHTAT
GENDER	-.010	-.098	-.067	-.039	.022	-.007
AGE		-.033	.107	-.031	.056	.065
PPHYSCG			.110	.181*	.078	.288*
PREPPEQ				.008	.564*	.109
PREHTAT					.035	.345*
POSTPPEQ						.290*

*Correlation is significant at the 0.05 level (2-tailed).

The dependent variable POSTPPEQ had significant correlation with PREPPEQ only. Other dependent variable, POSTHTAT, had significant correlation with both PPHYSCG and PREHTAT. However, there is a significant low correlation between PPHYSCG and PREHTAT (r = .181, p <. 05). Therefore, both PREHTAT and PPHYSCG can be selected as covariates. Correlation between PREHTAT and POSTHTAT and correlation between PREPPEQ and POSTPPEQ are significant at .01 levels. These correlations are less than .80 and there is no significant correlation between PREPPEQ and PREHTAT as desired. As a result, PPHYSCG, PREHTAT and PREPPEQ are decided to be used as three covariates in the data analysis.

4.4.2. Assumptions of MANCOVA

In order to conduct MANCOVA, there are five assumptions should be met: (a) independence of observations, (b) multivariate normality, (c) linearity and multicollinearity, (d) homogeneity of variance-covariance matrices, and (e) homogeneity of regression slopes.

4.4.2.1. Independence of Observations

Data collectors, researcher and teacher, observed each test administration process and verified that students completed their tasks on their own for each test. No violation was detected during data collection. Therefore, assumption of independence of observations was met.

4.4.2.2. Multivariate Normality

Univariate normality is important criteria to obtain evidence for multivariate normality. To check whether normality assumption was met, skewness and kurtosis values in Table 4.2 were examined initially. As values are between -2 and +2, normal distribution was observed among variables. As MANCOVA is quite sensitive to outliers in the data, univariate outliers were also examined. Each dependent variable was checked in order to see outliers, but there were no big differences in the series to call an outlier. Therefore, all subjects were remained in analysis.

Other tests for univariate normality (i.e. Kolmogorov-Smirnov, Shapiro-Wilk tests) provided by SPSS were also checked. These tests calculate probability that the sample is selected from a normal population. Therefore, insignificant results of these tests assure univariate normality. In Shapiro-Wilk test, obtaining value $W = 1$ corresponds to perfect normal distribution in data. As shown in Table 4.5, tests results are not statistically significant ($p > .05$). W values range between .964

and .988, very close to 1.0. Therefore, each variable score was normally distributed for all groups.

Table 4.5 Univariate normality tests' results for IVs and DVs in the study

	Teaching Method	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
	CI	.096	55	.200*	.974	55	.275
PPHYSCG	IEEI	.093	60	.200*	.964	60	.072
	EEEI	.060	57	.200*	.984	57	.671
	CI	.112	55	.080	.979	55	.442
PREPPEQ	IEEI	.071	60	.200*	.988	60	.844
	EEEI	.082	57	.200*	.983	57	.579
	CI	.074	55	.200*	.975	55	.318
PREHTAT	IEEI	.082	60	.200*	.978	60	.345
	EEEI	.078	57	.200*	.973	57	.239
	CI	.081	55	.200*	.982	55	.596
POSTPPEQ	IEEI	.077	60	.200*	.973	60	.196
	EEEI	.082	57	.200*	.964	57	.083
	CI	.068	55	.200*	.966	55	.118
POSTHTAT	IEEI	.097	60	.200*	.977	60	.306
	EEEI	.085	57	.200*	.988	57	.826

Note: This is a lower bound of the true significance.

To check multivariate outliers, Mahalanobis distance for each case was calculated firstly. Mahalanobis distance is the distance of an individual case from the centroid which is the point created by the means of all variables (Tabachnick & Fidell, 2001). By looking at Mahalanobis distance, discrepancies within the sample such as outliers can be detected. For two dependent variables, critical value of Mahalanobis distance is 13.82. If there is any value greater than critical value, multivariate outlier exists in the sample (see Table 4.6). Maximum values for CI, IEEI and EEEI are 6.360, 8.239 and 7.495 respectively, which do not exceed the critical value. It shows that there is no multivariate outlier in this sample.

Table 4.6 Mahalanobis distances of two dependent variables for each group

Teaching Method	Min	Max	Mean	S.D.	N
CI	.026	6.360	1.964	1.715	55
IEEI	.008	8.239	1.967	1.872	60
EEEI	.081	7.495	1.965	1.608	57

Note: Dependent variables: POSTHTAT and POSTPPEQ

4.4.2.3. Linearity and Absence of Multicollinearity

Linearity assumption seeks out the existence of a linear, straight-line, relationship between dependent variables (Pallant, 2001, p.223). In order to check the assumption, simple scatterplots of POSTPPEQ and POSTHTAT were produced for each group shown in Figure 4.3. These scatterplots do not display non-linearity that the assumption is met.

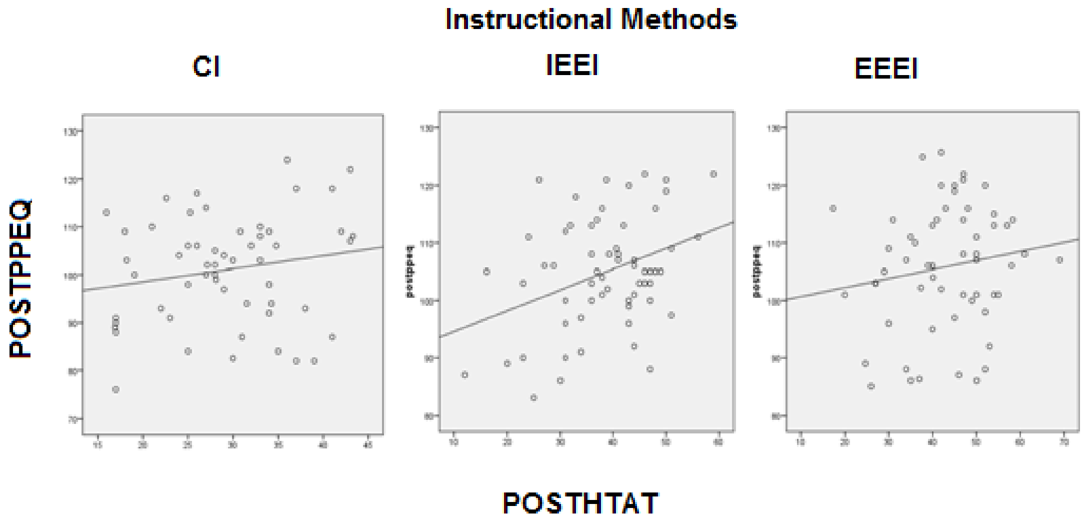


Figure 4.3 Scatterplots of POSTPPEQ versus POSTHTAT for CI, IEEI and EEEI groups

Multicollinearity is observed when dependent variables are highly correlated with each other. The POSTPPEQ and POSTHTAT scores were lowly correlated ($r = .290$, $p < .01$) as can be seen in Table 4.4. As a result, assumption of absence of multicollinearity is not violated.

4.4.2.4. Homogeneity of Variance-Covariance Matrices

Homogeneity of variance refers to variance-covariance matrices are equal across the cells due to between-subject effects. In order to test this assumption, Box's Test of Equality of Covariance Matrices (*Box's M test*) was checked. The assumption is not violated if the Sig. value of Box's M test is larger than .001 (Pallant, 2001, p.228; Tabachnick & Fidell, 2001, p.330). Result of Box's M test is given in Table 4.7. Sig. value is found .158 ($p > .001$). The assumption is verified.

Table 4.7 Results of Box's M test

Box's M	9.441
F	1.547
df1	6
df2	688678.510
Sig.	.158

The assumption of equality of variance for dependent variables can be checked by looking at Levene's Test of Equality of Error Variances. Null hypothesis of the test is that the error variance of dependent variable is equal across the groups. If Sig. value is less than .05, it indicates violation of the assumption (Pallant, 2001, p.228). For these two dependent variables, Sig. values are greater than .05 as shown in Table 4.8. Therefore, the assumption of equality of variance is also verified for both dependent variables.

Table 4.8 Results of Levene's Test

	F	df1	df2	Sig.
POSTPPEQ	.366	2	169	.694
POSTHTAT	1.985	2	169	.141

4.4.2.5. Homogeneity of Regression

In MANCOVA, assumption of homogeneity of regression indicates that “the regression between covariates and DVs in one group is the same as the regression in other groups” (Tabachnick & Fidell, 2001, p.331). Violation of this assumption implies interaction between independent variables and covariates. Moreover, it becomes more likely to make Type II errors. In order to test this assumption for MANCOVA, tests for overall and step-down homogeneity of regression are suggested by Tabachnick and Fidell (2001). For the current data analysis, PPHYSCG, PREPPEQ and PREHTAT were determined as covariates. There is only one independent variable, which is TEACHING METHOD. As it has 3 level group memberships, two dummy variables were created as M1 and M2:

Groups	M1	M2
EEEI	1	0
IEEI	0	1
CI	0	0

Tabachnick and Fidell (2001) illustrated syntax for testing of homogeneity of regression for MANCOVA (p.364). Based on explanation in the chapter, the following syntax was written for all tests in order to check assumption of homogeneity of regression, which is shown in Figure 4.4. The /ANALYSIS sentence with two dependent variables is for overall test while /ANALYSIS sentence with one dependent variable performs stepdown analysis.

```
MANOVA PPHYSCG, PREHTAT, PREPPEQ, POSTHTAT, POSTPPEQ BY M1(0,1)
M2(0,1)
    /PRINT=SIGNIF(BRIEF)
    /ANALYSIS=POSTPPEQ, POSTHTAT
    /DESIGN=PPHYSCG, PREHTAT, PREPPEQ, M1, M2
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M1 +
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M2 +
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M1 BY M2
    /ANALYSIS=POSTPPEQ
    /DESIGN=PPHYSCG, PREHTAT, PREPPEQ, M1, M2
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M1 +
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M2 +
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M1 BY M2
    /ANALYSIS=POSTHTAT
    /DESIGN=PPHYSCG, PREHTAT, PREPPEQ, M1, M2
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M1 +
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M2 +
POOL(PPHYSCG, PREHTAT, PREPPEQ) BY M1 BY M2.
```

Figure 4.4 Syntax for tests homogeneity of regression for MANCOVA

The ANALYSIS sentence with two dependent variables is for overall test while ANALYSIS sentence with one dependent variable performs stepdown analysis. After performing analysis by syntax, researcher checked out "POOL" results to consult homogeneity of regression assumption. SPSS output for overall test is shown in Table 4.9. Sig. value is .456 ($p > .01$) that homogeneity of regression assumption is not violated.

Table 4.9 Homogeneity of regression test: Overall test for MANCOVA

Source of Variation	Wilks Lambda	*F*	d*f*	Error d*f*	Sig. of *F*
PPHYSCG	.983	1.355	2	159	.261
PREHTAT	.872	11.611	2	159	.000
PREPPEQ	.772	23.429	2	159	.000
M1	.986	1.067	2	159	.346
M2	.986	1.048	2	159	.353
POOL (PPHYSCG, PREHTAT, PREPPEQ) BY M1 + POOL (PPHYSCG, PREHTAT, PREPPEQ) BY M2 + POOL (PPHYSCG, PREHTAT PREPPEQ) BY M1 BY M2	.929	.992	12	318	.456

The second ANALYSIS sentence in syntax performs test for the POSTPPEQ and output for the stepdown analysis is shown in Table 4.10. Here the POSTPPEQ serves as dependent variable with PPHYSCG, PREPPEQ and PREHTAT as covariates and M1 and M2 independent factors. The F value for homogeneity of regression is *F* (6, 160) = .48, p = .821. As Sig. of F value is greater than alpha level (.01), the homogeneity of regression assumption is verified for the dependent variable, the POSTPPEQ.

Table 4.10 Homogeneity of regression test for the POSTPPEQ

Source of Variation	SS	d*f*	MS	*F*	Sig. of *F*
WITHIN+RESIDUAL	12296.92	160	76.86		
PPHYSCG	.06	1	.06	.00	.979
PREHTAT	.01	1	.01	.00	.991
PREPPEQ	3572.22	1	3572.22	46.48	.000
M1	133.43	1	133.43	1.74	.190
M2	32.50	1	32.50	.42	.516
POOL (PPHYSCG, PREHTAT, PREPPEQ) BY M1 + POOL (PPHYSCG, PREHTAT, PREPPEQ) BY M2 + POOL (PPHYSCG, PREHTAT PREPPEQ) BY M1 BY M2	222.59	6	37.10	.48	.821

Third ANALYSIS sentence in syntax performs test for POSTHTAT and output for stepdown analysis is shown in Table 4.11. Here, POSTHTAT serves as dependent variable with PPHYSCG, PREPPEQ and PREHTAT as covariates. The F value for homogeneity of regression is *F* (6, 160) = 1.50, p = .181. Homogeneity of regression assumption is not violated for the dependent variable POSTPPEQ either.

Table 4.11 Homogeneity of regression test for the POSTHTAT

Source of Variation	SS	d*f*	MS	*F*	Sig. of *F*
WITHIN+RESIDUAL	11060.83	160	69.13		
PPHYSCG	182.12	1	182.12	2.63	.107
PREHTAT	1567.47	1	1567.47	22.67	.000
PREPPEQ	267.95	1	267.95	3.88	.051
M1	11.55	1	11.55	.17	.683
M2	94.58	1	94.58	1.37	.244
POOL (PPHYSCG, PREHTAT, PREPPEQ) BY M1 + POOL (PPHYSCG, PREHTAT, PREPPEQ) BY M2 + POOL (PPHYSCG, PREHTAT PREPPEQ) BY M1 BY M2	622.87	6	103.81	1.50	.181

4.4.3. Results of MANCOVA

Assumptions of MANCOVA analysis were verified in the previous section, which allowed us to perform MANCOVA to test the null hypotheses. For the test, PPHYSCG, PREHTAT and PREPPEQ were set as covariates while POSTHTAT and POSTPPEQ were defined as the dependent variables of the study. The independent variable was teaching method that included three group memberships: (1) EEEI, (2) IEEI, and (3) CI.

4.4.3.1. Main Problem

The null hypothesis for the main problem was "$H_0$1: There is no significant overall effect of the instructions (EEEI, IEEI and CI) on the population means of the combined dependent variables of ninth grade ATTHS students' post-test scores of physics achievement in heat and temperature unit and post-test scores of physics related personal epistemologies when students' age, gender, physics achievement in first semester, pre-test scores of physics achievement in heat and temperature unit and pre-test scores of physics related personal epistemologies are controlled."

In order to examine if there is statistically significant effect of instruction, MANCOVA test was performed. The results of MANCOVA, as shown in Table 4.12, indicated that there is a significant mean difference on the combined dependent variables of the POSTHTAT and the POSTPPEQ between CI, IEEI, and EEEI groups when the effects of covariates were controlled (Wilks' $\Lambda = .603$, $F\ (6, 330) = 15.809$, $p < .05$, partial eta-squared = .223). Therefore, the first null hypothesis was rejected. Observed power was greater than preset value, .80. Moreover, partial eta squared value is interpreted for effect-size of the independent variables on dependent variables. The value of 0.01 indicates small effect, 0.06 refers to medium effect, and 0.14 refers to large effect as interpreted by Cohen (1988). For this study, partial eta squared value was found .223 which indicates a large effect size.

Table 4.12 Results of MANCOVA test

Effect	Wilks' Lambda	*F*	d*f*	Error d*f*	Sig.	Partial Eta Squared	Observed Power
PPHYSCG	.986	1.142	2	165	.322	.014	.249
PREPPEQ	.660	42.561	2	165	.000	.340	1.000
PREHTAT	.816	18.648	2	165	.000	.184	1.000
METHOD	.603	15.809	6	330	.000	.223	1.000

As can be seen from Table 4.12, PREPPEQ and PREHTAT are contributed significantly to combined dependent variables of physics achievement and physics related personal epistemologies (Wilks' $\Lambda = .660$, $F\ (2, 165) = 42.561$, $p < .05$, partial eta squared = .340 for PREPPEQ and Wilks' $\Lambda = .816$, $F\ (2, 165) = 18.648$, $p < .05$, partial eta squared = .184 for PREHTAT). Large effect was found for both covariates. However, the third covariate (PPHYSCG) did not make any significant contribution to model (Wilks' $\Lambda = .986$, $F\ (2, 165) = 1.142$, $p > .05$, partial eta squared = .014).

Table 4.13 Estimated marginal means for POSTHTAT and POSTPPEQ

Dependent Variable	Teaching Method	Mean	Estimated Marginal Mean	Std. Error
POSTPPEQ	CI	101.01	100.72*	1.179
	IEEI	104.86	104.49*	1.123
	EEEI	105.83	106.49*	1.159
POSTHTAT	CI	29.14	29.00*	1.139
	IEEI	38.44	38.08*	1.085
	EEEI	42.98	43.48*	1.119

Note: Covariates appearing in the model are evaluated at the following values: PPHYSCG = 73.27, PREPPEQ = 102.43, PREHTAT = 25.85.

The estimated marginal means for the dependent variables are given in Table 4.13. Estimated marginal means are the adjusted mean values with the effect of covariates. The difference between estimated marginal means of CI and IEEI groups on POSTPPEQ was 3.771. It was 5.774 when CI and EEEI groups were compared, and the difference was 2.003 when EEEI and IEEI groups were compared. Without adjustment of covariates' effect, differences between the group means on POSTPPEQ were 3.85, 4.82 and 0.97 respectively. Similarly, the difference between estimated marginal means of CI and IEEI groups on post-HTAT was 9.078. It was 14.478 when CI and EEEI groups were compared and, the difference was 5.401 when EEEI and IEEI groups were compared. Without adjustment of covariates' effect, differences between the group means on POSTHTAT were 9.3, 13.84 and 4.54 respectively.

Table 4.14 summarizes the effect of instructions and effect of each single covariate on dependent variables separately. The results will be discussed in following sections.

Table 4.14 SPSS output for tests of between-subjects effects

Source	Dependent Variable	d*f*	Mean Square	*F*	Sig.	Partial Eta Squared	Observed Power
PPHYSCG	POSTHTAT	1	139.184	1.977	.162	.012	.287
	POSTPPEQ	1	7.841	.104	.748	.001	.062
PREPPEQ	POSTHTAT	1	302.513	4.298	.040	.025	.540
	POSTPPEQ	1	6437.417	85.356	.000	.340	1.000
PREHTAT	POSTHTAT	1	2636.555	37.460	.000	.184	1.000
	POSTPPEQ	1	45.796	.607	.437	.004	.121
METHOD	POSTHTAT	3	1943.049	27.606	.000	.333	1.000
	POSTPPEQ	3	665.204	8.820	.000	.137	.995
Error	POSTHTAT	166	70.384				
	POSTPPEQ	166	75.419				
Total	POSTHTAT	172					
	POSTPPEQ	172					

For MANCOVA analysis, preset value of alpha was set to .05 in which multiple comparisons were done simultaneously. In order to reduce the probability of making Type-I error for multiple comparisons separately for each dependent variable, Bonferroni adjustment was suggested (Tabachnick & Fidell, 2001). Bonferroni adjustment was done by dividing alpha by the number of dependent variables. The result of pairwise comparisons of the effect of teaching methods on POSTHTAT and POSTPPEQ are given in Table 4.15.

Table 4.15 SPSS output for pairwise comparisons on DVs

Dependent Variable	(I) Teaching Method	(J) Teaching Method	Mean Difference (I-J)	Std. Error	Sig.*
POSTHTAT	EEEI	IEEI	5.401	1.560	.002
		CI	14.478	1.607	.000
	IEEI	EEEI	-5.401	1.560	.002
		CI	9.078	1.574	.000
	CI	EEEI	-14.478	1.607	.000
		IEEI	-9.078	1.574	.000
POSTPPEQ	EEEI	IEEI	2.003	1.615	.650
		CI	5.774	1.664	.002
	IEEI	EEEI	-2.003	1.615	.650
		CI	3.771	1.629	.066
	CI	EEEI	-5.774	1.664	.002
		IEEI	-3.771	1.629	.066

Note: Pairwise comparisons are based on estimated marginal means. The mean difference is significant at the .05 level. Bonferroni adjustment was done for multiple comparisons.

To contrast effect of instructional methods separately, dummy variables M1 and M2 are used as in Section 4.4.2.5. The results of MANCOVA test by using dummy variables are given in Table 4.16.

Table 4.16 Results of MANCOVA test by using dummy variables

Effect	Wilks' Lambda	*F*	d*f*	Error d*f*	Sig.	Partial Eta Squared	Observed Power
PPHYSCG	.986	1.142	2	165	.322	.014	.249
PREPPEQ	.660	42.561	2	165	.000	.340	1.000
PREHTAT	.816	18.648	2	165	.000	.184	1.000
M1	.661	42.300	2	165	.000	.339	1.000
M2	.825	17.457	2	165	.000	.175	1.000

The results of MANCOVA by using dummy variables, as shown in Table 4.16, indicated that there is a significant mean difference on the combined dependent variables of the POSTHTAT and the POSTPPEQ between EEEI and other groups when the effects of covariates were controlled (Wilks' Λ = .661, F (2, 165) = 42.300, p < .05, partial eta-squared = .339). Similarly, there is a significant mean difference on the combined dependent variables of the POSTHTAT and the POSTPPEQ between IEEI and other groups when the effects of covariates were controlled (Wilks' Λ = .825, F (2, 165) = 17.457, p < .05, partial eta-squared = .175). Effects of independent variable on each dependent variable are shown in Table 4.17.

Table 4.17 SPSS output for tests of between-subjects effects by using M1 and M2

Source	Dependent Variable	d*f*	Mean Square	*F*	Sig.	Partial Eta Squared	Observed Power
PPHYSCG	POSTHTAT	1	139.184	1.977	.162	.012	.287
	POSTPPEQ	1	7.841	.104	.748	.001	.062
PREPPEQ	POSTHTAT	1	302.513	4.298	.040	.025	.540
	POSTPPEQ	1	6437.417	85.356	.000	.340	1.000
PREHTAT	POSTHTAT	1	2636.555	37.460	.000	.184	1.000
	POSTPPEQ	1	45.796	.607	.437	.004	.121
M1	POSTHTAT	1	5712.250	81.159	.000	.328	1.000
	POSTPPEQ	1	908.610	12.048	.001	.068	.932
M2	POSTHTAT	1	2340.701	33.256	.000	.167	1.000
	POSTPPEQ	1	404.026	5.357	.022	.031	.634
Error	POSTHTAT	166	70.384				
	POSTPPEQ	166	75.419				
Total	POSTHTAT	172					
	POSTPPEQ	172					

Tabachnick and Fidell (2001) stated that "it is appropriate to investigate further the nature of the relationships among IVs and DVs" in spite of significant main effects obtained from multivariate analysis (p.286). In order to clarify the relationships between DVs, step-down analysis were suggested as an additional follow-up procedure. In the analysis, univariate F tests are used to explore mean differences between groups on a single DV and "the difference in shared variance across dependent variables given an a priori ordering of these dependent variables" (Krach, 2001, p.3). Stevens (2009) emphasized two advantages of step-down analysis over univariate F tests: (a) It relies on a theoretical basis for priority ordering of DVs, and (b) it is statistically more desirable approach to estimate false rejections of null hypothesis (p.323).

There are only two DVs (POSTHTAT and POSTPPEQ) in the study. The related literature brought out evidence that achievement and personal epistemology are essentially interrelated constructs. Accordingly, the step-down analysis was conducted in order to explore unique effect of the epistemologically enhanced instructions on achievement and personal epistemology separately. In the analysis, highest priority was attributed to dependent variable of physics achievement (POSTHTAT) and second dependent variable was used as covariate.

Effects of type of instruction after adjustments for covariates (including POSTPPEQ) were investigated via step-down ANCOVA test, in which post achievement was given highest priority. Results of the analysis are summarized in Table 4.18. The effect of explicit epistemologically enhanced instruction was found significant ($F(2, 165) = 67.711$; $p = .00$) when compared to other groups. And the effect of implicit epistemologically enhanced instruction was found significant ($F(2, 165) = 28.663$; $p = .00$) when compared to other groups. These results indicated that the effect of epistemologically enhanced instruction on physics achievement after controlling the effect of posttest scores on physics related personal epistemology (POSTPPEQ) was significant. Moreover, physics achievement was also uniquely and significantly affected by the teaching method after its significant and unique effect on personal epistemology.

Table 4.18 Step-down ANCOVA test for the POSTHTAT variable by using the POSTPPEQ as covariate

Source	SS	d*f*	MS	*F*	Sig.	Partial Eta Squared	Observed Power
PPHYSCG	149.998	1	149.998	2.180	.142	.013	.219
PREPPEQ	12.765	1	12.765	.185	.667	.001	.039
PREHTAT	2515.980	1	2515.980	36.559	.000	.181	1.000
POSTPPEQ	328.494	1	328.494	4.773	.030	.028	.471
M1	4659.839	1	4659.839	67.711	.000	.291	1.000
M2	1972.594	1	1972.594	28.663	.000	.148	.999
Error	11355.211	165	68.819				
Total	255830.916	172					

Note: α=.025

When the POSTPPEQ scores were analyzed by attributing POSTHTAT scores as another covariate besides existing covariates in the data analysis, the effect of the teaching method was not significant (For EEEI: F (1, 165) = 2.640; p = .106, and for IEEI: F (1, 165) = 1.547; p = .215) as shown in Table 4.19. This result can be interpreted as students' physics related personal epistemology was not significantly and uniquely affected by the instruction beyond its effect on physics achievement. In other words, students' physics related personal epistemology was indirectly affected by teaching method.

Table 4.19 Step-down ANCOVA test for the POSTPPEQ variable by using the POSTHTAT as covariate

Source	SS	d*f*	MS	*F*	Sig.	Partial Eta Squared	Observed Power
PPHYSCG	23.225	1	23.225	.315	.575	.002	.049
PREPPEQ	5811.623	1	5811.623	78.810	.000	.323	1.000
PREHTAT	3.754	1	3.754	.051	.822	.000	.029
POSTPPEQ	351.993	1	351.993	4.773	.030	.028	.471
M1	194.668	1	194.668	2.640	.106	.016	.265
M2	114.099	1	114.099	1.547	.215	.009	.157
Error	12167.514	165	73.743				
Total	1878301.522	172					

Note: α=.025

4.4.3.2. Sub-problem 1

The null hypothesis for the first sub-problem was "$H_0$2: There is no significant effect of the instructions (EEEI, IEEI and CI) on the population means of ninth grade ATTHS students' post-test scores of physics achievement in heat and temperature when students' age, gender, physics achievement in first semester, pre-test scores of physics achievement in heat and temperature unit and pre-test scores of physics related personal epistemologies are controlled."

Results of test of between subject effects are presented in Table 4.14. Results revealed that there was statistically significant mean difference on the POSTHTAT variable between CI, IEEI, and EEEI groups when the covariates PPHYSCG, PREHTAT and PREPPEQ were controlled (F (3,166) = 27.606, $p < .05$). The observed effect size was found .333 which indicates large effect of the instructional method on students' achievement. Observed power was 1.00 which was greater than preset value. There is statistically significant mean difference between explicit epistemologically instruction when compared to CI and IEEI groups on physics achievement. Moreover, the mean difference on POSTHTAT scores between IEEI and CI groups was found significant.

Some statistical differences are observed when dummy variables are integrated into MANCOVA test as shown in 4.17. The results indicated that there is statistically significant mean difference with large effect between EEEI and other groups based on physics achievement in heat and temperature (F (1,166) = 81.159, p = .00, partial eta squared = .328). Implicit epistemologically enhanced instruction was also found effective method when compared to other groups with large effect size (F (1,166) = 33.256, p = .00, partial eta squared = .167).

4.4.4.2. Sub-problem 2

The null hypothesis for the second sub-problem was "$H_0$3: There is no significant effect of the instructions (EEEI. IEEI and CI) on the population means of ninth grade ATTHS students' post-test scores of physics related personal epistemologies when students' age, gender, physics achievement in first semester, pre-test scores of physics achievement in heat and temperature unit and pre-test scores of physics related personal epistemologies are controlled."

Results of univariate test provided in MANCOVA were presented in Table 4.14. The results indicated that there is a statistically significant mean difference on the POSTPPEQ variable between CI, IEEI and EEEI groups when the effect of covariates (PPHYSCG, PREHTAT and PREPPEQ) were controlled (F (3, 166) = 8.820, $p < .05$). The effect of instructional method on physics related personal epistemology was observed as large (partial eta squared = .137). Observed power was .995 which was greater than preset value. When Table 4.15 is considered, there is statistically significant mean difference between explicit epistemologically instruction when compared to CI on students' physics related personal epistemology. However, there is no statistically significant mean difference on POSTPPEQ scores between explicit and implicit instruction. Also, the mean difference on epistemology scores between IEEI and CI groups was not significant.

Performing MANCOVA by using dummy variables revealed that there is statistically significant difference between EEEI and other groups based on students' physics related personal epistemology with medium effect (F (1,166) = 12.048, p = .001, partial eta squared = .068) as shown in Table 4.17. However, implicit epistemologically enhanced instruction (IEEI) was not found practically effective method when compared to other (F (1,166) = 5.357, p = .022, partial eta squared = .031). The observed power (.634) was below the pre-set value (.80).

4.4.4.3. Sub-problem 3

The null hypothesis for the third sub-problem was "$H_0$4: There is no significant effect of the instructions (EEEI, IEEI and CI) on the population means of ninth grade ATTHS students' post-test subscores on physics related personal epistemology dimensions (i.e. coherent structure of knowledge, hierarchical structure of knowledge, justification of knowledge, changeability of knowledge, source of knowledge and quick learning) when students' age, gender, physics achievement in first semester, pre-test scores of physics achievement in heat and temperature unit and pre-test scores of physics related personal epistemologies are controlled."

The total score on the POSTPPEQ was included into previous MANCOVA test rather than using subscores on POSTPPEQ dimensions. In order to investigate any difference observed between PPEQ dimensions, another MANCOVA test was performed by using POSTHTAT and six dimensions of PPEQ (SKC, SKH, CK, JK, Source and QL) as dependent variables. For grouping variable, two dummy variables

(M1 and M2) were used. Same covariates (PPHYSCG, PREHTAT and PREPPEQ) were included into this MANCOVA test as in the previous one. The results are presented in Table 4.20.

Table 4.20 Results of MANCOVA test for the six dimensions of the POSTPPEQ

Effect	Wilks' Lambda	*F*	d*f*	Error d*f*	Sig.	Partial Eta Squared	Observed Power
PPHYSCG	.959	.974	7	160	.452	.041	.411
PREPPEQ	.943	1.370	7	160	.221	.057	.570
PREHTAT	.806	5.518	7	160	.000	.194	.998
M1	.638	12.955	7	160	.000	.362	1.000
M2	.784	6.314	7	160	.000	.216	1.000

By integrating six dimensions of the PPEQ as dependent variables into analysis, the observed effect sizes of the instructions are increased statistically. Still, the effect of teaching methods is statistically significant on combined dependent variables in the study with large effect (for EEEI: Wilks' $\Lambda = .638$, F $(7,160) = 12.955$, $p < .05$, partial eta squared = .362 and for IEEI: Wilks' $\Lambda = .784$, F $(7,160) = 6.314$, $p < .05$, partial eta squared = .216). In order to explore any significant change occurred between dimensions of PPEQ, results of the test between subjects effects are given in Table 4.21.

Results of the MANCOVA test showed that there is statistically significant small to medium effect on changeability of knowledge dimension (F $(1, 166) = 7.286$, $p < .05$, partial eta squared = .042), there are no statistically significant mean differences on other dimensions between the EEEI and other groups. There is statistically significant medium effect of IEEI on coherent structure of knowledge dimension when compared to CI and EEEI (F $(1, 166) = 9.604$, $p < .05$, partial eta squared = .055). Observed power (.869) is above the preset value.

Table 4.21 SPSS output for tests of between-subjects effects

Source	DV	d*f*	MS	*F*	Sig.	Partial Eta Squared	Observed Power
PPHYSCG	POSTHTAT	1	139.184	1.977	.162	.012	.287
	SKC	1	.259	.042	.837	.000	.055
	SKH	1	9.485	.931	.336	.006	.160
	JK	1	7.863	.708	.401	.004	.133
	CK	1	4.093	.577	.449	.003	.117
	SOURCE	1	3.496	.310	.578	.002	.086
	QL	1	7.396	.854	.357	.005	.151
PREPPEQ	POSTHTAT	1	302.513	4.298	.040	.025	.540
	SKC	1	26.614	4.353	.038	.026	.546
	SKH	1	14.320	1.405	.238	.008	.218
	JK	1	7.905	.712	.400	.004	.134
	CK	1	13.953	1.967	.163	.012	.286
	SOURCE	1	6.850	.608	.437	.004	.121
	QL	1	8.134	.939	.334	.006	.161
PREHTAT	POSTHTAT	1	2636.555	37.460	.000	.184	1.000
	SKC	1	4.883	.799	.373	.005	.144
	SKH	1	8.501	.834	.362	.005	.148
	JK	1	.265	.024	.877	.000	.053
	CK	1	2.465	.347	.556	.002	.090
	SOURCE	1	.571	.051	.822	.000	.056
	QL	1	1.784	.206	.651	.001	.074
M1	POSTHTAT	1	5712.250	81.159	.000	.328	1.000
	SKC	1	20.285	3.318	.070	.020	.441
	SKH	1	21.572	2.117	.148	.013	.304
	JK	1	3.631	.327	.568	.002	.088
	CK	1	51.699	7.286	.008	.042	.765
	SOURCE	1	14.006	1.244	.266	.007	.198
	QL	1	4.917	.568	.452	.003	.116
M2	POSTHTAT	1	2340.701	33.256	.000	.167	1.000
	SKC	1	58.716	9.604	.002	.055	.869
	SKH	1	5.538	.543	.462	.003	.113
	JK	1	30.258	2.725	.101	.016	.375
	CK	1	8.023	1.131	.289	.007	.185
	SOURCE	1	53.708	4.770	.030	.028	.584
	QL	1	.032	.004	.951	.000	.050
Error	POSTHTAT	166	70.384				
	SKC	166	6.114				
	SKH	166	10.191				
	JK	166	11.104				
	CK	166	7.095				
	SOURCE	166	11.260				
	QL	166	8.661				
Total	POSTHTAT	172					
	SKC	172					
	SKH	172					
	JK	172					
	CK	172					
	SOURCE	172					
	QL	172					

4.5. Results of the Classroom Observation Checklist

As aforementioned in Section, classroom observation checklist was developed in order to make valid observations about both treatment and control groups. The checklist was filled accordingly to ensure whether the instructions were implemented as stated in the study. The researcher attended and observed all of the sessions in all groups by using the classroom observation checklist. Each week, ninth grades took physics course for 2 lecture-hours and the implementation had continued for seven weeks. 14 observations were done for each class which means 84 classroom observations in total.

In order to confirm whether implementation was conducted as intended, quantitative analysis was done by scoring the checklist. There are two alternatives in the checklist that "yes" response scored as "1" and "no" response was scored as "0". There are 26 items in the classroom observation checklist. In Table 4.22, items in the checklist are grouped regarding to teaching method. There are 10 specific items for explicit instruction. And there are 11 items which include common characteristics of epistemologically enhanced instructions. And there are five items which can be observed in treatment and control groups.

Table 4.22 Grouping items in the classroom observation checklist

Groups	Item No.	N
EEEI	5, 6, 8, 12, 15, 19, 21, 22, 24, 25	10
Common for EEEI and IEEI	1,2, 4, 7, 11,13, 14, 16, 18, 20, 26	11
Common for EEEI, IEEI and CI	3, 9, 10,17, 23	5

The descriptive results of the classroom observation checklist are presented in Table 4.23. Number of observations (# of Obs.) was calculated in terms of weeks. The mean and standard deviation of each item was provided according the group membership.

Table 4.23 Descriptive results of classroom observation checklist for each group

	Experimental Groups						Control Groups		
	The EEEI			The IEEI			The CI		
Item	# of Obs. (Week)	Mean	S.D.	# of Obs. (Week)	Mean	S.D.	# of Obs. (Week)	Mean	S.D.
1	7	1.00	0.00	7	1.00	0.00	7	0.71	0.47
2	7	0.71	0.47	7	0.71	0.47	7	0.00	0.00
3	7	1.00	0.00	7	1.00	0.00	7	0.86	0.36
4	7	0.71	0.47	7	0.71	0.47	7	0.00	0.00
5	7	0.57	0.51	7	0.00	0.00	7	0.00	0.00
6	7	0.43	0.51	7	0.00	0.00	7	0.00	0.00
7	7	0.86	0.36	7	0.71	0.47	7	0.00	0.00
8	7	0.71	0.47	7	0.00	0.00	7	0.00	0.00
9	7	0.43	0.51	7	0.43	0.51	7	0.71	0.47
10	7	0.71	0.47	7	0.71	0.47	7	0.57	0.51
11	7	0.43	0.51	7	0.43	0.51	7	0.00	0.00
12	7	0.57	0.51	7	0.00	0.00	7	0.00	0.00
13	7	0.14	0.36	7	0.14	0.36	7	0.00	0.00
14	7	0.14	0.36	7	0.14	0.36	7	0.00	0.00
15	7	0.29	0.47	7	0.00	0.00	7	0.00	0.00
16	7	0.43	0.51	7	0.43	0.51	7	0.00	0.00
17	7	0.86	0.36	7	0.93	0.27	7	0.29	0.47
18	7	0.29	0.47	7	0.29	0.47	7	0.00	0.00
19	7	0.71	0.47	7	0.00	0.00	7	0.00	0.00
20	7	0.57	0.51	7	0.57	0.51	7	0.00	0.00
21	7	0.71	0.47	7	0.00	0.00	7	0.00	0.00
22	7	0.43	0.51	7	0.00	0.00	7	0.00	0.00
23	7	0.43	0.51	7	0.57	0.51	7	0.57	0.51
24	7	0.29	0.47	7	0.00	0.00	7	0.00	0.00
25	7	0.43	0.51	7	0.00	0.00	7	0.00	0.00
26	7	0.29	0.47	7	0.00	0.00	7	0.00	0.00

The descriptive statistics for the items in the classroom checklist were indicated specific differences between EEEI, IEEI and CI groups. In order to test the differences due to type of instruction in both treatment and control groups, a non-parametric test which is called Kruskal-Wallis H test was conducted. This test allows comparison of two or more independent groups of an IV on an ordinal DV. According to results of the Kruskal-Wallis H test, there were statistically significant differences in 19 items out of 26 (excluding items no. 3, 9, 10, 13, 14, 18 and 23) between different types of instruction. Item no. 3, 9, 10, and 23 were observed events in all groups that non-significant results were expectable. The difference in items 13 and 14 related to changeability of knowledge via historical content was found non-significant. These items were checked for only two weeks in EEEI and IEEI groups within seven weeks that might be the reason for non-significant result. For the items which are distinguishing characteristics of the EEEI from other instructions (see Table 4.22), the test results were statistically significant as shown in Table 4.24.

Table 4.24 Results of Kruskal Wallis H test for the items in classroom observation checklist

Items	χ^2	d*f*	Sig.
Item_1	8.632	2	.013
Item_2	18.636	2	.000
Item_3	4.100	2	.129
Item_4	18.636	2	.000
Item_5 Explicit – SK(1)	19.294	2	.000
Item_6 Explicit – SK(2)	13.667	2	.001
Item_7	23.109	2	.000
Item_8 Explicit JK(1) + Source	25.625	2	.000
Item_9	2.982	2	.225
Item_10	0.837	2	.658
Item_11	8.200	2	.017

Table 4.24 (continued)

Items	χ^2	d*f*	Sig.
Item_12 Explicit – SK(3)	19.294	2	.000
Item_13	2.158	2	.340
Item_14	2.158	2	.340
Item_15 Explicit – CK(1)	8.632	2	.013
Item_16	8.200	2	.017
Item_17	15.878	2	.000
Item_18	4.824	2	.090
Item_19 Explicit – JK (2) + Source	25.625	2	.000
Item_20	12.615	2	.002
Item_21 Explicit – CK(2)	25.625	2	.000
Item_22 Explicit – QL(1)	13.667	2	.001
Item_23	0.745	2	.689
Item_24 Explicit – QL(2)	8.632	2	.013
Item_25 Explicit – QL(3)	13.667	2	.001
Item_26	8.632	2	.013

In order to test whether implicit and explicit epistemologically enhanced instruction are distinguishable according to classroom observation checklist, the post-hoc analysis was conducted by using the non-parametric test: Mann-Whitney U test. The results of the test showed that there are significant differences in aforementioned items which included distinguishing characteristics of the EEEI. And no difference between two groups was observed for the remaining items. The results of Mann-Whitney U test is presented in Table 4.25. To conclude, the results of classroom observations showed that the teacher implemented characteristics of both IEEI and EEEI adequately as intended in treatment groups. In control groups, the teacher did not use same instructional strategies as provided in treatment groups. It can be stated that treatment verification of the study was established by the classroom observations.

Table 4.25 Results of Mann-Whitney U test for the items in classroom observation checklist

Items	Mann-Whitney U	Z	Sig.
Item_5 Explicit – SK(1)	42.000	-3.286	.001
Item_6 Explicit – SK(2)	56.000	-2.714	.007
Item_8 Explicit JK(1) + Source	28.000	-3.873	.001
Item_12 Explicit – SK(3)	42.000	-3.286	.001
Item_15 Explicit – CK(1)	70.000	-2.121	.034
Item_19 Explicit – JK (2) + Source	28.000	-3.873	.001
Item_21 Explicit – CK(2)	28.000	-3.873	.001
Item_22 Explicit – QL(1)	56.000	-2.714	.007
Item_24 Explicit – QL(2)	70.000	-2.121	.034
Item_25 Explicit – QL(3)	56.000	-2.714	.007

4.6. Summary of Findings

The results obtained from the current study can be summarized as follows:

- Type of instruction (EEEI, IEEI and CI) has statistically significant large effect on combined dependent variables (students' achievement on heat and temperature and physics-related personal epistemology) with a large effect size.
- The explicit epistemologically enhanced instruction (EEEI) is the most effective method to promote positive changes on students' physics achievement.
- Also, the implicit epistemologically enhanced instruction (IEEI) was found as an effective method to promote positive changes on students' physics achievement with large effect.
- When the effect of types of instruction on students' physics-related personal epistemology is concerned, the EEEI was found the most effective instruction

when compared to other groups with medium effect size. Pairwise comparisons revealed that there is statistically significant mean difference between the EEEI and CI groups. However, no significant mean difference was found between EEEI and IEEI.

- The IEEI was not an influential method on improving students' personal epistemology. The mean difference on POSTPPEQ score was significant between IEEI and CI groups with low power value. The results indicated low practical significance of IEEI on improving students' physics-related personal epistemologies.
- To sum up, explicit approach is superior to implicit approach in terms of improving students' physics-related personal epistemologies.
- The stepdown analysis indicated that type of instruction has direct and unique effect on students' physics achievement when POSTPPEQ scores are controlled with other covariates. On the contrary, unique effect of type of instruction was not found on students' physics related personal epistemology when POSTHTAT scores are controlled.
- When the six dimensions of personal epistemology were considered, there are few changes observed within dimensions. There is statically small to medium effect found on changeability of knowledge when the EEEI groups are compared with other groups. Also, there is statically medium effect found on coherent structure of knowledge when the IEEI groups are compared with other groups.
- No interaction is found between independent and dependent variables.

CHAPTER 5

DISCUSSION, IMPLICATIONS, SUGGESTIONS AND CONCLUSION

This chapter is divided into four sections. First section presents discussions about the contributions and limitations of the study. Second section includes the potential implications of the findings theoretically and practically, and presents suggestions for further research. Third section presents external validity of the study and the last section brings the thesis to a conclusion.

5.1. Discussion

This study investigated the effectiveness of explicit (EEEI) and implicit epistemologically enhanced instruction (IEEI) on ninth grade students' physics achievement on heat and temperature unit and their physics-related personal epistemology. For this purpose, two comparison groups and a control group design was adopted to test whether any changes occurred in aforementioned constructs due to effect of instructional methods. Comparison groups were exposed to different types of epistemologically enhanced instructions whereas control groups were instructed with a physics teacher's conventional teaching.

Epistemological enhancement was done explicitly and implicitly via different but interrelated instructions. In IEEI, dimensions of personal epistemology were embedded via different instructional strategies without explicit discussions on these dimensions. This instruction includes concept teaching, inquiry (mostly supplied by experimentations and observations), demonstrations, seeking consistency, constructing criteria to assess reliability of knowledge, effective use of reliable sources, opportunities to test (students' own) hypothesis, and use of logical reasoning. Teacher's role in IEEI was mostly facilitator; however, in some particular cases teacher was also becomes the source of knowledge in order to present content in an organized way by leading students to reach information. On the other hand, EEEI (explicit instruction) was enhanced by making implicit instruction explicit through iterative discussions on the dimensions of personal epistemology and teacher's purposive talks to create awareness on these dimensions. Instructions in both groups took seven weeks but the teacher put more effort and spent more time on presenting epistemological dimensions via discussions and talks in EEEI. Consequently, content teaching was shortened in EEEI when compared to IEEI.

By controlling the effects of students' physics achievement in first semester, pre-existing physics-related personal epistemologies and pre-achievement on heat and temperature unit, statistical significance with large effect (partial eta squared = .223) was found between instructional methods in the study. More specifically, the results of the study revealed that EEEI was more influential instructional method than IEEI and conventional instruction on the improvement of students' achievement in heat and temperature unit. Tapping students' personal epistemologies to improve their beliefs on how one knows, organizes his/her knowledge in an academic discipline, obtains information by judging credibility of external sources, justifies his/her knowledge, etc. seems assisted students in their learning process. This result supports the theoretical argument that personal epistemology is one of the most significant personal variable that effect students achievement proposed in the literature of personal epistemology (e.g. Hofer, 2001; Vosniadou, 2007; Chinn *et al*., 2011; Kelly *et al*., 2012).

Different from explicit epistemological interventions (i.e. Yerdelen-Damar, 2013; Yerdelen-Damar & Eryilmaz, 2016), this study also tested the possible effect of implicit epistemological interventions (IEEI) and showed that IEEI promoted improvement on students' achievement in physics much better than students' exposed to conventional instruction. In IEEI, personal epistemology dimensions were embedded implicitly by establishing conceptual links between different subjects, evaluation and justification of external source of information via observation, experimentation, and using logical tools without any explicit emphasis. It seems that implicit epistemologically enhanced instruction was also able to convey instructional messages about learning physics. This result is an important contribution of the current study to the literature because implicit instruction has a negative reputation in the literature of epistemology due to the results of empirical studies on the nature of science.

The current study also focused on the effectiveness of instructional methods on students' physics-related personal epistemology. The explicit epistemologically enhanced instruction was more effective than implicit and conventional instructions to foster students' epistemological beliefs. This result is compatible with the results of some intervention studies (e.g. Kienhues *et al*., 2008; Brownlee *et al*., 2011; Muis & Duffy, 2013; Yerdelen-Damar, 2013). When students' posttest scores on physics-related personal epistemology questionnaire (PPEQ) were concerned, groups' means were sorted from highest to lowest as EEEI, IEEI and CI as expected.

Additionally, EEEI and IEEI groups improved their mean PPEQ scores in posttest whereas mean of PPEQ scores of CI groups were decreased when pretest and posttest scores compared. It seems that CI groups' students regressed to more naive epistemological beliefs as they were constantly exposed to transmission of knowledge from authority (e.g. teacher, physics textbook) during physics instruction with minimum effort to obtain knowledge by themselves. The results of the study indicated that EEEI was more effective method with medium effect to improve students' physics-related personal epistemology when compared to CI. However, the implicit version of instruction did not create any significant change when compared to CI. Making epistemological dimensions visible during instructions seems to help students recognize more about their personal epistemology. Nevertheless, the difference between EEEI and IEEI groups on personal epistemology was not statistically significant. This result is parallel to findings in scientific epistemology (NOS) research (e.g. Abd-El-Khalick, 2001; Abell *et al.*, 2001; Khisfe, 2008) that explicit approach was more effective than implicit approach to convey messages about scientific epistemology. This can be argued that embedded activities in implicit version seems to change students' epistemological beliefs through practicing physics by themselves but this implicit messages do not seem to be as effective as the explicit messages provided through explicit instruction.

Moreover, the researcher has hypothesized that each instruction would stimulate specific epistemological beliefs depending on epistemological considerations of different type of instructions. According to results, some difference was found in students' physics-related personal epistemology (in spite of no statistical significance) when IEEI and CI groups were compared. It seems that implicit epistemological differences in instruction caused slight changes in terms of students' epistemological beliefs. Even though both IEEI and CI adopted different approaches in teaching (i.e. student-centered versus teacher-centered), implicit messages of instruction seems to be ignored by students. This is probably because, in Turkish educational system achievement is always superior goal in learning physics when compared to other outcomes (such as attitude toward physics course, epistemological beliefs, etc.) provided by the instruction. This result supports the related studies (i.e. Redish & Hammer, 2009; Yaman, 2013) that implicit modification of instruction was not an effective method to change students' personal epistemology.

Comparing to Yerdelen-Damar's (2013) results, which indicated large effect of explicit epistemological intervention on improvement of students' epistemological beliefs when compared to traditional instruction, medium effect was found between EEEI and CI groups in this study. The existence of additional group (IEEI) in the current study revealed medium effect of explicit instruction when compared to CI. Large effect could be found if only EEEI and CI were included in the current study.

The difference could be also associated with different epistemological measures (i.e. MPEX-II, PPEQ) used in both studies. These instruments focus on different dimensions of personal epistemology. However, results of both studies showed that there is not only one (unique) way of explicit instruction to tap students' epistemological beliefs. For instance, a structured instruction based on 7E-learning cycle was implemented to probe epistemological dimensions in Yerdelen-Damar's study. On the contrary, various instructional strategies were used in the current study to stimulate different epistemological dimensions in each instruction. In spite of effectiveness of both explicit instructions, these instructions might affect different epistemological dimensions regarding the structure of treatment that should be considered in further research.

Results of descriptive analysis of sub-dimensions for PREPPEQ and POSTPPEQ implied that there are some changes in several dimension of personal epistemology occurred in different instructions. Decline in mean scores of justification of knowledge and quick learning dimensions were observed within control groups. Continuous transmission of knowledge in a teacher-centered instruction may be the potential cause of this result. The content of heat and temperature begins with introduction of thermodynamics concepts and continues with analysis of different events by using graphs and mathematical calculations. It seems that students exposed to CI began to ignore justification by themselves as content became more complex. As content required more individual effort to learn, students seems to develop beliefs that they are not able to learn or they do not have ability to learn physics.

On the contrary, minor improvements in different dimensions of personal epistemology were observed in IEEI and EEEI groups. There was significant increase in mean scores of EEEI groups in terms of changeability of knowledge. This change might be emanated from visibility of epistemological dimension (CK: changeability of knowledge) from history of science examples in two weeks of the treatment. However, similar change on CK dimension was not observed in IEEI.

Significantly positive change was observed in hierarchical structure of knowledge dimension between IEEI and other groups. It seems that linkages between different concepts in different units (e.g. kinetic energy with temperature, phase change with potential energy) and concepts within heat and temperature unit helped students to recognize more about structure of their physics knowledge. Interestingly, the EEEI did not create similar effect on this dimension in spite of explicit linkages. Moreover, integrating six dimensions of the PPEQ model provided more insight epistemological change in IEEI groups. Because there was no statistically significant mean difference on total PPEQ scores between IEEI groups and other groups.

As can be seen from the results, epistemologically enhanced instructions were more effective on improving students' physics achievement than enhancing their physics related personal epistemology. Step-down analyses also revealed that epistemologically enhanced instruction has unique and direct effect on improving students' physics achievement. In other words, improvement of physics achievement is independent from epistemological improvement. On the contrary, results of step-down analysis indicated that epistemological improvement is not independent from improvement in physics achievement. It seems that students' achievement in physics assists students to reach more sophisticated personal epistemology.

5.2. Implications and Suggestions

Current study presumed that high school students have epistemological beliefs with varying sophistication level as stated in the literature (e.g. Kuhn *et al.*, 2000; Elder, 2002; Mansfield & Clinchy, 2002; Burr & Hofer; 2002; Haerle & Bendixen, 2008) and naive epistemologies could be improved by well designed instructions. This study showed that student's personal epistemology is subject to change if the epistemological constructs (or its dimensions) were aligned with appropriate instructions. The results of the study suggest that tapping students' epistemological beliefs in early ages (i.e. in formal operational stage) may help students reach more sophisticated levels which is more productive than expecting students' epistemological development by maturation through years. Nonetheless, dimensional differences of personal epistemology among different groups were also observed in the study after the treatments, which imply that dimensional analysis would be more informative than unitary approach on the effectiveness of instruction. Further research can focus on the possible benefit of particular instructional strategies on different dimension(s) of personal epistemology.

In order to enhance students' personal epistemology, the explicit and implicit instructions were designed by using different instructional strategies. By this way, student exposed to explicit epistemologically enhanced instruction got more benefit on physics achievement when compared to implicit instruction or traditional instruction. This result implies that physics or science teachers might help students to improve their achievement in physics by using different methods rather than sticking to one concrete and stable instruction. However, content of the unit could be restrictive for such implementation. The "heat and temperature" unit as outlined in the national curriculum includes both conceptual physics knowledge and mathematical calculations (quantitative knowledge) which allowed the researcher to use different instructional strategies. However, some of the units in the curriculum such as radioactivity and modern physics may not allow researchers to use wide range of instructional strategies because of the limited scope of the objectives. Consequently, the results of the study may be generalized to the units in physics with similar scope. The effectiveness of implicit and explicit epistemologically enhanced instructions may change due to this restriction. More intervention studies are required in order to obtain big picture about physics-related personal epistemology and its dependence on content.

This study offered statistically and practically positive changes in both students' personal epistemology and physics achievement due to use of explicit epistemologically enhanced instruction within seven weeks. Even though no interaction was found between these constructs in this study as in previous research (i.e. Yerdelen-Damar, 2013), results imply that affective variables such as personal epistemology should not be ignored when physics achievement is on the carpet. Sophistication in personal epistemology may mediate students' learning process and the learning difficulties they encountered. And it may help students to figure out how they learn and how they can improve their learning in any subject. In this study, the researcher considered only personal epistemology and physics achievement as outcome variables. Further research might be helpful to understand the effectiveness of explicit and implicit instructions on other affective constructs such as motivation to learn physics or attitude towards physic.

Teacher's personal epistemology was out of focus in this study that all instructional material for treatments was already developed by the researcher. As observed in conventional instruction, the teacher tends to teach physics knowledge economically by transmitting knowledge without any other effort (such as using demonstrations, experimentation in laboratory, or use of historical cases). Researcher did not examine whether treatments affected teacher's physics-related personal epistemology. Teacher dimension could be integrated in further studies.

Permanence of instructional effect on students' physics achievement and physics-related personal epistemology was not explored in this study. As claimed in belief literature, changing beliefs takes time. However, no data related to stability of epistemological beliefs was collected in the current study because students continued to take conventional instruction in the following semester after the study. In order to determine whether instructional effect is permanent or temporary, retention tests could be used in further studies by using the necessary arrangements.

Lastly, the sample of this study was included ninth grade high school students. Even though ninth graders have not been specialized in a specific field yet (e.g. literature, mathematics, science, social arts), several studies reported emergence of differences on domain-specific and general epistemological beliefs among university students and adults due to their majors in the literature (i.e. Hofer, 2000; Palmer & Marra, 2004). In this study, students' domain-general epistemological beliefs were not measured in order to explore whether any changes occurred due to effect of epistemologically enhanced instructions. Also, no information is obtained on whether epistemologically enhanced instructions can effect students' epistemological beliefs or their achievement in other science courses (e.g. biology, chemistry, mathematics). This can be investigated in future studies.

5.3. External Validity of the Study

The accessible population of the study was all ninth grade students at ten Anatolian Teacher Training High Schools (ATTHS) in Ankara. The current study was conducted at one of two ATTHSs in Çankaya district and sample of the study was about 14 percent of the target population and 42 percent of accessible population. Therefore, the results of the study could be generalized to the population. Additionally, most of the students in ATTHSs in Çankaya district were high achievers at TEOG (the entrance examination for high schools). The results of the study could be generalized to the schools with similar student characteristics.

5.4. Conclusion

Based on the results of the study, the explicit epistemologically enhanced instruction is an effective method to improve not only students' physics-related personal epistemologies but also their physics achievement on heat and temperature. Moreover, embedding dimensions of personal epistemology into instruction without any explicit epistemological emphasis was found to be effective method to improve students' physics achievement. Nevertheless, implicit epistemologically enhanced instruction is not as effective method as explicit epistemologically enhanced instruction to improve students' physics-related personal epistemologies. The results suggest that embedding the dimensions of personal epistemology into instruction can improve students' physics achievement but adding explicit discussions about epistemological issues can also improve their physics-related personal epistemology. Needless to add that these conclusions can only be generalized to the similar settings within the limitations of the study discussed in previous sections.

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APPENDIX A

INSTRUCTIONAL OBJECTIVE LIST OF THE HTAT

1. **(9.5.1.1.) Isı, sıcaklık ve iç enerji kavramlarını tanımlar ve birbirleriyle ilişkilendirir.**
   Specific Objectives
   1. Define heat, temperature and internal energy.
   2. Relate heat, temperature and internal energy with each other.
2. **(9.5.1.2.) Kullanım amaçlarına göre termometre çeşitlerini ve sıcaklık birimlerini karşılaştırarak sunar.**
   Specific Objectives
   3. Compare thermometer types according to their aim of usage.
   4. Compare different temperature units.
3. **(9.5.1.3.) Farklı ısı ve sıcaklık birimlerinin ortaya çıkış nedenlerini açıklar.**
   a. **Isı (kalori ve Joule) ve sıcaklık (^oC, ^oF, K) için birim dönüşümleri yapılır.**
   Specific Objectives
   5. Explain why different heat units were emerged.
   6. Explain why different temperature units were emerged.
   7. Make conversion of heat units (calorie and Joule).
   8. Make conversion of temperature units (^oC, ^oF, K).
4. **(9.5.1.4.) Öz ısı ve ısı sığası kavramlarını açıklar.**
   a. **Öz ısının maddeler için ayırt edici bir özellik olduğu vurgulanır.**
   b. **Öğrencilerin farklı maddelerin öz ısılarını ısı-sıcaklık grafiklerinden hesaplamaları sağlanır.**
   c. **Öğrencilerin öz ısıları farklı maddelerin sıcaklık değişimlerinin günlük hayattaki etkileri ile ilgili örnekler vermeleri sağlanır.**
   Specific Objectives
   9. Explain specific heat concept.
   10. Explain heat capacity concept.
   11. Explain the effects of temperature change in daily life according to different matters with different specific heat.
5. **(9.5.2.1.) Ortamdan enerji alınması veya ortama enerji verilmesi ile hâl değişimi arasındaki ilişkiyi açıklar.**

a. **Öğrencilerin donma, erime, kaynama ve yoğunlaşma kavramlarını enerji ile ilişkilendirmeleri sağlanır.**
b. **Öğrenciler maddelerin sıcaklık ve hald eğişimi için gerekli ısıyı hesaplar, ısı-sıcaklık grafiklerini çizer.**
c. **Öğrencilerin ısı-sıcaklık grafiklerini çizmeleri ve yorumlamaları sağlanır.**

Specific Objectives

12. Explain the relationship between exothermic and endothermic process and change in state of matter.
13. Calculate the required heat to change temperature and state of the matter.
14. Draw temperature-heat graphs.
15. Analyze temperature-heat graphs.

6. **(9.5.3.1.) Isıl denge kavramının sıcaklık farkı ve ısı kavramlarıyla olan ilişkisini açıklar.**
   a. **Öğrencilerin simülasyonlar ve gösterimler kullanarak ısıl dengenin sıcaklık değişimi ve ısı ile ilişkisini gözlemlemeleri sağlanır.**

   Specific Objectives

   16. Explain the relationship among thermal equilibrium, temperature difference and heat concepts by using related simulations and demonstrations.

7. **(9.5.4.1.) Enerji iletim yollarını açıklar.**
   a. **Öğrencilerin iletim, ışıma ve konveksiyon yolu ile enerji aktarımını en iyi gerçekleştiren katı, sıvı ve gazlara örnekler vermeleri sağlanır.**
   b. **Öğrencilerin enerji iletim yolları kullanılarak geliştirilen uygulamalara örnekler vermeleri sağlanır.**

   Specific Objectives

   17. Explain the types of energy transfer.
   18. Give examples of solid, liquid and gases which transfer energy the best by conduction, convection and radiation.
   19. Differentiate daily life examples according to types of energy transfer.

8. **(9.5.4.2.) Bir maddedeki enerji iletim hızını etkileyen değişkenleri açıklar.**
   a. **Öğrencilerin maddelerin enerji iletim hızını günlük hayat olayları ile ilişkilendirmeleri sağlanır.**
   b. **Matematiksel işlemlere girilmez.**

   Specific Objectives

   20. Explain the factors affecting the rate of energy transfer.
   21. Relate rate of energy transfer at different matters in daily life phenomena.

9. **(9.5.4.3.) Enerji tasarrufu için yaşam alanlarının yalıtımına yönelik tasarım yapar.**
   a. **Öğrencilerin ısı yalıtım yollarını araştırmaları sağlanır.**
   b. **Öğrenciler ısı yalıtımı ile ilgili günlük hayattan bir problem belirlemeleri ve çözümler üretmeleri sağlanır.**
   c. **Proje tasarımında gruplar oluşturulmasına, ortak kararlar alınmasına, görevlerin paylaştırılmasına, sürecin ve ürünün değerlendirilmesine imkân verilir.**

Specific Objectives

22. Make design aimed to insulation of living areas for energy saving.
23. Provide solutions for problems related with heat insulation in daily life.

10. (9.5.4.4.) Hissedilen ve gerçek sıcaklık arasındaki farkın nedenlerini açıklar.

Specific Objectives

24. Explain the reason of difference between felt and real temperature.

11. (9.5.4.5.) Küresel ısınma olayının sebepleri ve küresel ısınmanın ortaya çıkardığı etkiler üzerine argüman oluşturur.

Specific Objectives

25. Explain the factors related with global warming.
26. Explain effects of global warming.

12. (9.5.5.1.) Katı, sıvı ve gazlarda genleşme ve büzülme olaylarını karşılaştırır.

a. Öğrencilerin günlük hayattaki olayları inceleyerek genleşmenin etkilerini karşılaştırmaları sağlanır.

b. Öğrencilerin suyun diğer maddelerden farklılık gösteren sıcaklık-hacim ve sıcaklık-özkütle grafiklerini yorumlamaları ve günlük hayattaki etkilerini tartışmaları sağlanır.

c. Matematiksel işlemlere girilmez.

Specific Objectives

27. Compare thermal expansion/contraction phenomena for different matters.
28. Give examples about effects of thermal expansion in daily life.
29. Examine volume-temperature and density-temperature graphs of water.
30. Explain effects of water’s unique expansion characteristics on daily life.

APPENDIX B

FIRST VERSION OF THE HTAT

2013-2014 2. Dönem

ISI ve SICAKLIK BAŞARI TESTİ

Adı-Soyadı:________________________ **Okul Adı:** ________________________

Oğrenci No: ________________________ **Sınıf/Şube:** ________________________

Bu test toplam 37 tane soru içermektedir. Açıklama istenen sorularda cevaplarınız açık ve öz olsun. Çoktan seçmeli sorularda işaretlemelerinizi ayrıt edilebilir bir şekilde yaptığınızdan emin olunuz. Lütfen soruları boş bırakmayınız. Bilemediğiniz ya da yapamadığınız sorular için konulmuş kutucukları işaretleyiniz. Sınav toplam 100 puandır.

Başarılar dileriz.

1. Bölüm (10 Puan)
Aşağıda ısı ve sıcaklık konusu kavramlarıyla ilgili ifadeler listelenmiştir. Verilen ifade doğruysa ***D****, yanlışsa* ***Y*** *harfini yuvarlak içine alınız.* ***Yanlış olduğunu düşündüğünüz cevapların doğrularını bırakılan boşluklara yazınız.*** *Her doğru cevap 1 puandır.*

				Bilmiyorum Yapamıyorum
1.	D	Y	Isı ve sıcaklık birbiri yerine kullanılan kavramlardır. ________________________	☐
2.	D	Y	Buzdolabından çıkarılan bir şişe suyun ısısı bir süredir tezgahta duran bir şişeye göre daha azdır. ________________________	☐
3.	D	Y	Soğuk cisimlerin sıcaklığı vardır. ________________________	☐
4.	D	Y	Iç enerjisi artan bir maddenin ısısı da artar. ________________________	☐
5.	D	Y	Iç enerjisi artan bir maddenin sıcaklığı da artar. ________________________	☐
6.	D	Y	Sıcaklık, bir maddenin ortalama kinetik enerjisidir. ________________________	☐
7.	D	Y	Isı, sıcak bir cisimden soğuk bir cisme doğru gerçekleşen enerji transferidir. ________________________	☐
8.	D	Y	Bir cismin ya da maddenin ısısından bahsedilemez. ________________________	☐
9.	D	Y	Moleküler düzeyde bir maddenin sahip olduğu potansiyel ve kinetik enerji toplamı iç enerji olarak tanımlanır. ________________________	☐
10.	D	Y	Bir cismi yerden alıp 2.0m yüksekliğinde bir rafa koyarsak iç enerjisi artar. ________________________	☐

2. Bölüm (10 Puan)
B sütununda verilen kavramlar ile A sütununda verilen örnek olayları eşleştiriniz. Boş bırakılan yerlere (____) a, b, ya da c harflerinden uygun olan ya da uygun olanları yazarak cevaplayınız. Her doğru cevap 1 puandır.

	Bilmiyorum Yapamıyorum	A. Günlük hayattan örnekler	B. Enerji iletim yolları
11.	☐	(____) Güneşli bir günde arabanın dış yüzeyinin ısınması	
12.	☐	(____) Tencerede suyun kaynatılması	
13.	☐	(____) Sıcak çorbanın içine bırakılan kaşığının zamanla ısınması	
14.	☐	(____) Kalorifer peteği üzerinde ısınan havanın yükselmesi	**a.** İletim
15.	☐	(____) Yanan şömine ile ısınma	**b.** Konveksiyon
16.	☐	(____) Demirin şeklini değiştirmek için kızdırılması	**c.** Işıma
17.	☐	(____) Mikrodalga fırında yemek ısıtmak	
18.	☐	(____) Gömleğin ütülenmesi	
19.	☐	(____) Sıcak hava balonunun şişmesi	
20.	☐	( ) Güneş panellerinin çalışması	

3. Bölüm (18 puan)
Bu bölümde verilen soruların cevaplarını boş bırakılan yere kısaca açıklayarak yazınız. Her bir soru 3 puandır.

21. Çalışan bir motorun yanmasını engellemek için öz ısısı yüksek soğutucu sıvı mı yoksa öz ısısı düşük bir soğutucu sıvı mı kullanırdınız?

Bilmiyorum / Yapamıyorum ☐

____

____

22. Neden sıvılı termometrelerde genellikle cıva kullanılır?

Bilmiyorum Yapamıyorum ☐

____

____

23. Seramik zemine çıplak ayakla bastığımızda ayağımız üşürken, parke (tahta) zemine bastığımızda ayağımızın üşümesinin nedenini açıklayınız.

Bilmiyorum Yapamıyorum ☐

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24. Neden kayak yapan sporcular kalın bir mont yerine, birden çok giysiyi üst üste giyerler?

Bilmiyorum Yapamıyorum ☐

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25. Su ısıtıcılarında su doldurulan haznede "buraya kadar doldurun" ► işareti bulunur. Buna göre ısıtıcının ağzına kadar tamamen suyla **doldurulamamasının** nedeni nedir?

Bilmiyorum Yapamıyorum ☐

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26. Esra: "Dün çok soğuktu, sıcaklık 265'e inmişti."

Sizce Esra hangi sıcaklık ölçeğine göre böyle söylemiştir

Bilmiyorum Yapamıyorum ☐

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4. Bölüm (32 Puan)

Bu bölümde verilen çoktan seçmeli soruları doğru cevabı yuvarlak içine alacak şekilde işaretleyerek cevaplayınız. Her sorunun tek bir doğru cevabı vardır ve her soru 4 puandır.

27. Ayşe kendisine bir fincan sıcak çay hazırlar. Kardeşi için buzdolabından meyve suyu çıkarır. Çayın sıcaklığı yaklaşık 90°C, meyve suyu ise 5°C'dir. Meyve suyunu da rafta duran başka bir fincana doldurur ve iki fincanı da masaya koyar. Odanın sıcaklığı yaklaşık 20°C dir.

Buna göre 10 dakika sonra sırasıyla çayın ve meyve suyunun sıcaklıkları aşağıdakilerden hangisi olabilir?

A) 90°C ve 5°C

B) 80°C ve 5°C

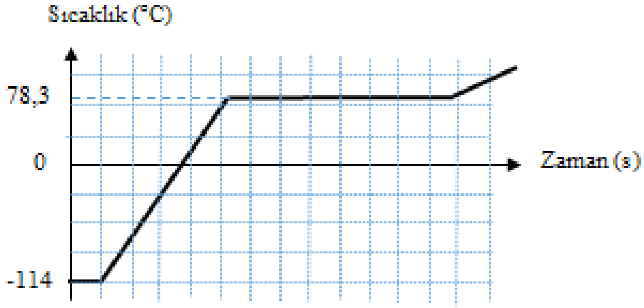
C) 70°C ve 10°C

D) 50°C ve 20°C

E) Ikisi de 20°C dir.

Bilmiyorum Yapamıyorum ☐

28.



Deniz bir fizik laboratuvarında teknisyen olarak çalışmaktadır. Dolaplardaki malzemeleri incelerken, bir rafta etiketlenmemiş bir şişe sıvı bulur. Sıvının kokusundan alkol olduğu anlaşılmaktadır. Bu alkolün türünü bulmak için sıvıyı bir müddet ısıtarak kaynatır. Sıvının kaynama sıcaklığının 78,5°C olduğunu bulur. İnternetten araştırdığında bu sıcaklığın etil alkolün kaynama sıcaklığına (78,3°C) çok yakın olduğunu görür. İnternette gördüğü etil alkolün hal değiştirme grafiğini inceler. Bu grafik sabit bir ısıtıcı kullanılarak elde edilmiştir.

Deniz grafiği incelerken bazı yorumlar yapar. Aşağıda verilen yorumlardan hangisi **yanlıştır**?

A) Etil alkol -115°C sıcaklıkta katı halde bulunur.

B) Sıvı hale geçen etil alkolün kaynama sıcaklığına gelmesi için verilen ısı miktarı buharlaşması için verilen ısıdan daha fazladır.

C) Etil alkolün kaynama ısısı erime ısısından çok daha fazladır.

D) Etil alkol kullanılan bir termometre ile 79°C sıcaklık değeri ölçülemez.

E) Laboratuvarımızdaki soğutucuların sıcaklığı en düşük -20°C olduğu için etil alkolü katılaştıramayız.

Bilmiyorum / Yapamıyorum ☐

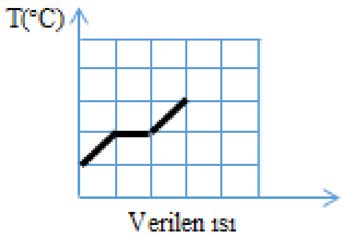
29. İsmail usta, bir evde meydana gelen elektrik arızası sebebiyle arıza çıkan binaya gitmesi gerekmiştir. Arabasını gölgelik bir yer olmadığı için güneş alan bir yere park etmiştir. **Arabanın bagajında** bir plastik su şişesi, metal çiviler ve kauçuk eldivenlerini bırakmıştır. 3 saat boyunca güneşin altında bekleyen arabanın içerisindeki sıcaklık 35 °C dir.

Arabada kalan eşyaların sıcaklıkları aşağıdaki seçeneklerden hangisi gibi olur?

	Plastik su şişesi	Metal çiviler	Kauçuk eldivenler
A)	35°C	35°C	35°C
B)	35°C	70°C	35°C
C)	60°C	80°C	20°C
D)	60°C	80 C	60°C
E)	60°C	80°C	80°C

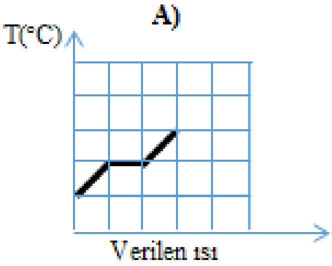
Bilmiyorum / Yapamıyorum ☐

30. Sabit ısıtıcı ile ısıtılan bir su örneğinin ısı-sıcaklık değişimi aşağıdaki grafikte gösterilmiştir.

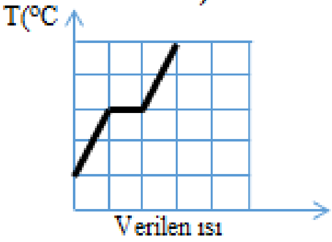


Suyun kütlesi iki katına çıkartılıp verilen ısı miktarı değiştirilmezse, ısı-sıcaklık değişimi grafiği aşağıdakilerden hangisi gibi olur? (Bütün grafikler için birim kareler özdeştir.)

A)

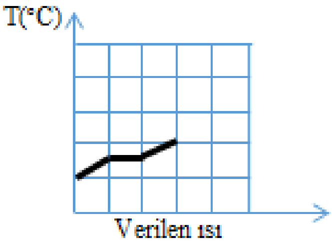


B)

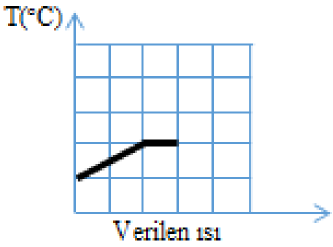


Bilmiyorum
Yapamıyorum ☐

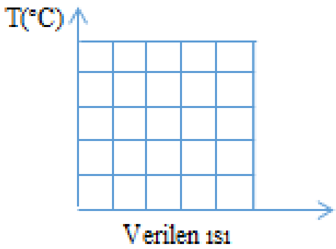
C)



D)



E) Kendi çizimim:



31. Alüminyumun öz ısısı, bakırın öz ısısının iki katıdır. 0°C de aynı kütlede bir parça alüminyum ve bir parça bakır aynı sıcak su dolu kovaya atılmıştır. Buna göre sistem ısıl dengeye geldiğinde, alüminyum ve bakır parçaların sıcaklıklarıyla ilgili aşağıdaki ifadelerden hangisi doğrudur?

Bilmiyorum
Yapamıyorum ☐

A) Alüminyum parça bakır parçadan daha sıcaktır.

B) Bakır parça alüminyum parçadan daha sıcaktır.

C) Alüminyum ve bakır parçalar aynı sıcaklıktadır.

D) Alüminyum ve bakır parçalar arasındaki sıcaklık farkı su miktarına bağlıdır.

E) Alüminyum ve bakır parçalar arasındaki sıcaklık farkı suyun ilk sıcaklığına bağlıdır.

32. Mustafa ABD'ye gideceği dönemdeki aylık hava sıcaklıklarını inceler.

WISCONSIN (Milwaukee)	Ocak	Şubat	Mart	Nisan	Mayıs	Haziran
Ortalama en yüksek sıcaklık (°F)	29	33	42	54	65	75
Ortalama en düşük sıcaklık (°F)	16	19	28	37	47	57

TEXAS (Austin)	Ocak	Şubat	Mart	Nisan	Mayıs	Haziran
Ortalama en yüksek sıcaklık (°F)	62	65	72	80	87	92
Ortalama en düşük sıcaklık (°F)	42	45	51	59	67	72

Aşağıdaki seçeneklerden hangisinde iki şehir için kaydedilen ortalama en yüksek sıcaklık °C cinsinden doğru verilmiştir?

	Wisconsin (°C)	**Texas** (°C)
A)	75	92
B)	43	25
C)	41.67	51.11
D)	37.5	46
E)	23.89	33.33

Bilmiyorum Yapamıyorum ☐

Aşağıda verilen tabloyu inceleyiniz ve 33. ve 34. soruları bu bilgiler doğrultusunda cevaplayınız.

Madde	**A**	**B**	**C**
Kütlesi	2g	25g	5g
Isı Sığası	$4.0 \frac{J}{°C \times g}$	$2.0 \frac{J}{°C \times g}$	$4.0 \frac{J}{°C \times g}$
Sıcaklığı	30°C	30°C	25°C

33. A ve B maddeleri birbirine temas etmektedir. Buna göre aşağıdaki ifadelerden hangisi doğrudur?

A) B'nin kütlesi fazla olduğu için enerji transferi B'den A'ya doğru gerçekleşir.

B) Kütle ve öz ısı çarpımı B için daha büyük olduğu için enerji transferi B'den A'ya doğru gerçekleşir.

C) A'nın birim kütle başına düşen ısı miktarı B'den büyük olduğu için A'dan B'ye gerçekleşir.

D) Enerji transferi gerçekleşmez.

E) A'nın öz ısısı daha büyük olduğu için enerji transferi A'dan B'ye doğru gerçekleşir.

Bilmiyorum Yapamıyorum ☐

34. B ve C maddeleri birbirine temas etmektedir. Buna göre aşağıdaki ifadelerden hangisi doğrudur?

A) B'nin sıcaklığı daha yüksek olduğu için enerji transferi B'den C'ye doğru gerçekleşir.

Bilmiyorum
Yapamıyorum ☐

B) C'nin öz ısısı daha büyük olduğu için enerji transferi C'den B'ye doğru gerçekleşir.

C) B'nin kütlesi daha büyük olduğu için enerji transferi B'den C'ye doğru gerçekleşir.

D) B ve C'nin öz ısı ve kütle çarpımları eşit olduğu için enerji transferi gerçekleşmez.

E) Hiçbiri

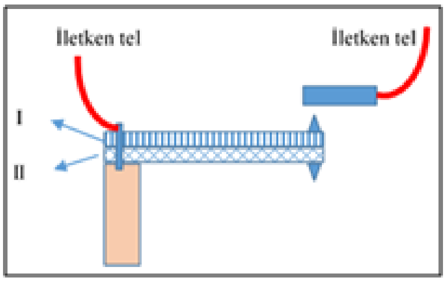
Bölüm 5. (30 puan)

Bu bölümde verilen soruları matematiksel hesaplamaları verilen boşluğa yazarak cevaplayınız. Lütfen sorularda verilen birimlere dikkat ediniz.

Madde	Erime Isısı (kJ/kg)	Öz Isı (kJ/kg.°C)	Erime Sıcaklığı (°C)	Genleşme Katsayısı (10^{-6} m/m °C)
Alüminyum	321	0.91	660	22.2
Krom	134	0.46	1860	6.2
Bakır	176	0.39	1084	16.6
Kurşun	22.4	0.13	327.5	28.0
Nikel	297	0.44	1453	13.0
Çinko	118	0.39	419.5	29.7

Yukarıdaki tabloyu inceledikten sonra 35. ve 36. sorularını cevaplandırınız.

35. Sıcaklık kontrolünü sağlamak için geliştirilmiş basit bir düzenek yandaki şekilde gösterilmiştir. Düzenek iki farklı metalin sıcaklık değişimine verdiği tepki sonucu elektrik devresinin tamamlanmasını sağlamaktadır. Bu sayede sistemin istenilen sıcaklığa gelmesi ve sıcaklığının daha fazla yükselmemesi sağlanır.



Tabloda verilen metalleri kullanarak, <u>700°C sıcaklığı ölçmek için ayarlanmış</u> şekilde verilen sistemde kullanabileceğiniz:

a) (3 puan) Metal türlerini yazınız ve bu metal türlerini neden seçtiğinizi açıklayınız.

Bilmiyorum
Yapamıyorum ☐

b) (7 puan) I ve II'ye gelecek metal türlerini belirterek oluşturacağınız metal çiftlerini yazınız ve bu metal çiftlerini neden seçtiğinizi açıklayınız.

Bilmiyorum
Yapamıyorum ☐

36. (8 puan) Farklı metal türlerinin belirli özellikleri yukarıdaki tabloda verilmiştir. İlk sıcaklıkları eşit olacak şekilde her bir maddeden 10g alınarak özdeş ısıtıcılarla ısıtılırsa hangi metal türünün sıcaklık değişimi en fazla olur?

Bilmiyorum Yapamıyorum ☐

37. (12 puan) Evinizdeki yakıt giderlerinizi azaltmak için oturduğunuz binaya yalıtım yapılması söz konusudur. Bina yalıtımında kullanılabilecek farklı yalıtım malzemeleri aşağıdaki tabloda verilmiştir. Bina yöneticisi ve apartman sakinleri hem ekonomik hem de dayanıklı bir yalıtım yaptırmak istemektedirler.

Yalıtım Malzemesi	**Sıcaklık Aralığı**	**Isı İletim Katsayısı**	**Yoğunluk**	**Fiyat* (m^2)**
Bakalitli Cam Yünü	+230°C'ye kadar	0.040W/mK (20°C)	10-80 kg/m^3	26.20 TL (4cm)
Bakalitsiz Cam Yünü	+555°C'ye kadar	0.045W/mK (50°C)	130 kg/m^3	30.20 TL (4cm)
Yüksek Yoğunluklu Taşyünü	0°C / +800°C	0.043W/mK (50°C)	100 kg/m^3	45.90 TL (5cm)
Düşük Yoğunluklu Taşyünü	0°C / +800°C	0.043W/mK (10°C)	33 kg/m^3	43.90TL (5cm)
Genleştirilmiş Polistren (EPS)	-100°C / +80°C	0.033W/mK (10°C)	15-30 kg/m^3	33.44TL (5cm)
Ekstrüde Polistren (XPS)	-60°C / +75°C	0.026W/mK (10°C)	45 kg/m^3	38.63TL (5cm)

*Fiyatlar 4 cm ve 5 cm kalınlığındaki yalıtım malzemelerinin metrekare (m^2) fiyatlarıdır.

Elinizdeki bu verilere göre, bina yöneticisine hangi malzeme ile yalıtım yaptırmasını önerirsiniz? Açıklayarak yazınız.

Bilmiyorum Yapamıyorum ☐

APPENDIX C

THE EXPERT OPINION DOCUMENT FOR THE HTAT

Uzman Görüşü

Sayın Uzman,

Tez çalışmamda kullanmak üzere 9. sınıf Isı ve Sıcaklık konusu ile ilgili bir başarı testi geliştirmekteyim. Bu dokümanda öğretim programında verilen kazanımlar ve daha açık ve net olması bakımından bu kazanımlarla alakalı alt kazanımlar yazılmıştır. Kazanımların verildiği listeden sonra *Isı ve Sıcaklık Başarı Testi* için oluşturulan test belirtke tablosu verilmiştir.

Buna göre lütfen;

1. Isı ve Sıcaklık Başarı Testi dosyasında bulunan soruları inceleyerek Bloom Taksonomisi'nde bulunan bilişsel alan seviyelerine göre belirtke tablosunda kodlayınız.

2. Isı ve Sıcaklık Başarı Testi soruları hakkında görüş ve önerilerinizi yazmak üzere testin sonunda ayrı bir bölüm oluşturulmuştur. Çıkarılmasını ya da geliştirilmesini uygun gördüğünüz soruları lütfen belirtiniz.

3. Isı ve Sıcaklık Başarı Testi'nin cevap anahtarı oluşturulmuştur. Lütfen cevapların doğruluğunu kontrol ediniz. Gerekli değişiklikleri lütfen Görüş ve Öneriler tablosuna yazınız.

Vakit ayırdığınız için teşekkür ederim.

Kübra Eryurt

			Levels							
Topic	Objective List	Q #	R.	U.	Ap.	An.	E.	C.	Total	%
Heat, Temperature, Internal Energy	**9.5.1.1.** Define heat, temperature and internal energy, and relate them with each other.									
	9.5.1.1.a. Define heat.									
	9.5.1.1 b. Define temperature.									
	9.5.1.1.c. Define internal energy									
	9.5.1.1.d. Relate heat with temperature.									
	9.5.1.1.e. Relate heat with internal energy.									
	9.5.1.1.f. Relate temperature with internal energy.									
Thermometers	**9.5.1.2.** Compare thermometer types according to their aim of usage and compare temperature units.									
	9.5.1.2.a. Compare thermometer types according to their aim of usage.									
	9.5.1.2.b. Compare different temperature units.									
Heat and Temperature Units	**9.5.1.3.** Explain why different heat and temperature units were emerged.									
	9.5.1.3.a. Explain why different heat units were emerged.									
	9.5.1.3.b. Explain why different temperature units were emerged.									
	9.5.1.3.c. Make conversion of units									
Specific Heat and Heat Capacity	**9.5.1.4.** Explain concepts of specific heat and heat capacity.									
	9.5.1.4.a. Define specific heat concept.									
	• Emphasize that specific heat is distinctive feature/characteristics for matters.									
	• Provide heat and temperature graphics to students in order to calculate specific heat for different matters/materials.									
	• Students are asked to give examples for the effects of temperature change in daily life for materials with different specific heat.									
	9.5.1.4.b. Define heat capacity concept.									
Phase Change	**9.5.2.1.** Explain the relationship between exothermic and endothermic process and change of state.									
	9.5.2.1.a. Relate the concepts of freezing, melting, boiling and condensation with energy.									
	9.5.2.1.b. Students calculate the heat needed to change temperature and phase of matters and draw heat and temperature graphics.									
	Sub-total 1									

			Levels							
Topic	Objective List	Q #	R.	U.	Ap.	An.	E.	C.	Total	%
Thermal Equilibrium	**9.5.3.1.** Explain relationship between thermal equilibrium concept and temperature difference and heat concepts.									
Ways of Energy Transfer	**9.5.4.1.** Explain ways of energy transfer.									
	9.5.4.1.a. Give examples for solid, liquid and gases which transfer energy very well by conduction, convection and radiation.									
	9.5.4.1.b. Give examples of developed applications by using ways of energy transfer.									
Speed of Energy Transfer	**9.5.4.2.** Explain the factors affecting the speed of energy transfer.									
	9.5.4.2.a. Relate speed of energy transfer for different matters with daily life experiences.									
Insulation	**9.5.4.3.** Make design for saving energy by insulation of living areas.									
	9.5.4.3. a. Students make research on the ways of heat insulation.									
	9.5.4.3. b. Students determine a problem related with heat insulation form daily life and provide solutions for these problems. (PROJECT)									
	9.5.4.4. Explain the reason of difference between chill factor and real temperature.									
	9.5.4.5. Make argument for the factors related with emergence of global warming and the effects of global warming.									
Thermal Expansion	**9.5.5.1.** Compare thermal expansion and condensation phenomena for solid, liquid and gases.									
	9.5.5.1.a. Students investigate the real life phenomena and compare the effects of thermal expansion.									
	9.5.5.1.b. Differently from other matters, students interpret water's temperature-volume and temperature-density graphs and discuss their effects on daily life.									
Sub-total 2										
	Total									

Görüş ve Öneriler

Soru	Açıklama	Cevap Anahtarı
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
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35a		
35b		
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37		

APPENDIX D

TABLE OF SPECIFICATION FOR THE FIRST VERSION OF THE HTAT

Subject	Cognitive Domain in Bloom's Taxonomy						Total
	Remembering	Understanding	Applying	Analyzing	Evaluating	Creating	
Heat, Temperature and Internal Energy	**1**(1,6,7, 9)	**2**(2,3,4,5,8, 10)					2(10)
Units		**4**(16a,b,c) **8**(28)					2(2)
Specific heat and heat capacity		**11**(11, 12)					1(2)
Phase change of matter			**13**(35)	**14**(29) **15**(31)			3(3)
Thermal Equilibrium		**16**(30, 32,33)					1(3)
Types of Energy Transfer		**17**(17a,b,c) **19**(21, 22,23, 24,25, 26,27)					2(8)
Rate of Energy Transfer		**21(**13)					1(1)
Heat Insulation		**24**(18)	**23**(14)		**22**(36)		3(3)
Thermal Expansion	**29**(19)	**28**(15) **30**(20)		**27**(34)			4(4)

APPENDIX E

THE FINAL VERSION OF THE HTAT

ISI ve SICAKLIK TESTİ

Adı-Soyadı: ______________________ **Okul Adı:** ______________________

Öğrenci No: ______________________ **Sınıf/Şube:** ______________________

Bu test beş bölümden oluşmaktadır. Test toplam 37 tane soru içermektedir. Açıklama istenen sorularda cevaplarınızın açık ve öz olmasına dikkat ediniz. Çoktan seçmeli sorularda işaretlemelerinizi ayırt edilebilir bir şekilde yaptığınızdan emin olunuz. **Lütfen soruları boş bırakmayınız.**

Başarılar dileriz ☺

1. Bölüm

Aşağıda ısı ve sıcaklık konusu kavramlarıyla ilgili ifadeler listelenmiştir. Verilen ifade doğruysa **D**, yanlışsa **Y** harfini yuvarlak içine alınız. **"Yanlış" cevabını verdiğiniz ifadelerin neden yanlış olduğunu bırakılan boşluklara yazınız.**

Örnek:

Y Kağıdın yanması fiziksel bir değişimdir.

X Kağıdın yanması fiziksel değişim değildir.

✔Kağıdın yanması kimyasal değişimdir.

1. D Y Isı ve sıcaklık kavramları birbirinin yerine kullanılır.

____

2. D Y Buzdolabından yeni çıkarılmış bir şişe suyun ısısı, uzun süre masanın üzerinde beklemiş bir öncekiyle özdeş bir şişe suyun ısısından daha azdır.

____

3. D Y Soğuk cisimlerin sıcaklığı vardır.

____

4. D Y İç enerjisi artan bir maddenin ısısı da artar.

____

5. D Y İç enerjisi artan bir maddenin kesinlikle sıcaklığı da artar.

____

6. D Y Sıcaklık, bir maddenin ortalama kinetik enerjisidir.

____

7. D Y Isı, sıcaklık farkından dolayı aktarılan enerjidir.

____

8. D Y Bir cismin ısısından bahsedilemez.

____

9. D Y Moleküler düzeyde bir maddenin sahip olduğu potansiyel ve kinetik enerji toplamı iç enerji olarak tanımlanır.

____

10. D Y Bir cismi yerden alıp 2m yüksekliğinde bir rafa koyarsak iç enerjisi artar.

____

1

2. Bölüm

Bu bölümde verilen soruların cevaplarını boş bırakılan yerlere **kısaca (birkaç cümle ile) sebebini yazarak açıklayınız**.

11. Çalışan bir motorun yanmasını engellemek için öz ısısı yüksek bir soğutucu sıvı (antifriz) mı yoksa öz ısısı düşük bir soğutucu sıvı mı kullanırdınız?

____

Neden?____

____

12. Vücut sıcaklığımızı ölçmek için kullandığımız sıvılı termometrelerde su yerine genellikle cıva veya etil alkol kullanılır. Bunun nedenini **özısı** ve **genleşme** kavramlarından hangisi ya da hangileri ile açıklarsınız?

____

Neden?____

____

13. Seramik zemine çıplak ayakla bastığımızda ayağımız üşürken, parke (tahta) zemine bastığımızda ayağımızın **üşümemesinin** sebebi nedir?

____

____

14. Kayak yapan sporcular **kalın bir mont** yerine **birden çok giysiyi üst üste giyerek** vücut sıcaklıklarını daha iyi dengelerler. Bunun sebebi nedir?

____

____

15. Arabalarda **ısınan motoru soğutmak** için radyatör kullanılır. Radyatör, yaklaşık 3 - 3,5 litre su ve antifriz karışımının doldurulduğu bir hazneden (kap) ve sıvının dolaşmasını sağlayan borulardan oluşur. Hazneye konulan karışım **ancak belli bir noktaya kadar konulur**, tamamen doldurulmaz.Bunun sebebi nedir?

____

____

16. *Burçin:* "Dün hava çok soğuktu. Dijital termometre evin sıcaklığını 50 derece gösteriyordu."

a. Bu dijital termometre hangi sıcaklık birimini göstermektedir?________________________

b. Bu dijital termometreye göre suyun donma sıcaklığı kaç derecedir? ____________________

c. Bu dijital termometreye göre suyun kaynama sıcaklığı kaç derecedir? ____________________

17. Enerji iletim yollarından iletim, konveksiyon ve ışımayı birer cümle ile açıklayınız.

*a. İletim:*____

*b. Konveksiyon:*____

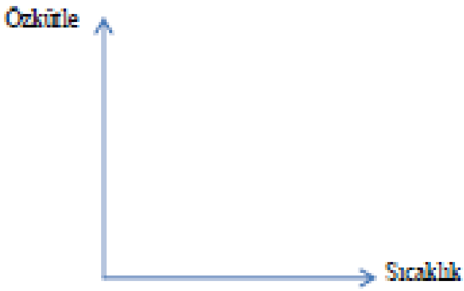
*c. Işıma:*____

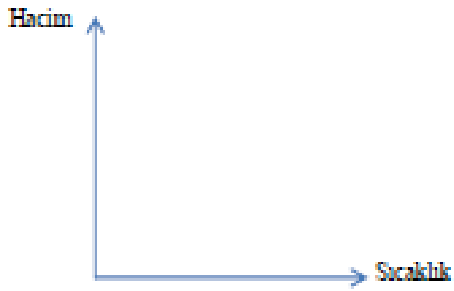
18. Yaz mevsiminde Ankara'daki hava sıcaklığı ile Ankara'da **hissedilen sıcaklık** arasındaki fark, Adana'dakine göre **daha azdır**. Bu durumun sebebini açıklayınız.

____

____

19. Suyun +4°C'deki özel durumunu gösteren suyun **özkütle-sıcaklık** ve **hacim-sıcaklık** grafiklerini çiziniz.





20. Günlük yaşamda +4°C'deki suyun özel durumunu gözlemlediğimiz olaylara bir örnek veriniz.

____

____

3. Bölüm

Aşağıda, soldaki sütunda verilen günlük hayat örneklerinin hangi enerji iletim yoluyla gerçekleştiğini, sağdaki sütunda verilen farklı enerji iletim yollarıyla eşleştiriniz. Boş bırakılan yerlere (____) **A,B,C** harflerinden **birini** kullanarak ve günlük hayat örneklerinde verilen **baskın durumları** düşünerek cevaplayınız. Her harfi birden çok kez kullanabilirsiniz.

	Günlük hayattan örnekler	**Enerji iletim yolları**
(____)	**21.**Bir evin kaloriferle ısıtılması	
(____)	**22.**Yanan soba üzerindeki tencerenin ısınması	**A.** İletim
(____)	**23.**Kış mevsimde güneşte kalan cisimlerin ısınması	
(____)	**24.**Sıcak çorbanın içinde kalan metal kaşığın elimizi yakması	**B.** Konveksiyon
(____)	**25.**Şöminede yanan ateşin yakın mesafedeki havayı ısıtması	
(____)	**26.** Uzun süre kömürle ısıtılan ızgaranın, kömür döküldükten sonra çevresini ısıtmaya devam etmesi	**C.** Işıma
(____)	**27.**Kaynayan suda yumurtanın pişmesi	

4. Bölüm

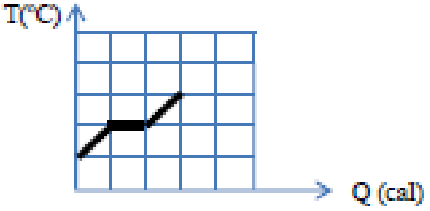
Bu bölümde verilen çoktan seçmeli soruları doğru cevabı yuvarlak içine alacak şekilde işaretleyerek cevaplayınız. Her sorunun **bir doğru** cevabı vardır.

28. Mayıs ayında Wisconsin'de 77°F, Texas'ta ise 95°F sıcaklık ölçülmüştür.

Aşağıdaki seçeneklerden hangisinde iki şehir için kaydedilen sıcaklıklar **°C cinsinden** doğru verilmiştir?

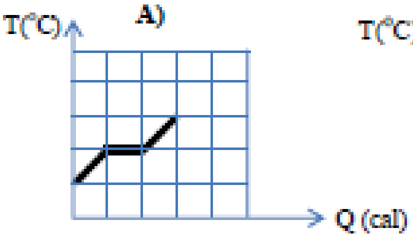
	Wisconsin (°C)	**Texas (°C)**
A)	77	95
B)	45	63
C)	42,77	52,77
D)	38,5	47,5
E)	25	35

29. Bir ısıtıcı ile ısıtılan bir miktar suyun sıcaklık-ısı grafiği aşağıda verilmiştir.

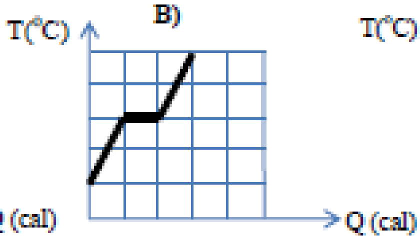


Suyun **kütlesi iki katına çıkartılıp** verilen ısı miktarı değiştirilmezse, sıcaklık-ısı grafiği aşağıdakilerden hangisi gibi olur? (Bütün grafikler için birim kareler özdeştir.)

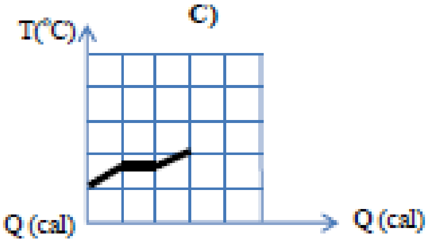
A)



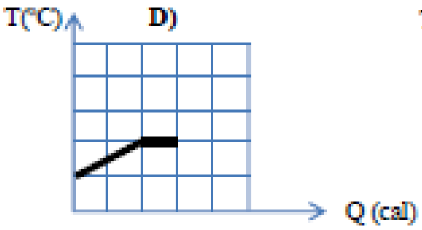
B)



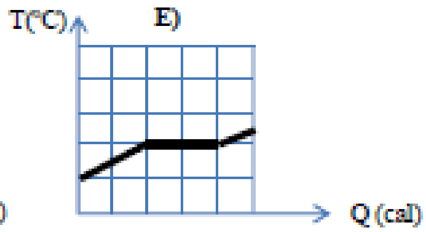
C)



D)



E)



30. İsmail Usta arabasında bir plastik su şişesi, birkaç metal çivi ve bir çift kauçuk eldivenlerini bırakmıştır. Kapalı garajda bekleyen arabanın içerisindeki sıcaklık 15 °C'dir.

2 gün boyunca arabada kalan bu eşyaların (şimdiki) sıcaklıkları aşağıdaki seçeneklerden hangisi gibi olabilir?

	Plastik su şişesi	**Metal çiviler**	**Kauçuk eldivenler**
A)	5°C	2 °C	10 °C
B)	10 °C	2 °C	10 °C
C)	10°C	5 °C	20°C
D)	15 °C	5 °C	37,5 °C
E)	15 °C	15 °C	15 °C

31. ve 32. soruları aşağıdaki tabloda verilen bilgilere göre cevaplayınız.

Madde	**A**	**B**	**C**
Kütlesi	10 g	10 g	5 g
Öz ısısı	$3 \frac{J}{°C \times g}$	$2 \frac{J}{°C \times g}$	$4 \frac{J}{°C \times g}$
Sıcaklığı	30 °C	30 °C	25 °C

31. A ve B maddeleri birbirine temas ettirilirse **enerji transferi** ile ilgili aşağıda verilen ifadelerden hangisi doğru olur?

A) Enerji transferi A'dan B'ye doğru gerçekleşir, çünkü A'nın öz ısısı B'nin öz ısısından büyüktür.

B) Enerji transferi A'dan B'ye doğru gerçekleşir, çünkü A'nın ısı sığası B'ninkinden büyüktür.

C) Enerji transferi A'dan B'ye doğru gerçekleşir, çünkü kütle, özısı ve sıcaklık çarpımı A'da B'dekinden fazladır.

D) Enerji transferi gerçekleşmez, çünkü A ve B'nin kütleleri eşittir.

E) Enerji transferi gerçekleşmez, çünkü A ve B'nin sıcaklıkları eşittir.

32. B ve C maddeleri birbirine temas ettirilirse **enerji transferi** ile ilgili aşağıda verilen ifadelerden hangisi doğru olur?

A) Enerji transferi B'den C'ye doğru gerçekleşir, çünkü B'nin kütlesi C'ninkinden büyüktür.

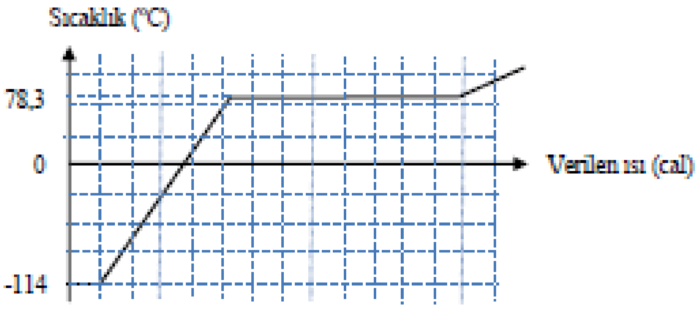
B) Enerji transferi B'den C'ye doğru gerçekleşir, çünkü B'nin sıcaklığı C'nin sıcaklığından yüksektir.

C) Enerji transferi B'den C'ye doğru gerçekleşir, çünkü kütle, öz ısı ve sıcaklık çarpımı B'de C'dekinden fazladır.

D) Enerji transferi C'den B'ye doğru gerçekleşir, çünkü C'nin öz ısısı B'ninkinden büyüktür.

E) Enerji transferi gerçekleşmez, çünkü B ve C'nin ısı sığaları eşittir.

33. Aşağıdaki grafikte, başlangıçta tamamı katı olan bir miktar etil alkolün hal değişim grafiği verilmiştir.



Grafiği inceleyen bir öğrenci şu çıkarımları yapar:

1. Etil alkol -115°C sıcaklıkta katı halde bulunur.
2. Tamamen sıvı hale geçen etil alkolün kaynama sıcaklığına getirilmesi için verilen ısı miktarı tamamen buharlaşması için verilen ısıdan daha fazladır.
3. Etil alkolün buharlaşma ısısı erime ısısından çok daha fazladır.
4. Laboratuarımızdaki soğutucuların en düşük sıcaklığı -20 °C, bu yüzden etil alkolü katılaştıramayız.

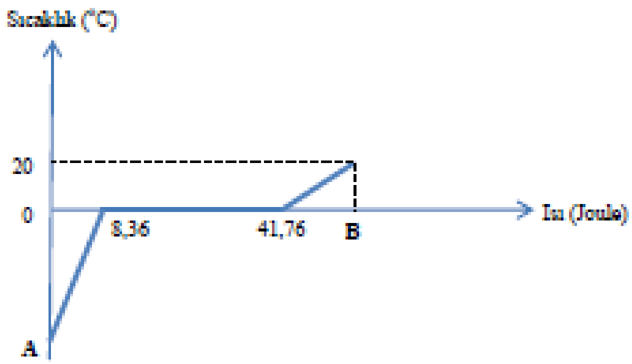
Öğrencinin yaptığı çıkarımlardan **<u>hangisi ya da hangileri doğrudur</u>**?

A) 1 ve 2 **B)** 1 ve 4 **C)** 2 ve 4 **D)** 1, 3 ve 4 **E)** 1, 2, 3 ve 4

Bölüm 5.

Bu bölüm **<u>1 açık uçlu</u>** sorudan oluşmaktadır. Soruları dikkatlice okuyarak istenilen cevabı gerekçelerini yazarak vermeniz gerekmektedir. Her bir sorunun cevabı altında bırakılan boşluğa yazılmalıdır.

34. 100 g buzun hal değişim grafiği aşağıda verilmiştir. Bu grafiğe göre aşağıdaki soruları cevaplayınız.



c_{buz} = 2,09 kJ/(kg °C)

c_{su} = 4,18 kJ/(kg °C)

L_{erime} = 334 kJ/kg

$L_{buharlaşma}$ = 2260 kJ/kg

a. Grafikte "**A**" ile gösterilen sıcaklık değeri kaç °C'dur?

b. Grafikte "**B**" ile gösterilen ısı değeri kaç Joule'dür?

c. Grafiği verilen 100 g buzun tamamen buharlaşması için gereken enerji kaç Joule'dür?
(**Hatırlatma**: Buzun ilk sıcaklığı A ile gösterilmiştir.)

d. 100 g buzun tamamen su buharına dönüştüğünü gösteren sıcaklık-ısı grafiğini çiziniz.
(**Hatırlatma**: Grafik üzerinde sıcaklık ve ısı değerlerini göstermeyi unutmayınız.)

APPENDIX F

ANSWER KEY FOR THE HTAT

1. Bölüm D/Y (Toplam 20 puan) : Her tam doğru cevap 2 puandır.

		Açıklama	Puan
1.	D		0
	Y	*(Açıklama yazılmamış.)*	1
	Y	Sıcaklık ve ısı, ikisi farklı kavramlardır.	1
	Y	**Isı, sıcaklık farkından dolayı aktarılan enerjidir.**	**2**
2.	D		0
	Y	*(Açıklama yazılmamış.)*	1
	Y	**Çünkü bir maddenin ısısından bahsedilemez.**	**2**
	Y	**Çünkü maddenin sıcaklığı vardır, ısısı yoktur.**	**2**
	Y	**Sıcaklığı daha azdır.**	**2**
3.	**D**		**2**
4.	D		0
	Y	*(Açıklama yazılmamış.)*	1
	Y	Isısı değil sıcaklığı artar.	1
	Y	**Maddenin ısısı yoktur. / Isı maddenin bir özelliği değildir.**	**2**
5.	D		0
	Y	*(Açıklama yazılmamış.)*	1
	Y	Sıcaklığı artmayabilir.	1
	Y	**İç enerji, moleküler düzeyde kinetik enerjiyi arttırmıyorsa maddenin sıcaklığı artmaz.**	**2**
6.	D		0
	Y	*(Açıklama yazılmamış.)*	1
	Y	**Sıcaklık, bir maddenin ortalama kinetik enerjisinin bir ölçüsüdür/göstergesidir.**	**2**
7.	**D**		**2**
8.	**D**		**2**
9.	**D**		**2**
10.	D		0
	Y	*(Açıklama yazılmamış.)*	1
	Y	Kinetik enerji artmadığı için iç enerjisi artmaz.	1
	Y	**İç enerji yükseklikle alakalı değildir.**	**2**

Y	**Çünkü moleküler düzeyde bir hareket yapılmamıştır.**	**2**

2. Bölüm Kısa Cevap Soruları (Toplam 25 puan)

11.	Özısısı yüksek olan antifrizi kullanırız.	1
	Özısısı yüksek olan antifrizi kullanırız. Çünkü daha zor ısınıp daha geç ısı verir.	**3**
12.	Özısı	1
	Özısı. Çünkü suyun özısısı cıva ve etil alkolden fazla olduğundan sıcaklık değişiminin gerçekleşmesi için daha fazla enerji alışverişinin olması gerekir.	3
13.	Seramik zeminin *ısı (enerji) iletim hızının* parkedekine göre yüksek olması.	**3**
14.	Isı yalıtımı	0
	Giysiler arasında kalan hava enerji iletim hızı yavaş olduğu için ısı yalıtımı sağlar.	**3**
15.	Genleşme	**3**
16.	**a.** Fahrenheit	1
	b. 32 Fahrenheit	1
	c. 212 Fahrenheit	1
17.	**a.** İletim	1
	b. Konveksiyon	1
	c. Işıma	1
18.	Nem, iklim	**3**
19.	Sadece özkütle-sıcaklık grafiğini doğru çizme	2
	Sadece hacim-sıcaklık grafiğini doğru çizme	2
	İki grafiği de doğru çizme	**4**
20.	Kışın hava sıcaklığı düştüğü için deniz ve göllerin üzeri buzla kaplanır. Bütün göl donmadığı için buzun altında +4 derece su bulunur. Bu sayede suda yaşayan canlılar yaşamlarını devam ettirir.	**3**

3. Bölüm (Toplam 7 puan): Her doğru cevap 1 puandır.

21.	**b**	**Konveksiyon**	Bir evin kaloriferle ısınması
22.	**a**	**İletim**	Yanan soba üzerindeki tencerenin ısınması
23.	**c**	**Işıma**	Kış mevsiminde güneşte kalan cisimlerin ısınması
24.	**a**	**İletim**	Sıcak çorbanın içinde kalan metal kaşığın elimizi yakması
25.	**c**	**Işıma**	Şöminede yanan ateşin yakın mesafedeki havayı ısıtması
26.	**c**	**Işıma**	Uzun süre kömürle ısıtılan ızgaranın, kömür döküldükten sonra çevreyi ısıtmaya devam etmesi
27.	**b**	**Konveksiyon**	Kaynayan suda yumurtanın pişmesi

4. Bölüm (Toplam 30 puan)

- **Herbir doğru cevap 5 puandır.**

28. E **29.** D **30.** E **31.** E **32.** B **33.** D

5. Bölüm Açık Uçlu Soru (Toplam 18 puan)

34. (18 puan)

a. (3 puan)

2000 cal = 100g x 0,5 cal/(g ^{o}C) x ΔT

2000 / 50 = (0 – T)

T= -40^{o}C

b. (4 puan)

Q = 100g x 1 cal/(g ^{o}C) x 20 ^{o}C = 2000 cal

B = 10000+2000 = 12000 cal

c. (5 puan)

1 cal = 4,18 J

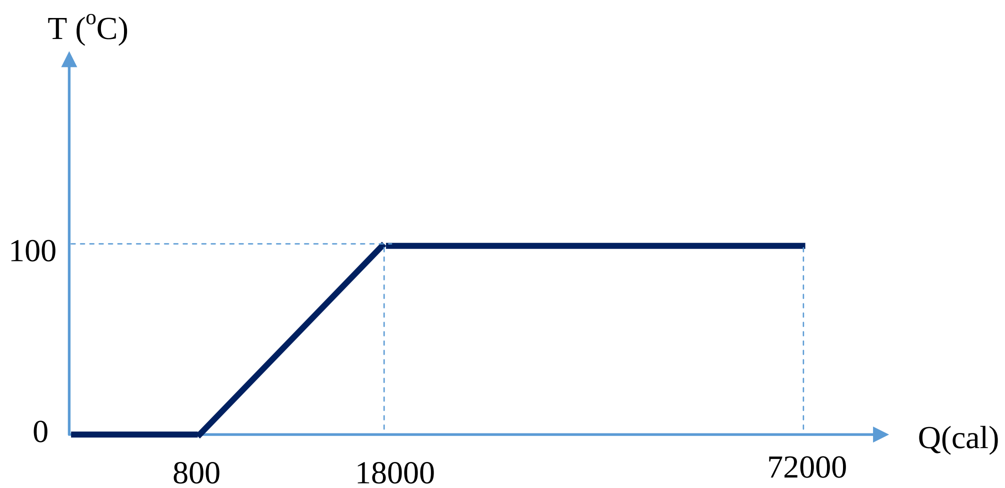
Buzun tamamen buharlaşması için gereken ısı: Grafikte buzun tamamen suya dönüştüğü değer 10000 cal enerji transferi gerçekleştiği zamandır. Bundan sonraki hesaplamaları yaparak sonuç bulunur.

Q = 100 x 1 x 100 = 10000 cal (kaynama noktasına gelen su)

Q= 100 x 540 = 54000 cal (tamamen buharlaması için gereken enerji)

Q total = 10000 + 10000 + 54000 = 74000 cal = 309320 J

d. (6 puan)



APPENDIX G

THE CLASSROOM OBSERVATION CHECKLIST

	Sınıfta öğretmen ve öğrenciler tarafından gösterilmesi gereken davranışlar	**E**	**H**
1	Öğrencilerin önbilgilerini ortaya çıkartmak için hatırlatıcı bilgi verildi.		
2	Öğrencilerin önbilgilerini kullanarak yeni konu ile ilgili tartışma sorularını tartışmaları sağlandı.		
3	Öğrencilerin önbilgileriyle yeni konu arasında bağlantı kuruldu.		
4	Öğretmen bilimsel kavramların birbirleriyle ilişki olduğunu vurguladı.		
5	**Öğretmen öğrencilerin ön bilgilerinin yeni bilgiyi öğrenirken anlamalarını kolaylaştırdığını örnekler vererek vurguladı.**		
6	**Öğretmen öğrencilerin bilgi yapılarında okulda öğrendikleri bilgilerin yanında sezgisel olarak oluşturdukları bilgilerinde öğrenmelerinde rol oynadığını vurguladı.**		
7	Öğrenciler deney veya gözlem yaparak bilgilerin mantığını sorguladılar.		
8	**Öğretmen herbir bilginin kim tarafından verilirse verilsin öğrencilerin kendileri tarafından doğruluğunun sorgulanması gerektiğini vurguladı.**		
9	Öğrenciler öğrendikleri bilgileri kullanarak örnek soru çözdü.		
10	Öğrenciler konu ile ilgili günlük hayat örneklerini inceledi.		
11	Öğretmen öğrencilerin sahip olduğu kavram yanılgılarını ortaya çıkardı.		
12	**Öğretmen kavram yanılgıları ve öğrenilen yeni bilgiler arasındaki çelişkilere dikkat çekti.**		
13	Öğrenciler bilim tarihinden örnekleri inceleyerek bilimsel bilginin gelişerek değişmesi ile ilgili çıkarımlar yaptı.		
14	Öğrenciler bilim tarihinden örnekleri inceleyerek bilimsel bilginin çürütülerek değişmesi ile ilgili çıkarımlar yaptı.		

15	**Öğretmen bilim tarihinde olduğu gibi kendi bilgilerimizin de gelişebileceği ya da değişebileceğini vurguladı.**		
16	Öğretmen öğrencilerin sahip olduğu kavram yanılgılarını değiştirmeye yönelik etkinlikler yaptı.		
17	Öğrenciler deney ve gözlem yaparak konu ile ilgili sorulara cevap vermeye çalıştılar.		
18	Öğrenciler bilim tarihinden örnekler inceleyerek bilimsel bilginin kabul görmesi için geçen süreci inceledi.		
19	**Öğretmen, öğrenme sürecinde öğrencilerin de bilginin doğruluğunu farklı yöntemler kullanarak test edebileceklerini vurguladı.**		
20	Öğrencilerin sahip oldukları bilgiler ile yeni bilgi arasında oluşan çelişkileri gidermeleri için ortam sağlandı. (tartışma, deney, gözlem, mantık yürütme)		
21	**Öğretmen öğrencilerin sahip oldukları bilgilerin sorgulayarak ve deliller arayarak değişebileceğini vurguladı.**		
22	**Öğretmen öğrencilerin fizik bilgisini öğrenirken çaba göstermeleri gerektiğini vurguladı.**		
23	Öğretmen öğrencinin başarabildiğini göstermek için kolaydan zora doğru farklı seviyelerde soru sordu.		
24	**Öğretmen öğrencilere farklı seviyelerde sorular çözebildiklerini gösterip öğrencinin fizik dersinde başarılı olabileceğini vurguladı.**		
25	**Öğretmen öğrenmenin zaman alan bir süreç olduğunu vurguladı.**		
26	Öğretmen formüllerin kavramlar arası ilişkileri göstermek için kullanılan matematiksel modeller olduğunu vurguladı.		

APPENDIX H

THE PHYSICS RELATED PERSONAL EPISTEMOLOGY QUESTIONNAIRE (PPEQ) - FIRST VERSION

Fiziği Nasıl Öğreniyorum?

Okulunuz:________________________ Sınıf/Şube:_____/___ Yaş:______ Cinsiyet:______ Aşağıda fiziği öğrenme süreciniz ile ilgili düşüncelerinizi belirlemek için bazı ifadeler yer almaktadır. Her cümlenin karşısında "*Kesinlikle Katılmıyorum*", "*Katılmıyorum*", "*Kararsızım*", "*Katılıyorum*" ve "*Kesinlikle Katılıyorum*" olmak üzere beş seçenek verilmiştir. Lütfen her maddeyi dikkatle okuyunuz ve size uygun olan tek bir yanıtı "X" ile işaretleyiniz. Unutmayın ***Doğru***ya da ***Yanlış*** cevap yoktur. **Araştırmanın geçerliliği açısından cevaplarınızın eksiksiz olması gereklidir.** Bilimsel bir çalışmaya katkıda bulunduğunuz için teşekkür ederiz.	Kesinliklekat ılmıyorum	Kat ılmıyorum	Kararsızım	Kat ılıyorum	Kesinlikle kat ılıyorum
A01. Fizik dersindeki farklı konularda öğrendiğim bilgilerinbirbirleriyle ilişkisini**kurmam**.	☐	☐	☐	☐	☐
A02. Fizik dersinde yeni bilgileri **sahip olduğum bilgilerle**ilişkilendirerek öğrenirim.	☐	☐	☐	☐	☐
A03. Fizik dersinde bir konuyu anlayabilmem için **konuyla ilgili temel kavramları** anlamam gerekir.	☐	☐	☐	☐	☐
A04. Fizik dersinde öğrendiğim bilgiler **birbiriyle tutarlı** (uyumlu) olmak **zorunda değil**.	☐	☐	☐	☐	☐
A05. Fizik dersinde birkonuyu**önceden öğrendiğim bilgiler** sayesinde anlarım.	☐	☐	☐	☐	☐
A06. Fizik dersinde **karmaşık ya da üst düzeykonuları** anlayabilmem için temel kavramları anlamam gerekir.	☐	☐	☐	☐	☐
A07. Fizik dersinde bir konuyu anlayabilmem için **önceden öğrendiğim bilgilere**ihtiyacım yok.	☐	☐	☐	☐	☐
A08. Fizik dersinde yeni konuyla ilgili kavramları bildiklerimle **ilişkilendirerek**anlamlandırırım.	☐	☐	☐	☐	☐
A09. Fizik dersinde verilen bilgilerle önceden öğrendiğim bilgiler **uyumlu olmalıdır**.	☐	☐	☐	☐	☐
A10. Fizikteki bir konuyla ilgili sahip olduğum bilgiler arasında **birbirleriyle çelişen bilgiler** olabilir.	☐	☐	☐	☐	☐
B01. Fizik dersinde verilen bilgiler benim doğru bildiklerime **ters düşerse** bu bilgilerin mantığını sorgularım.	☐	☐	☐	☐	☐
B02. Fizik dersinde öğrendiğim bilgilerle **günlük hayattaki tecrübelerim** çelişirse sorgulamam, derste verilen bilgileri doğru kabul ederim.	☐	☐	☐	☐	☐
B03. Fizik dersinde verilen bilgilerin mantığını**kendi gözlemlerimle**test ederim.	☐	☐	☐	☐	☐
B04. Fizik dersinde verilen bilgilerin mantığını yapabileceğim **deneylerle** test ederim.	☐	☐	☐	☐	☐
B05. Fizik dersinde verilen bilgiler **önceki bildiklerimle çelişirse**, bu bilgilerin mantığını **sorgulamam.**	☐	☐	☐	☐	☐
B06. Fizik dersinde verilen bilgileri ancak üzerinde düşünürsem (sorgularsam)**kendim için anlamlı hale** getirebilirim.	☐	☐	☐	☐	☐
B07. Fizik dersinde verilen bilgiler doğru olabilir ancak bu bilgilerin benim bilgilerimle**uyumlu**(tutarlı) olup olmadığını sorgularım.	☐	☐	☐	☐	☐
B08. Fizikteki bilgiler **bilim insanları** tarafından keşfedilmiş olabilir, ama bize verilen bu bilgileri ancak üzerinde düşünürsem (sorgularsam)**kendi bilgim** haline getirebilirim.	☐	☐	☐	☐	☐
C01. Fizik dersinde mantığını anladığım bilgilerimi ne olursa olsun**değiştirmem.**	☐	☐	☐	☐	☐
C02. Fizik dersinde öğrendiğim bilgiler hiçbir zaman değişmeyecek fiziksel gerçeklerdir; bu yüzden kendi bilgilerim de **değişmeyecektir**.	☐	☐	☐	☐	☐
C03. Fizik ile ilgili şu an doğru olarak öğrendiklerim (yakın ya da uzak) gelecekte çürütülebilir; bu yüzden gerekirse kendi fizik bilgilerimi **değiştiririm**.	☐	☐	☐	☐	☐
C04. Mantıklı açıklamalarla desteklenen yeni bilgiler sunulursa önceki fizik bilgilerimi **değiştiririm**.	☐	☐	☐	☐	☐
C05. Fizik dersinde doğru olarak öğrendiğim ve mantığını kavradığım bilgilerin sonradan **değişeceğine inanmıyorum**.	☐	☐	☐	☐	☐
C06.Öğrendiğim yeni bilgiler sayesinde sahip olduğum fizik bilgisi **değişir ve gelişir**.	☐	☐	☐	☐	☐

Fiziği Nasıl Öğreniyorum? (devamı)

	Kesinlikle katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle katılıyorum
D01. Fizik dersinde verilen **formülleri** bilmem konuyu anlamam için yeterlidir; bu yüzden konuyla ilgili başka bir şey öğrenmem gerekmez.	☐	☐	☐	☐	☐
D02. Fizik dersinde verilen **formülleri** konuyu anlamak için değil **sadece** konu ile ilgili **sayısal soruları çözebilmek** için ezberlerim.	☐	☐	☐	☐	☐
D03. Fizik dersinde verilen **formüller sadece** konuyla ilgili sayısal soru çözerken matematiksel işlem yapmamı sağlar.	☐	☐	☐	☐	☐
D04. Fizik dersinde verilen **formüller**, konuyla ilgili kavramların arasındaki ilişkileri gösterir.	☐	☐	☐	☐	☐
D05. Fizik dersinde verilen **formülleri** ezberlemem gerekmez, çünkü kavramlar arasındaki ilişkileri bildiğim zaman formülleri kendim bulabilirim.	☐	☐	☐	☐	☐
E01. Yeterince zaman ayırıp çalıştığımda fizik dersinde verilen bilgilerin mantığını anlayabilirim.	☐	☐	☐	☐	☐
E02. Fizik dersinde bir **konunun mantığını anlamam** için çok fazla düşünmem **gerekmez**, çünkü anlatılanları ilk seferde (hemen) anlarım.	☐	☐	☐	☐	☐
E03. Fizikte anlayamadığım bir konu üzerinde **tekrar tekrar düşünsem de** konunun mantığını anlayamam.	☐	☐	☐	☐	☐
E04. Fizik dersinde ilk seferde anlayamadığım bir konunun mantığını anlamak için **çaba gösteririm**.	☐	☐	☐	☐	☐
E05. Fizikteki bazı konuları anlayabilmem için **çaba göstermem gerekir**.	☐	☐	☐	☐	☐
E06. Fizik dersinde verilen bilgileri **ilk seferde** anlamayabilirim, bu fiziği anlamayacağım anlamına gelmez.	☐	☐	☐	☐	☐
F01. Fizik öğretmenimin anlattıklarını sorgulamadan kabul ederim.	☐	☐	☐	☐	☐
F02. Fizik dersinde öğrendiğim bilgiler bilim insanları tarafından kabul edilmiş gerçeklerdir, bu bilgileri **sorgulamam gerekmez**.	☐	☐	☐	☐	☐
F03. Fiziği anlamamın sebebi fizik bilgisini **doğrudan veren bir öğretmene** sahip olmamdır.	☐	☐	☐	☐	☐
F04. Fiziği anlamamın sebebi fizik bilgisini **doğrudan veren bir ders kitabına** sahip olmamdır.	☐	☐	☐	☐	☐
F05. Fizik dersinde bir konuyla ilgili öğretmenimin verdiği bilgileri sorgulamama **gerek yoktur**.	☐	☐	☐	☐	☐
F06. Fizik dersinde **öğretmenimin verdiği bilgilerin mantığı** üzerinde düşünürüm ve tartışma ihtiyacı hissederim.	☐	☐	☐	☐	☐
F07. Derste kullandığımız **fizik kitabımızdaki bilgilerin mantığı** üzerinde düşünürüm ve tartışma ihtiyacı hissederim.	☐	☐	☐	☐	☐

APPENDIX I

THE PHYSICS RELATED PERSONAL EPISTEMOLOGY QUESTIONNAIRE (PPEQ) - REVISED VERSION

Fiziği Nasıl Öğreniyorum?

Adınız Soyadınız: ______________________________

Okulunuz: ____________________________________ **Sınıf/Şube:** _____/____

Yaşınız: ______ *Cinsiyetiniz:* ☐ Kız ☐ Erkek

Birinci dönem fizik dersinden aldığınız dönem sonu (karne) notu: ____/100

Aşağıda fiziği öğrenme sürecinizi ile ilgili düşüncelerinizi belirlemek için bazı ifadeler yer almaktadır. Lütfen her ifadeyi dikkatle okuyunuz ve size uygun olan tek bir yanıtı "X" ile işaretleyiniz. Unutmayın ***Doğru*** *ya da* ***Yanlış*** *cevap yoktur.* ***Araştırmanın geçerliliği açısından cevaplarınızın eksiksiz olması gereklidir.*** *Bilimsel bir çalışmaya katkıda bulunduğunuz için teşekkür ederim.* Kübra Eryurt (ODTÜ Eğitim Fakültesi)	Kesinlikle katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle katılıyorum
A01. Fizik dersindeki farklı konularda öğrendiğim bilgilerin birbirleriyle ilişkisini **kurmam**.	☐	☐	☐	☐	☐
A02. Fizik dersinde yeni bilgileri **sahip olduğum bilgilerle** ilişkilendirerek öğrenirim.	☐	☐	☐	☐	☐
A03. Fizik dersinde bir konuyu anlayabilmem için **konuyla ilgili temel kavramları** anlamam gerekir.	☐	☐	☐	☐	☐
A04. Fizik dersinde öğrendiğim bilgiler **birbiriyle tutarlı** (uyumlu) olmak **zorunda değil**.	☐	☐	☐	☐	☐
A05. Fizik dersinde bir konuyu **önceden öğrendiğim bilgiler** sayesinde anlarım.	☐	☐	☐	☐	☐
A06. Fizik dersinde **karmaşık ya da üst düzey konuları** anlayabilmem için temel kavramları anlamam gerekir.	☐	☐	☐	☐	☐
A07. Fizik dersinde bir konuyu anlayabilmem için **önceden öğrendiğim bilgilere** ihtiyacım yok.	☐	☐	☐	☐	☐
A08. Fizik dersinde yeni konuyla ilgili kavramları önceden öğrendiklerimle **ilişkilendirerek** anlamlı hale getiririm.	☐	☐	☐	☐	☐
A09. Fizik dersinde verilen bilgilerle önceden öğrendiğim bilgiler **uyumlu olmalıdır**.	☐	☐	☐	☐	☐
B01. Fizik dersinde verilen bilgiler benim doğru bildiklerime **ters düşerse** bu bilgilerin mantığını sorgularım.	☐	☐	☐	☐	☐
B02. Fizik dersinde verilen bilgiler **önceki bildiklerimle çelişirse**, bu bilgilerin mantığını **sorgulamam**.	☐	☐	☐	☐	☐
B03. Fizik dersinde verilen bilgileri ancak üzerinde düşünürsem (sorgularsam) **kendim için anlamlı hale** getirebilirim.	☐	☐	☐	☐	☐
B04. Fizik dersinde verilen bilgiler doğru olabilir ancak bu bilgilerin benim bilgilerimle **uyumlu** (tutarlı) olup olmadığını sorgularım.	☐	☐	☐	☐	☐
B05. Fizikteki bilgiler **bilim insanları** tarafından keşfedilmiş olabilir, ama bize verilen bu bilgileri ancak üzerinde düşünürsem (sorgularsam) **kendi bilgim** haline getirebilirim.	☐	☐	☐	☐	☐

Arka sayfaya geçiniz. →

Fiziği Nasıl Öğreniyorum? (devamı)	Kesinlikle katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle katılıyorum
C01. Fizik dersinde öğrendiğim bilgiler hiçbir zaman değişmeyecek fiziksel gerçeklerdir; bu yüzden kendi bilgilerim de **değişmeyecektir**.	☐	☐	☐	☐	☐
C02. Fizik ile ilgili şu an doğru olarak öğrendiklerim (yakın ya da uzak) gelecekte çürütülebilir; bu yüzden gerekirse kendi fizik bilgilerimi **değiştiririm**.	☐	☐	☐	☐	☐
C03. Mantıklı açıklamalarla desteklenen yeni bilgiler sunulursa önceki fizik bilgilerimi **değiştiririm**.	☐	☐	☐	☐	☐
C04. Fizik dersinde doğru olarak öğrendiğim ve mantığını kavradığım bilgilerin sonradan **değişeceğine inanmıyorum**.	☐	☐	☐	☐	☐
C05. Öğrendiğim yeni bilgiler sayesinde sahip olduğum fizik bilgisi **değişir ve gelişir**.	☐	☐	☐	☐	☐
D01. **Fizik öğretmenimin anlattıklarını** sorgulamadan kabul ederim.	☐	☐	☐	☐	☐
D02. Fizik dersinde öğrendiğim bilgiler bilim insanları tarafından kabul edilmiş gerçeklerdir, bu bilgileri **sorgulamam gerekmez**.	☐	☐	☐	☐	☐
D03. Fizik dersinde bir konuyla ilgili öğretmenimin verdiği bilgileri sorgulamama **gerek yok**.	☐	☐	☐	☐	☐
D04. Fizik dersinde **öğretmenimin verdiği bilgilerin mantığı** üzerinde düşünürüm ve tartışırım.	☐	☐	☐	☐	☐
E01. **Yeterince zaman ayırıp çalıştığımda** fizik dersinde verilen bilgilerin mantığını anlayabilirim.	☐	☐	☐	☐	☐
E02. Fizikte anlayamadığım bir konu üzerinde **tekrar tekrar düşünsem de** konunun mantığını anlayamam.	☐	☐	☐	☐	☐
E03. Fizik dersinde ilk seferde anlayamadığım bir konunun mantığını anlamak için **çaba sarf ederim**.	☐	☐	☐	☐	☐
E04. Fizik dersinde verilen bilgileri **ilk seferde** anlamayabilirim, bu fiziği anlamayacağım **anlamına gelmez**.	☐	☐	☐	☐	☐

Anketi doldurduğunuz için teşekkür ederim. ☺

APPENDIX J

RECODING ITEMS FOR REVISED AND FINAL VERSION OF THE PPEQ

Initial Version			Revised Version			Final Version
Factor	Item	EFA Decision	Factor	Item	CFA Decision	Item
SK	ITEMA01	Remained	SKH	ITEMA01	Remained	ITEMA01
SK	ITEMA02	Remained	SKH	ITEMA02	Remained	ITEMA02
SK	ITEMA03	Remained	SKC	ITEMA03	Remained	ITEMA03
SK	ITEMA04	Remained	SKC	ITEMA04	Remained	ITEMA04
SK	ITEMA05	Remained	SKH	ITEMA05	Remained	ITEMA05
SK	ITEMA06	Remained	SKC	ITEMA06	Remained	ITEMA06
SK	ITEMA07	Remained	SKC	ITEMA07	Remained	ITEMA07
SK	ITEMA08	Remained	SKH	ITEMA08	Remained	ITEMA08
SK	ITEMA09	Remained	SKC	ITEMA09	Remained	ITEMA09
SK	ITEMA10	Deleted				
JK	ITEMB01	Remained	JK	ITEMB01	Remained	ITEMB01
JK	ITEMB02	Deleted				
JK	ITEMB03	Deleted				
JK	ITEMB04	Deleted				
JK	ITEMB05	Remained	JK	ITEMB02	Remained	ITEMB02
JK	ITEMB06	Remained	JK	ITEMB03	Remained	ITEMB03
JK	ITEMB07	Remained	JK	ITEMB04	Remained	ITEMB04
JK	ITEMB08	Remained	JK	ITEMB05	Remained	ITEMB05

Initial Version			Revised Version			Final Version
Factor	Item	EFA Decision	Factor	Item	CFA Decision	Item
CK	ITEMC01	Deleted				
CK	ITEMC02	Remained	CK	ITEMC01	Deleted	
CK	ITEMC03	Remained	CK	ITEMC02	Remained	ITEMC01
CK	ITEMC04	Remained	CK	ITEMC03	Remained	ITEMC02
CK	ITEMC05	Remained	CK	ITEMC04	Remained	ITEMC03
CK	ITEMC06	Remained	CK	ITEMC05	Remained	ITEMC04
EQ	ITEMD01	Deleted				
EQ	ITEMD02	Deleted				
EQ	ITEMD03	Deleted				
EQ	ITEMD04	Deleted				
EQ	ITEMD05	Deleted				
QL	ITEME01	Remained	QL	ITEME01	Remained	ITEME01
QL	ITEME02	Deleted				
QL	ITEME03	Remained	QL	ITEME02	Remained	ITEME02
QL	ITEME04	Remained	QL	ITEME03	Remained	ITEME03
QL	ITEME05	Deleted				
QL	ITEME06	Remained	QL	ITEME04		ITEME04
Source	ITEMF01	Remained	Source	ITEMD01	Remained	ITEMD01
Source	ITEMF02	Remained	Source	ITEMD02	Remained	ITEMD02
Source	ITEMF03	Deleted				
Source	ITEMF04	Deleted				
Source	ITEMF05	Remained	Source	ITEMD03	Remained	ITEMD03
Source	ITEMF06	Remained	Source	ITEMD04	Remained	ITEMD04
Source	ITEMF07	Deleted				

APPENDIX K

GOODNESS-OF-FIT CRITERIA FOR THE PPEQ

AMOS OUTPUT: Model Fit Summary
CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	89	443.856	262	.000	1.694
Saturated model	351	.000	0		
Independence model	26	3777.880	325	.000	11.624

RMR, GFI

Model	RMR	GFI	AGFI	PGFI
Default model	.049	.912	.882	.681
Saturated model	.000	1.000		
Independence model	.341	.281	.224	.260

Standardized RMR= .0435

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.883	.854	.948	.935	.947
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

Non-normed fit (NNFI) = .935

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.806	.711	.764
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

NCP

Model	NCP	LO 90	HI 90
Default model	181.856	127.571	244.021
Saturated model	.000	.000	.000
Independence model	3452.880	3258.665	3654.419

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	1.290	.529	.371	.709
Saturated model	.000	.000	.000	.000
Independence model	10.982	10.037	9.473	10.623

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.045	.038	.052	.877
Independence model	.176	.171	.181	.000

AIC

Model	AIC	BCC	BIC	CAIC
Default model	621.856	637.017	963.932	1052.932
Saturated model	702.000	761.792	2051.084	2402.084
Independence model	3829.880	3834.309	3929.812	3955.812

ECVI

Model	ECVI	LO 90	HI 90	MECVI
Default model	1.808	1.650	1.988	1.852
Saturated model	2.041	2.041	2.041	2.215
Independence model	11.133	10.569	11.719	11.146

HOELTER

Model	HOELTER .05	HOELTER .01
Default model	234	247
Independence model	34	36

APPENDIX L

ETHICAL PERMISSION

O.D.T.Ü
FEN BİLİMLERİ ENSTİTÜSÜ
YÖNETİM KURULU KARARI

Tarih: 30.01.2014
Sayı: FBE: 2014/ 12

GÖREVLENDİRME VE İZİN

Ortaöğretim Fen ve Matematik Alanları Eğitimi EABD doktora programı öğrencisi Kübra Eryurt'un 10 Şubat-13 Haziran 2014 tarihleri arasında "*Epistemolojik olarak zenginleştirilmiş öğretim yönteminin 9. sınıf öğrencilerinin ısı ve sıcaklık konusuyla ilgili başarılarına, kişisel epistemolojilerine ve bilim doğasını anlamalarına etkisi* " başlıklı araştırmasına ilişkin hazırlanan anketi, ekli etik komite başvuru formunda belirtilen okullarda uygulama yapmak için görevlendirilme başvurusu incelenmiş; ilgili danışman görüşüne dayanarak adı geçen öğrencinin isteği doğrultusunda görevlendirilmesine oybirliği ile karar verilmiştir.

Prof. Dr. Canan Özgen *FBE Müdürü*	**Prof. Dr. Gürsevil Turan** *FBE Müd. Yard.*	**Prof. Dr. Gülbin Dural** *FBE Müd. Yard.*
Prof.Dr. Ayşen Savaş *Üye*	**Prof. Dr. İnci Batmaz** *Üye*	**Prof. Dr. Serkan Dağ** *Üye*

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

ÖĞ... Cİ İŞLE...
DA... ...KAN...
Ev. ...

Sayı : 14588481/605.99/764046 — 20/02/2014
Konu: Araştırma izni

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2012/13 nolu Genelgesi.
b) 05/02/2014 tarih ve 1485 sayılı yazınız.

Üniversiteniz Ortaöğretim Fen ve Matematik Alanları Eğitimi Anabilim Dalı Doktora Öğrencisi Kübra ERYURT' un **"Epistemolojik olarak zenginleştirilmiş öğretim yönteminin 9. sınıf öğrencilerinin ısı ve sıcaklık konusuyla ilgili başarılarına, kişisel epistemolojilerine ve bilim doğasını anlamalarına etkisi"** konulu tezi kapsamında çalışma yapma talebi Müdürlüğümüzce uygun görülmüş ve araştırmanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Anket formlarının (18 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde iki örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme Bölümüne gönderilmesini arz ederim.

Hakan GÖNEN
Müdür a.
Şube Müdürü

Güvenli Elektronik İmza
Aslı İle Aynıdır.
20/02/2014

Mehmet ÖZDEMİR

24-02-2014-3574

Bu belge, 5070 sayılı Elektronik İmza Kanununun 5 inci maddesi gereğince güvenli elektronik imza ile imzalanmıştır
Evrak teyidi http://evraksorgu.meb.gov.tr adresinden 8678-7efe-365f-8213-5267 kodu ile yapılabilir.

Konya yolu Başkent Öğretmen Evi arkası Beşevler ANKARA
e-posta: istatistik06@meb.gov.tr

Ayrıntılı bilgi için: Emine KONUK
Tel: (0 312) 221 02 17/135

APPENDIX M

SAMPLE CONSENT FORM

Sevgili Öğrenci,

Bu çalışmada, sizin fizik bilginizi ve fiziği öğrenme sürecinde etkin olan düşüncelerinizi ortaya çıkarmak ve geliştirmek hedeflenmektedir. Fizik dersi içeriğinde (anlatılması gereken konularda) herhangi bir değişiklik olmayacaktır. Çalışma, *Isı ve Sıcaklık* Ünitesi boyunca yaklaşık 7 hafta sürecektir.

Bu çalışmadan elde edilecek bilgiler sadece araştırmacı tarafından değerlendirilecektir. **Verdiğiniz bilgiler kesinlikle gizli tutulacak ve sadece bilimsel araştırma amacıyla kullanılacaktır.** Çalışma sırasında uygulanacak testler ve ölçekler kişisel rahatsızlık verecek sorular içermemektedir. Ancak, çalışmaya katılımınızda uygulanan testlerden ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz çalışmayı yarıda bırakabilirsiniz. Bu formu imzaladıktan sonra istediğiniz zaman herhangi bir yaptırıma maruz kalmadan çalışmadan ayrılma hakkına sahipsiniz. Çalışmadan ayrıldığınız takdirde sizden elde edilen veriler hiçbir şekilde çalışmada kullanılmayacaktır.

Çalışmaya katılarak bize sağlayacağınız bilgiler, lise öğrencilerinin fiziği öğrenmesinde etkili olan inanışlarını ve düşüncelerini şekillendirerek daha etkili bir öğrenme ortamı oluşturulmasına katkıda bulunacaktır.

Bu çalışmaya katıldığınız için şimdiden teşekkür ederim. Araştırmayla ilgili sorularınız aşağıdaki e-posta adresini veya telefon numarasını kullanarak bana yöneltebilirsiniz.

Saygılarımla,

Kübra Eryurt

Araştırma Görevlisi ve Doktora Öğrencisi
Orta Doğu Teknik Üniversitesi, Eğitim Fakültesi
Ortaöğretim Fen ve Matematik Alanları Eğitimi Bölümü
Tel: (0312) 210 6489
E-posta: keryurt@metu.edu.tr

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayınlarda kullanılmasını kabul ediyorum. (Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

Ad Soyad	**Tarih**	**İmza**
	---- / ---- /------	

APPENDIX N

TEACHER'S GUIDEBOOK

Introduction

1. Conceptually, we modified the sequence of the lecture. We didn't follow the conceptual sequence in 9th grade physics textbook and curriculum objectives.

2. By rearranging the objectives, we tried to create a coherent structure of physics knowledge in which students can link concepts easily with their previous knowledge. Our aim is to assist students to create more coherent structure for their own knowledge system. Therefore, all lesson plans are implicitly focusing on structure of knowledge dimension.

3. In this document, we only present explicitly epistemologically enriched instructions' lesson plans.

4. You can reach detailed lesson plans starting from page 14.

Outline of Lectures

Lesson Plan-1: Heat, Temperature and Internal Energy (2 Lecture Hours)

Specific Objectives:

Define heat, temperature and internal energy.

Relate heat, temperature and internal energy with each other.

Reflecting thoughts about previous knowledge: "What do I know?"

Includes also epistemological questions indicating "how is it related to future learning"

Focused Epistemological Dimension – Structure of Knowledge

Motto: "*I relate new knowledge with my previous knowledge coherently.*"

Detecting prior knowledge: For what, do you use heat and temperature concepts?

Transition to energy concept at molecular level from macroworld

Kinetic and potential energy of an object → what's happening in molecular level?

Average kinetic energy and average potential energy

Transition to temperature concept from kinetic energy in molecular level

Transition to heat concept from temperature concept

"Does temperature flow from one matter to another?"

Relating internal energy, temperature and heat concepts with each other.

Epistemological Discussion – Structure of Knowledge

Teacher's talk

Reflecting thoughts about acquired new knowledge: "What did I learn?"

Lesson Plan-2: Thermal Equilibrium (1 Lecture Hour)

Specific Objectives:

Explain the relationship among thermal equilibrium, temperature difference and heat concepts by using related simulations and demonstrations.

Reflecting thoughts about previous knowledge and experience: "What do I know?"

Includes also epistemological questions indicating "how is it related to future learning"

Focused Epistemological Dimension – Justification of Knowledge

Motto: "*I inquire/question new knowledge with different activities such as experimenting, observing to question its rationality.*"

Detecting prior knowledge: Does temperature flow?

Transition to thermal equilibrium concept from heat concept.

Experiment: When does energy flow between two system ends?

Testing new knowledge: Is this simulation working correctly?

Epistemological Discussion – Structure of Knowledge and Justification of knowledge

Lesson Plan-3: Thermal Expansion (1 Lecture Hour)

Specific Objectives:

Compare thermal expansion and contraction phenomena for solids, liquids and gases.

Give examples about effects of thermal expansion in daily life.

Interpret volume-temperature and density-temperature graphs of water.

Explain effects of water's unique expansion characteristics on daily life.

Focused Epistemological Dimension – Justification and Structure of Knowledge

Motto:"I can reach new knowledge by rational thought. I can examine differences and irrational ideas by using my mind tools."

Transition to thermal expansion concept for liquids

Detecting difference: Discussion of water's behavior at $+4^{o}C$

Transition to solids' thermal expansion

Transition to gases' thermal expansion

Epistemological Discussion – Structure of Knowledge and Justification of knowledge

Teacher's talk

Reflecting thoughts about new knowledge: "What did I learn?"

Lesson Plan-4: Types of Thermometers and Temperature Units (2 Lecture Hours)

Specific Objectives:

Compare thermometer types according to their aim of usage.

Compare different temperature units.

Explain why different temperature units were emerged.

Focused Epistemological Dimension – Changeability of Knowledge

Motto:"My knowledge changes when I relate new knowledge with previous ones."

Reflecting thoughts about previous knowledge: "What do I know?"

Introducing types of thermometers

Liquid, solid and gas thermometers (and some more)

Transition to scaling thermometers and temperature units.

Reading (from history of science): When did an instrument use to gauge temperature?: Thermometers

Fahrenheit, Celsius and Kelvin

Answering questions about reading

Epistemological Discussion – Changeability of Knowledge

Teacher's talk

Reflecting thoughts about new knowledge: "Let's Think!"

Lesson Plan-5: Conversion of Temperature and Heat Units (2 Lecture Hours)

Specific Objectives:

Explain why different heat units were emerged.

Make conversion of heat units (calorie and joule) and temperature units (^{o}C, ^{o}F, K).

Focused Epistemological Dimension – Fixed Ability and Quick Learning

Motto: "I don't have to be a genius to understand physics. As long as I put effort to relate new knowledge with old ones, I can learn progressively."

Focused Epistemological Dimension – Changeability of Knowledge

Motto: "I can develop intuitive ideas. By learning physics, I can replace (change) my knowledge with scientific knowledge."

Reflecting thoughts about previous knowledge: "What do I know?"

Epistemological Discussion – Fixed Ability and Quick Learning

Transition to conversion of temperature units (Celcius, Fahrenheit and Kelvin)

Solving problems related with conversions

Teacher's talk (shortly about learning process)

Transition to historical development of heat concept

Reading (from history of science): Historical development of heat concept

Epistemological Discussion – Justification of Knowledge

Teacher's talk

Epistemological Discussion – Changeability of Knowledge

Teacher's talk

Transition to conversion of heat units (Calorie and Joule)

Lesson Plan-6: Specific Heat and $Q=m \times c \times \Delta T$ (3 Lecture Hours)

Specific Objectives:

Explain specific heat concept.

Give examples of temperature change effects for matters with different specific heat in daily life.

Explain heat capacity concept.

Focused Epistemological Dimension – Justification of Knowledge

Motto: "I can generate formula by conducting controlled experiments. I use formulas to understand relationship among different concepts."

Epistemological Discussion – Structure of Knowledge

Transition to relation between heat and temperature difference

Which formula is correct? $\Delta Q = mc\Delta T$ or $Q = mc\Delta T$?

Experiment:

a. What is the relationship between heat and temperature difference?

b. Is the $Q/\Delta T$ proportion same for different materials?

c. Is the $Q/\Delta T$ proportion same for different masses of same matter?

Wrapping the findings of three parts of the experiment

Emphasis on justification by experiment and rational thought

Transition to detailed investigation of specific heat concept

Transition to heat capacity concept

Epistemological Discussion – Justification of Knowledge and Structure of Knowledge

Teacher's talk

Öğrencilere empoze edeceğimiz epistemolojik düşünceler:

1. Kendi fizik bilgilerimi birbiriyle ilişkilendirdiğimde mantıklı bir bilgi yapısı oluştururum.

2. Önbilgilerim ya da önceki tecrübelerim yeni bilgileri anlamamda etkili olur.

3. Yeni bilgilerin mantığını, sahip olduğum bilgileri kullanarak rasyonel düşünceyle (mantık yürüterek) sorgularım.

4. Yeni bilgiler sahip olduğum bilgilerle çeliştiğinde (tutarsızlık gösterdiğinde) fark ederim.

5. Yeni bilgiler sahip olduğum bilgilerle çeliştiğinde bu bilgiyi farklı yollarla (deney ve gözlemlerle) test ederim.

6. Fizikte kullanılan matematiksel formüller aslında fizikteki kavramlar arasındaki ilişkileri göstermenin kısa yoludur.

7. Fizikteki kavramların birbirleriyle ilişkilerini bildiğimde matematiksel formüllerini kendim çıkarabilirim.

8. Yeni bilgileri bildiklerimle ilişkilendirdiğimde fizik bilgim anlamlı bir şekilde gelişir.

9. Yanlış olarak öğrendiğim ya da tecrübelerimden edindiğim bilgiler mantıklı bilgiler sunulduğunda değiştiririm.

10. Fizik bilgilerim zamanla yeni bilgiler öğrenerek geliştiririm.

11. Çaba gösterdiğim zaman fizik bilgilerini anlarım.

12. Fizik bilgilerim günlük hayatta karşılaştığım olaylarda da geçerlidir, yani tutarlıdır.

13. Kendi fizik bilgimi kendim oluştururum.

14. Fiziği öğrenirken kavramlar arası bağlantılar kurmam fiziği anlamamı kolaylaştırır.

Epistemolojik Olarak Zenginleştirilmiş Öğretim Yöntemi ile ilgili Ders Planları

Bu dosya uygulama yapacak öğretmenin kılavuz kitapçığıdır. Epistemolojik olarak zenginleştirilmiş öğretim yöntemi uygulanacak sınıflarda dersin nasıl ilerleyeceği hakkında bilgi vermektedir. Ders planları 2013 yılında kabul edilen *Ortaöğretim Fizik Dersi Öğretim Programı*'nda verilen kazanımlara uygun bir şekilde geliştirilmiştir. Seçilen konu 9. sınıf *Isı ve Sıcaklık* konusudur. Aşağıdaki tabloda ders planlarının hangi kazanımlarla eşleştiği verilmiştir. Haftalık planların süreleri öğretmen tarafından değiştirilebilir.

Hafta	**Süre /Saat**	**Ders Planı**	**Konu Başlığı**	**Kazanım**
1	2	1	Isı, Sıcaklık ve Enerji	9.5.1.1. Isı, sıcaklık ve iç enerji kavramlarını tanımlar ve birbirleriyle ilişkilendirir.
2	1	2	Isıl denge	9.5.3.1. Isıl denge kavramının sıcaklık farkı ve ısı kavramlarıyla olan ilişkisini açıklar.
2	1	3	Genleşme	9.5.5.1. Katı, sıvı ve gazlarda genleşme ve büzülme olaylarını karşılaştırır. a. Öğrencilerin günlük hayattaki olayları inceleyerek genleşmenin etkilerini karşılaştırmaları sağlanır. b. Öğrencilerin suyun diğer maddelerden farklılık gösteren sıcaklık-hacim ve sıcaklık-özkütle grafiklerini yorumlamaları ve günlük hayattaki etkilerini tartışmaları sağlanır.
3	2	4	Termometre Çeşitleri ve sıcaklık birimleri	9.5.1.2.a Kullanım amaçlarına göre termometre çeşitlerini karşılaştırarak sunar. 9.5.1.2.b. Kullanım amaçlarına göre sıcaklık birimlerini karşılaştırarak sunar. 9.5.1.3.b. Farklı sıcaklık birimlerinin ortaya çıkış nedenlerini açıklar.
4	2	5	Isı Birimleri	9.5.1.3.a. Farklı ısı birimlerinin ortaya çıkış nedenlerini açıklar. 9.5.1.3.c. Isı (Kalori ve Joule) ve sıcaklık (^{o}C, ^{o}F, K) için birim dönüşümleri yapılır.
5	2	6	Öz ısı ve Isı Sığası	9.5.1.4. Öz ısı ve ısı sığası kavramlarını açıklar. a. Öz ısının maddeler için ayırt edici bir özellik olduğu vurgulanır. b. Öğrencilerin farklı maddelerin öz ısılarını ısı-sıcaklık grafiklerinden hesaplamaları sağlanır. c. Öğrencilerin öz ısıları farklı maddelerin sıcaklık değişimlerinin günlük hayattaki etkileri ile ilgili örnekler vermeleri sağlanır.

Hafta	**Süre /Saat**	**Ders Planı**	**Konu Başlığı**	**Kazanım**
6	3	7	Hal Değişimi	9.5.2.1. Ortamdan enerji alınması veya ortama enerji verilmesi ile hâl değişimi arasındaki ilişkiyi açıklar. a. Öğrencilerin donma, erime, kaynama ve yoğunlaşma kavramlarını enerji ile ilişkilendirmeleri sağlanır. b. Öğrenciler maddelerin sıcaklık ve hal değişimi için gerekli ısıyı hesaplar, ısı-sıcaklık grafiklerini çizer. c. Öğrencilerin ısı-sıcaklık grafiklerini çizmeleri ve yorumlamaları sağlanır.
7	2	8	Enerji İletimi	9.5.4.1. Enerji iletim yollarını açıklar. a. Öğrencilerin iletim, ışıma ve konveksiyon yolu ile enerji aktarımını en iyi gerçekleştiren katı, sıvı ve gazlara örnekler vermeleri sağlanır. b. Öğrencilerin enerji iletim yollarını kullanılarak geliştirilen uygulamalara örnekler vermeleri sağlanır. 9.5.4.2. Bir maddedeki enerji iletim hızını etkileyen değişkenleri açıklar. a. Öğrencilerin maddelerin enerji iletim hızını günlük hayat olayları ile ilişkilendirmeleri sağlanır.
Toplam	18 saat (Öğretim Programında ayrılan süre)			

DERS PLANI-1 (Isı, Sıcaklık ve İç Enerji)

Sınıf: 9

Ünite: Isı ve Sıcaklık

Süre: 1 saat

Konu: Isı, Sıcaklık ve İç Enerji

Kazanım:9.5.1.1. Isı, sıcaklık ve iç enerji kavramlarını tanımlar ve birbirleriyle

> **Epistemolojik tartışma sorusu: [Bilginin Yapısı]** Şimdiye kadar öğrendiklerinizin ve bildikleriniz ısı ve sıcaklık ünitesini anlamanızda nasıl bir rolü olacak?

ilişkilendirir.

Dersin başında "Neleri Biliyorum?" kâğıdı dağıtılır ve öğrencilerin cevaplamaları için 3-4 dakika verilir. Sonrasında epistemolojik tartışma sorusu yöneltilerek kısa süreli bir tartışma yaratılır. Öğretmen öğrenci cevaplarını irdeler.

Öğretmen aşağıdaki soruyu sınıfa yönelterek, öğrencilerin önbilgilerini ve kavramalarını ortaya çıkarır. Dersin sonunda bu soruya geri dönülecektir.

Ön bilgileri ortaya çıkartma: Günlük hayatta sıcaklık ve ısı kelimelerini hangi durumlarda ve ne için kullanırsınız?

Makro düzeyde (mekanik) enerjiden moleküler düzeyde enerjiye geçiş:

Tartışma Sorusu: "Masanın üstünde duran bir kitabın enerjisi ile ilgili olarak neler söyleyebiliriz?"

Bir önceki ünitede enerji türlerini kinetik ve potansiyel enerji olarak ikiye ayırmıştık. Kitap hareket etmediği için kinetik enerjisinden bahsedemeyiz. Konumundan dolayı potansiyel enerjisi vardır. Dışarıdan kitaba baktığımızda ancak böyle bir çıkarım yapabiliriz.

"Kitabın duruyor olması, kinetik enerjiye sahip olmadığının bir göstergesi midir?"

Makro düzeyde evet; mikro düzeyde ise hayır. Moleküler düzeyde, bir katı cismin moleküllerinin yaya benzer kuvvetlerle birbirine bağlı olduğu şeklinde modelleyebiliriz. Makro düzeyde hareketsiz olan cisim, moleküler düzeyde birbirlerine bağlı olan bu moleküller sürekli salınım hareketi yapar.

“Moleküler düzeyde bir katı cismin enerjisiyle ilgili olarak neler söyleyebiliriz?”

Bir maddenin içyapısını incelediğimizde atom ve moleküllerden meydana geldiğini söyleyebiliriz. Bu atom ve moleküller her zaman hareket halindedir. Bu hareketlilik atomların enerjiye sahip olduğunu gösterir. Hareket eden cisimlerin kinetik enerjisi olduğunu biliyoruz. Eğer bir cismin sürati artarsa, kinetik enerjisi de artar. Sürati azaldığında ise kinetik enerjisi azalır. O zaman bir maddenin atom ve moleküllerinin hızlı hareket etmesi, yavaş hareket ettikleri duruma göre kinetik enerjilerinin daha yüksek olduğu anlamına gelir.

Simülasyon gösterimi: ThermalExpansion-1.exe (katı haldeki bir maddenin atomlarının titreşimi gösterilir.)

Maddeler konumlarından dolayı kütle çekim potansiyel enerjiye sahip olduğunu biliyoruz. Örneğin, dalından kopan bir elma neden yere düşer? Çünkü elma ve dünya arasında kütle çekim kuvveti vardır. Moleküler düzeyde maddenin potansiyel enerjisi var mıdır? Aralarında çekme veya itme kuvveti bulunan atomların (elektrik) potansiyel enerjileri vardır. Katı maddeler, moleküller arası elektriksel çekimin yüksek olması sebebiyle şekillerini koruyabilirler.

Bir madde çok fazla sayıda atom ve molekülden meydana geldiği için tek bir atom ya da tek bir molekülün hareketiyle ilgilenemeyiz. Her bir atom ya da molekülün hareketinin toplam etkisi bize madde hakkında daha genel bilgi verir. Bu yüzden **ortalama** büyüklüklerden bahsetmek işimizi kolaylaştırır. Örneğin ortalama potansiyel enerji, ortalama kinetik enerji gibi.

Ortalama Kinetik Enerji: Her bir molekülün sahip olduğu kinetik enerjinin toplamının toplam molekül sayısına bölünmesiyle bulunur.

“Katılar moleküler düzeyde ortalama kinetik ve potansiyel enerjiye sahiplerse, sıvı ve gaz haldeki maddeler içinde bu geçerli midir? ”

Öğrencilerin tahminlerini ifade etmeleri için zaman verin.

Aynı maddenin sıvı hali için: katı hale göre moleküller arası bağlar daha zayıftır. Bu sayede moleküller birbirleri üzerinde hareket edebilir. Hem hareketleri hem de moleküller arası bağların varlığı sebebiyle kinetik ve potansiyel enerjiye sahiptir.

Aynı maddenin gaz hali için: moleküller arası bağlar katı ve sıvı hallerine göre oldukça zayıftır. Bu bağlarda depolanan potansiyel enerjinin çok düşük olduğunu ve gaz molekülerinin sahip oldukları kinetik enerjiyle rahatça moleküller arası bağları koparttıklarını söyleyebiliriz.

UYARI: Burada katı, sıvı ve gazların kinetik ve potansiyel enerjilerini karşılaştırmak gibi bir niyetimiz yok. Katı sıvıdan daha fazla potansiyele sahiptir gibi cümleler kullanmayalım.

Sonuç olarak **makro düzeyde** duran bir cismin ya da maddenin, **moleküler düzeyde** enerjiye sahip olduğu çıkarımını yapabiliriz. Aynı şekilde sıvı ve gaz halde bulunan maddeler de mikroskobik düzeyde potansiyel ve kinetik enerjiye sahiptirler. Moleküler düzeyde maddelerin sahip oldukları kinetik ve potansiyel enerji toplamına **İç Enerji** denir.

İç enerji mikroskobik düzeyde sistemin bütün enerjisidir. (Farklı hareketlerinden kaynaklanan) Öteleme, dönme ve titreşim kinetik enerjisi ve titreşim potansiyel enerjisi ve moleküller arası kuvvetten doğan elektrik potansiyel enerjiyi içerir. **Makro düzeyde bir hareketlilik buna dâhil değildir**. Kitap sürtünmesiz bir yer üzerinde hareket ettirilse bile iç enerjisini değiştirmez. Konumlarından dolayı cisimlerin sahip oldukları potansiyel enerjideki değişim de moleküler düzeyde iç enerjiyi değiştirmez.

Kinetik enerjiden sıcaklık kavramına geçiş:

Her bir maddeyi oluşturan atom ve moleküller farklılık gösterdiği gibi, bu atom ve moleküllerin hareketleri de birbirine göre farklıdır. Atomik ve moleküler hareketlilik **termal hareket** olarak tanımlanır. Termal hareket maddenin hangi halde bulunduğuna bağlıdır. Örneğin katılarda moleküller salınım yapar, sıvılarda moleküller birbiri üzerinden öteleme hareketi yapabilir. Gazlarda ise moleküller serbestçe hareket ederek sürekli birbirleriyle çarpışırlar.

Gösteri Deneyi 1 – Mürekkebin sudaki hareketi

Soru: Kaplarda bulunan farklı sıcaklıklardaki sulara birer damla mürekkep damlatırsak ne gözlemleriz? *(Öğrencilerin tahminleri tahtaya kısaca yazılabilir. Bu aşamada öğretmen doğru cevabı vermemelidir.)*

Gözlem: İki cam beher alınır ve farklı sıcaklıklarda su ile doldurulur. (Biri musluk suyu diğeri ısıtıcıyla bir süre ısıtılmış daha sıcak bir su olabilir.) Bu iki kaba birer damla mürekkep damlatılır ve mürekkebin iki kapta nasıl dağıldığı gözlemlenir.

Soru: Mürekkep sıcak suda daha hızlı dağılırken, soğuk suda yavaşça dağılır. Bu durumu nasıl açıklarız?

Açıklama: Farklı sıcaklıktaki su moleküllerinin farklı hızlara sahip olmasından dolayı farklılık gözlenir. Sıcak suda hareketlilik daha fazladır ve mürekkep hızla suya karışır. (Sıcak suda enerji aktarımı soğuk sudakine göre daha fazladır. Farklı bir derste buna tekrar değinilecektir).

Moleküler düzeydeki termal hareket **maddenin sıcaklığı** ile ilgilidir. Yani moleküllerin hızlı hareket etmesi daha yüksek sıcaklıkta olmasıyla alakalıdır.

"Buradan yola çıkarak sıcaklığı nasıl tanımlarız?"

Mürekkep deneyinde de gözlemlediğimiz gibi sıcak su molekülleri soğuk olana göre daha hızlı hareket etmektedir. Dolayısıyla bu hareketlilik maddenin sıcaklığı ile ilişkilendirilebilir**. Sıcaklık** bir maddenin sahip olduğu moleküllerin ortalama kinetik enerjisinin bir ölçüsüdür.

UYARI: Sıcaklık, moleküler düzeyde moleküllerin sahip olduğu ortalama kinetik enerjisi değildir; kinetik enerjisinin bir ölçüsüdür. Yüksek sıcaklık, maddenin moleküllerinin ortalama kinetik enerjisinin yüksek olduğunun bir göstergesidir.

Kavram Yanılgısı Tanı Koyma: Soğuk maddelerin sıcaklığı var mıdır?

UYARI: Sıcaklık kelime olarak sıcak cisim ya da maddeleri çağrıştırıyor olabilir. Bu yüzden soğuk cisimlerin de moleküller düzeyde termal hareket yaptıklarını dolayısıyla sıcaklığının olduğunu vurgulamamız gerekir.

Sıcaklık kavramından ısıya geçiş:

Tartışma Sorusu: "Farklı sıcaklıklardaki maddeler temas ettirildiğinde ne gözlemleriz?"

(Sıcak soğurken, soğuk ısınır.) Buradan yola çıkarak, sıcaklık aktarılır diyebilir miyiz?

Ortaya çıkabilecek kavram yanılgısı: Sıcaklık bir nesneden diğerine geçebilir.

Sıcaklık, bir maddenin moleküller düzeyde hareketliliğini gösterir. Sıcak maddenin moleküler hareketliliği daha fazladır. Bu yüzden soğuk maddeye aktarılan 'şey' onun da moleküler düzeyde biraz daha hareketlenmesini sağlar. Dolayısıyla aktarılan 'şey' hareketliliğin kendisidir. Moleküler hareketlilik de maddenin iç enerjisiyle ilişkilidir. Hareketliliğin artması kinetik enerjinin arttığını gösterir. Buradan hareketle, aktarılan 'şeyin' enerji olduğunu çıkarabiliriz. Ancak enerji aktarıldıktan sonra soğuk cismin sıcaklığının yükseldiğini söyleyebiliriz. Sonuç olarak sıcaklık bir maddeden diğerine aktarılmaz. Enerji aktarılır ve sıcaklık değişimi bunun sonucunda gözlemlenir.

Sıcaklık farkından dolayı gerçekleşen bu enerji transferine **ısı** denir. Isı, aktarılan enerjidir. Daha genel bir ifade ile ısı, bir cisim/sistem ve bu cismi/sistemi çevreleyen ortam arasındaki sıcaklık farkından dolayı meydana gelen enerji transferidir.

"İç enerji, sıcaklık ve ısı kavramları arasındaki bağlantı nedir?" *Öğrencilerin düşünmesi ve cevap vermesi için süre tanıyın. Bu soruyla dersi öğrencilerle birlikte özetleyelim.*

Beklenen cevap: İç enerji moleküllerin ortalama kinetik ve potansiyel enerjileri toplamıdır. Sıcaklık ise moleküller düzeyde ortalama kinetik enerjisinin bir ölçüsüdür. Sıcaklık değişimi, cismin/maddenin iç enerjisinde değişimle sonuçlanır. Isı ise, iki cisim arasındaki sıcaklık farkından dolayı transfer edilen enerjidir. Bir sistem ısıtıldığında, sistemin kinetik enerjisi artar dolayısıyla sıcaklığı yükselir. Ayrıca iç enerjisi de artar.

Epistemolojik tartışma soruları:

[Bilginin yapısı] 1. Bu derste sizin için yeni olan kavramlar var mıydı?

[Bilginin yapısı] 2. Önceki bilgileriniz bugünkü dersi anlamanızda nasıl bir rolü oldu? (Yardımcı, zorlaştırıcı, vs.) Neden böyle düşünüyorsunuz?

[Bilginin yapısı] 3. Önceden enerji kavramı ile ilgili öğrendikleriniz bugün ısı ve sıcaklık konusunda öğrendiklerinizle nasıl ilişkiliydi?

[Bilginin yapısı] 4. Günlük hayatta kullandığınız haliyle ısı ve sıcaklık kavramları bugün öğrendiklerinizden farklı mı? Sizce böyle olması mantıklı mı?

Epistemolojik Boyut - Bilginin Yapısı: (Öğretmen Konuşması)

Yaşadığımız çevrede karşılaştığımız olaylar için bir takım tanımlamalar yaparız aynı fizikte olduğu gibi. Isı neden transfer edilen enerji olarak tanımlanmış diye sormaktan ziyade, gözlemlediğimiz olayda bir enerji transferi söz konusu, bunu nasıl adlandıralım sorusunu sormak daha anlamlıdır. Zincirin halkaları gibi düşünürsek "ısı ve sıcaklık" tanımları ilk halkaları oluştururken bu halkalara uygun diğer halkalar bu tanımlamaların üzerine inşa edilir. Bu şekilde anlamlı, tutarlı bir yapı elde edilir.

Kendi bilgilerimiz için de aynı şeyi söylemek mümkün. Önceden bildiklerimiz olmasa, yeni gelen bilgileri ilişkilendirebileceğimiz hiçbir bilgi olmayacaktır. Bugünkü öğrendiklerinizi enerji ile ilgili bilgilerinizi kullanarak anlamlandırmaya çalıştık. İşimizi biraz kolaylaştırdık. Bu yüzden yeni bir bilgi ile karşılaştığımızda bunun bizim bilgilerimizle uyuşup uyuşmadığına dikkat etmeliyiz. Yoksa sanki her biri birbirinden alakasız bilgilermiş gibi her birini ayrı ayrı zihnimizde tutmaya çalışırız. Bu da bizi genellikle ezberlemeye yöneltir. Ezberlemek işimizi kolaylaştıran değil zorlaştıran bir durumdur. Ve bu bilgileri zihnimizde tutmak hiç kolay değildir. Zihnimiz çalışkandır, işine yarayan bilgileri, bildiklerimizle ilişkilendirerek kodladığımız bilgileri daha uzun süre hafızada tutar. Gereksiz olanları unutarak yeni bilgi için yer açar. Yani ezberlediğiniz çoğu şeyi öğrenmemişsinizdir. Zaman bizim için kıymetli olduğu için neden unutacak şekilde bilgileri hafızamıza yerleştirelim? Bu yüzden sorgulamak, mantıklı bilgiyi mantıksızdan ayırt etmek ve bunu kullanabilecek şekilde öğrenmek işimizi kolaylaştırır. Fizik, doğayı anlamaya, anlamlandırmaya çalışan bir bilimdir. Doğayı anlamak dışında bir iş yapıyorsak bu fizikle uğraşmadığımızın bir göstergesidir.

[Öğretmen öğrencilere bilimsel kavramların birbirleriyle, bu konuda olduğu gibi, ilişkili olduklarını vurgular. Aynı şekilde öğrencilerin de öğrendikleri fizik kavramlarını birbirleriyle ilişkilendirerek öğrenmeleri fiziği daha iyi anlamalarını sağlayacaktır. Öğrencilerin önceki sınıflarda öğrendiklerinin lisede görecekleri konularla ilişkili olduğunu ve temel konuların üzerine yeni öğrenmeleri inşa edeceklerini söyler.]

DERS PLANI-2 (Isıl Denge)

Sınıf: 9

Ünite: Isı ve Sıcaklık

Konu: Isıl Denge

Süre: 1 saat

Kazanım: 9.5.3.1. Isıl denge kavramının sıcaklık farkı ve ısı kavramlarıyla olan ilişkisini açıklar.
a. Öğrencilerin simülasyonlar ve gösterimler kullanarak ısıl dengenin sıcaklık değişimi ve ısı ile ilişkisini gözlemlemeleri sağlanır.

Isı kavramından ısıl denge kavramına geçiş:

- Farklı sıcaklıklardaki iki cismi birbirlerine temas ettirelim. Bu cisimlerin sıcaklıkları nasıl değişir?

Konuyla ilgili tecrübeleri ortaya çıkarma: Gözlemleriniz size ne söylüyor?
Tartışma soruları:

- Bu durumda sıcaklık alışverişi oluyor diyebilir miyiz? *Sıcaklığın tanımı hatırlatılır. Enerji aktarımına bağlanır.*
- Bu iki cisim arasında enerji aktarımı ne zaman biter?
- Enerji transferi bittiğinde, iki cismin sıcaklıkları için ne söyleyebiliriz?

Öğrencilerin tahminlerini sınıfta konuşalım.
Dersin bu bölümünde öncelikle sınıfla birlikte aşağıdakine benzer bir deney tasarlanır ve yaptırılır.

Deney – Isı Alışverişi Ne Zaman Biter?

Araç gereçler

- İki adet plastik bardak
- Soğuk ve sıcak su
- Pipet ya da ince boru
- Mandal
- İki adet termometre
- Cam macun ya da oyun hamuru

Deneyin yapılışı

1. Plastik bardakların tabanlarına yakın bir yerden birer küçük delik açalım.
2. Plastik bardakları birleştirecek şekilde pipetin uçlarını deliklerden geçirelim.
3. Pipetin deliklerden girdiği uçlarını oyun hamuruyla sıkıştıralım.
4. Pipeti ortasından bir mandal ile sıkıştıralım.
5. Plastik bardaklara eşit miktarda birine soğuk diğerine sıcak olmak üzere su koyalım.
6. Kaplardaki suların başlangıç sıcaklıklarını termometre ile ölçerek tabloya kaydedelim.
7. Mandalı çıkaralım ve belirli aralıklarla termometreleri gözlemleyip verileri kaydedelim.

Kap	İlk Sıcaklık (^oC)	1dk (^oC)	2dk (^oC)	3dk (^oC)	4dk (^oC)	5dk (^oC)	6dk (^oC)
1.							
2.							

Sonuca ulaşalım

Aldığımız verileri kullanarak bardaklardaki sıcaklık değişimlerini yorumlayalım.
Öğretmen şu soruları sorabilir:

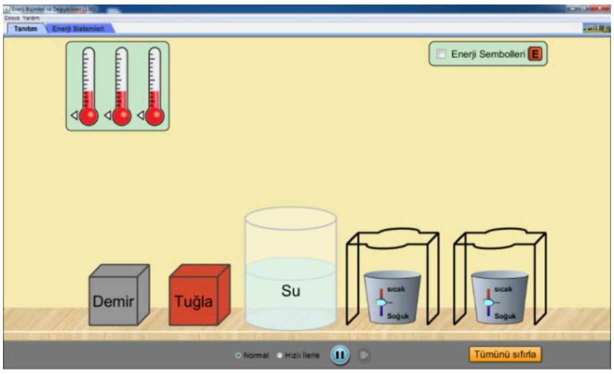
- *Birinci kaptaki suyun sıcaklığı nasıl değişti?*
- *İkinci kaptaki suyun sıcaklığı nasıl değişti?*
- *Neden iki kaptaki sıcaklıkta değişti? (Moleküler boyutta inceleyelim.)*

Beklenen Cevap: Sıcak su ve soğuk su kısa bir süre sonra ılıklaşacaktı. Bir noktaya kadar, yani ılıklaşıncaya kadar, suyun sabit/belirli bir sıcaklığından bahsedemeyecektik. Çünkü sıcak ve soğuk su arasında enerji aktarımı devam edecekti. Sıcaklık ve sıcaklığa bağlı değişkenler artık değişmediği andan itibaren suyun **ısıl dengeye** ulaştığı söylenir. Deneyde de plastik kaplar ısıl dengeye ulaştığında, ikisi de eşit sıcaklıktadır. Isıl dengeye ulaşan sistemler aynı sıcaklıktadır ve birbirleri arasında enerji aktarımı/transferi (ısı) gerçekleşmez.

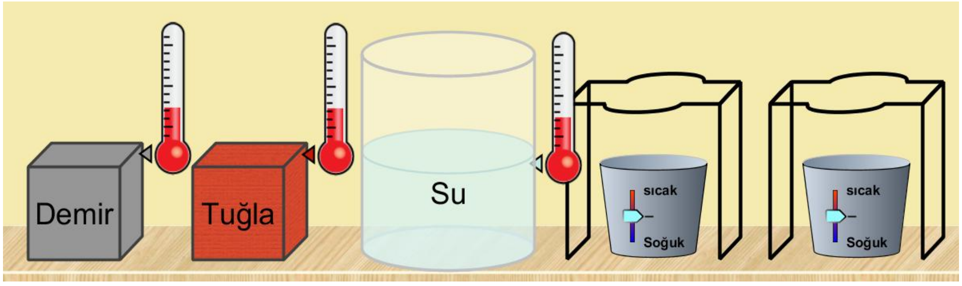
Öğrendiklerimizi kullanarak bir simülasyonu test edelim.
Bu etkinliğin amacı öğrencilerin kendi bilgilerinin mantığını kullanarak sorgulamalarını sağlamaktır.

Simülasyon dosyası: enerji biçimleri.jar

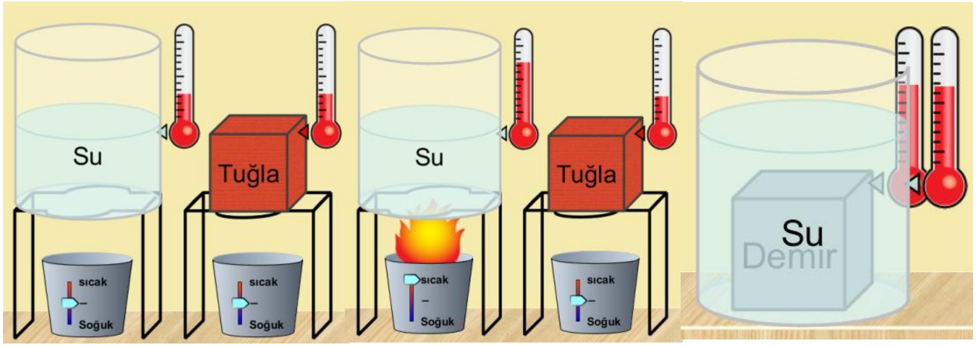
Ulaşılamadığı durumda indirmek için bu linki kullanın:http://phet.colorado.edu/sims/energy-forms-and-changes/energy-forms-and-changes_tr.jar



Şekil 1 Simülasyonun açılış ekranı



Şekil 2. Termometreleri maddelere iliştirdiğimizde o maddelerin sıcaklığını ölçmektedir.



Şekil 3. Maddeleri ve su kabını ısıtıcı/soğutucunun üzerine yerleştirerek sıcaklıklarını değiştirebilirsiniz. Su kabının içine demir parçasını ve tuğlayı ayrı ayrı ya da birlikte koyabilirsiniz.

Bu etkinlikte öncelikle öğrencilerin aktivite kâğıdındaki boşlukları doldurmaları istenir. Daha sonra her bir durum simülasyon üzerinde denenir.

Beklenen cevaplar:

Kontrol Edelim – Bu simülasyon doğru çalışıyor mu?

1. Aynı sıcaklıktaki demir parçası ve tuğlayı temas ettirdiğimizde:

a. Demir parçasının sıcaklığı değişmez

b. Tuğlanın sıcaklığı değişmez.

Çünkü aralarında sıcaklık farkı olmadığı için aralarında ısı alışverişi olmaz.

Şimdi simülasyonda deneyelim. Doğru çalışıyor mu? Evet / Hayır

2. Suyla aynı sıcaklıktaki demir parçası su dolu kaba konulduğunda:

a. Demir parçasının sıcaklığı değişmez.

b. Suyun sıcaklığı değişmez.

Çünkü aralarında sıcaklık farkı olmadığı için aralarında ısı alışverişi olmaz.

Simülasyon doğru çalışıyor mu? Evet / Hayır

3. Suyla aynı sıcaklıktaki tuğla su dolu kaba konulduğunda:

a. Tuğlanın sıcaklığı değişmez.

b. Suyun sıcaklığı değişmez.

Çünkü aralarında sıcaklık farkı olmadığı için aralarında ısı alışverişi olmaz.

Simülasyon doğru çalışıyor mu? Evet / Hayır

4. Su dolu kabı kaynayana kadar ısıtalım. Daha sonra içine demir parçasını koyalım.

a. Demir parçasının sıcaklığı artar.

b. Suyun sıcaklığı azalır.

Çünkü aralarında sıcaklık farkı olduğu için aralarında ısı alışverişi olur.

Öğretmen sorar: Ne zamana kadar ısı alışverişi devam eder?

Simülasyon doğru çalışıyor mu? Evet / Hayır

5. Demir parçasını ısıtalım. Tezgahta duran tuğla ile temas ettirelim.

a. Demir parçasının sıcaklığı azalır.

b. Tuğlanın sıcaklığı artar.

Çünkü aralarında sıcaklık farkı olduğu için aralarında ısı alışverişi olur.

Simülasyon doğru çalışıyor mu? Evet / Hayır

İpucu: Demir parçasını ve tuğlayı yan yana koyduklarında ısı-alışverişi gözlenmiyor. Ancak üst üste konulduklarında bu gözlem yapılabiliyor.

Öğrencilerin istedikleri farklı durumlar da test edilebilir.

Tartışma sorusu: Deneyde kullandığımız termometrelerin gösterdiği değerleri göz önünde bulundurursak, **termometrelerin ölçtüğü sıcaklık neyin sıcaklığıdır**?

Termometre, bir ısıl sistemin sıcaklığını nicel olarak ölçen bir araçtır; genellikle sistemin sıcaklığıyla **ısıl dengeye gelerek ölçüm** almamızı sağlar.

- Termometre aslında kendi sıcaklığını ölçer diyebilir miyiz? Sizce bu mantıklı mı? Neden?

Sistemle ısıl dengeye gelen termometre, sistemle aynı sıcaklıktadır. Termometre kendi sıcaklığını ölçüyor diyebiliriz.

Epistemolojik tartışma soruları:

[Bilginin Gerekçelendirilmesi]1.Gözlem yapmak sunulan bilgileri anlamanızda nasıl bir katkısı oluyor?

[Bilginin Yapısı]2.Şimdiye kadar öğrendiklerinizle önceden bildikleriniz arasında çelişen bir durum oldu mu?

[Bilginin Gerekçelendirilmesi]3. Yeni öğrendiklerinizle bildikleriniz çeliştiğinde ne yaparsınız?

[Bilginin Yapısı]4. Fizik bilgileriniz kendi içerisinde tutarlı olmak zorunda mı? Derste öğrendiğiniz bilgileri başka yerlerde ya da durumlarda kullanabiliyor musunuz? Nasıl?

DERS PLANI-3 (Genleşme)

Sınıf: 9

Ünite: Isı ve Sıcaklık

Konu: Genleşme

Süre: 1 saat

Kazanım: 9.5.5.1. Katı, sıvı ve gazlarda *genleşme* ve *büzülme* olaylarını karşılaştırır.

a. Öğrencilerin günlük hayattaki olayları inceleyerek genleşmenin etkilerini karşılaştırmaları sağlanır.

b. Öğrencilerin suyun diğer maddelerden farklılık gösteren sıcaklık-hacim ve sıcaklık-özkütle grafiklerini yorumlamaları ve günlük hayattaki etkilerini tartışmaları sağlanır.

Genleşme kavramına geçiş:

- Sıcaklığı ölçmek için kullandığımız termometreleri incelediniz mi? Yapısı hakkında neler söyleyebiliriz?
- Öğrenciler termometreleri inceleyebilirler. Cam bir hazne ve içinde renklendirilmiş bir sıvı olduğunu görürler.
- Sizce bu termometreler nasıl çalışıyorlar? *Öğrencilerin cevapları dinlenir.*

Gösteri Deneyi

Yapılışı: Bir erlenmayer kabı ağzına kadar su ile doldurup, boya katarak renklendirelim. Kabın ağzına delikli bir tıpa yerleştirip cam boruyu delikten geçirelim.
Durum: Kabı ısıtırsak ne gözlemleriz?
Tahminler: *(Öğrencilere bu alternatifler sunulur. Verdikleri cevapların nedenlerini açıklamaları istenir.)*
(a) Cam boruda hiçbir değişiklik meydana gelmez.
(b) Cam boruda su yükselir.

Gözlem: Isıtılan kaptaki su cam boruda yükselir. Termometrede okunan değer artar.
Açıklama: Boyalı su cam boruda neden yükselir?
Suyun kütlesi değişmediği halde cam boruda yükselmesi, suyun hacminin arttığını gösterir.
Maddeler ısıtıldığı zaman, madde içindeki atom veya moleküller daha hızlı hareket eder ve birbirlerinden uzaklaşır. Bu yüzden daha fazla alana/hacme yayılırlar. Maddelerin enerji alış-verişi sonucunda sıcaklıklarındaki değişme nedeni ile hacimlerinde meydana gelen değişime **genleşme** denir.

Farklı sıvıların genleşme miktarları da farklıdır. Genleşme, **sıcaklık değişimi ile maddelerin hacmindeki** artışı ifade etmek için kullanılır. Maddelerin sıcaklığı azaldığında hacimleri de azalır. Bu duruma da **büzülme** denir. Bazı sıvı maddeler için genleşme katsayılarını inceleyelim.

Bazı sıvılar için ısıl genleşme katsayıları (20 ℃)	
Madde	**Katsayı (K^{-1})**
Etil Alkol	11.2×10^{-4}
Benzin	9.5×10^{-4}
Cıva	1.82×10^{-4}
Su	2.07×10^{-4}
Aseton	14.3×10^{-4}
Amonyak	24.5×10^{-4}

Katsayıları incelediğimizde sıvıların genleşme kat sayılarının oldukça küçük sayılar olduğunu görüyoruz. Günlük hayatta en çok uğraştığımız sıvı su olduğu için evde fazla suyla doldurulmuş çaydanlıktan ya da tencereden kaynayan suların taştığını görürüz.

- Buradan yola çıkarak termometrenin çalışma prensibini nasıl açıklarsınız?

Sıvılı termometreler de sıcaklık değişimi sonucunda genleşme ilkesiyle çalışan bir araçtır. Termometrenin içindeki sıvı bu sayede ince boruda sıcaklık değişimine göre yükselir ya da alçalır.

- Cıva veya etil alkol kullanılan termometrelerde, tabloda görüldüğü gibi genleşme miktarları oldukça küçüktür. Buna rağmen sıcaklık değişimi net bir şekilde okunur. Bunun sebebi ne olabilir? Termometrenin yapısına bakarak bunu hangi konuyla açıklayabiliriz?

Termometrenin içinde bulunan sıvının genleştiği boru ya da tüpün yarıçapı çok küçüktür. Bu yüzden kılcallık olayı devreye girer.

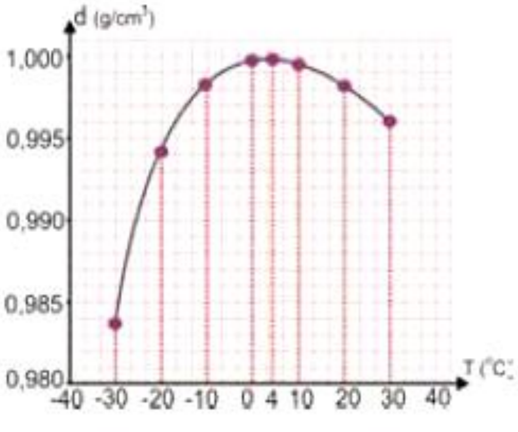
http://www.engineersgarage.com/insight/how-mercury-thermometer-works?page=4

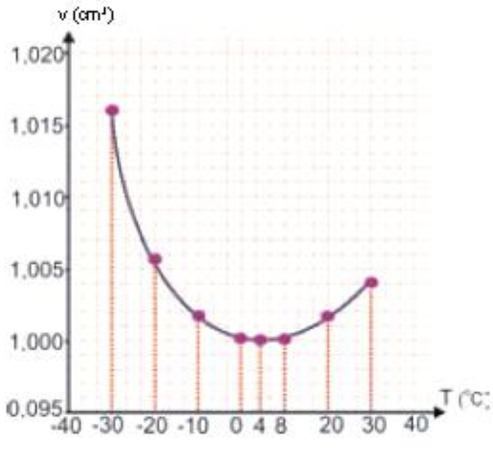
Tekrar sıvılarda genleşmeye dönersek, suyun farklı sıcaklıklardaki özkütlesini gösteren tabloyu inceleyelim.

Sıcaklık (°C)	**Saf suyun özkütlesi** (g/cm^3)
0 (sıvı)	0.9999
4	1.0000
20	0.9982
40	0.9922
60	0.9832
80	0.9718

- Verilen tabloyu incelediğinizde şimdiye kadar genleşme üzerine konuştuklarımızla çelişen bir durum farkettiniz mi?

- Çok küçük bir miktarda olsa 0 – 4°C aralığında suyun özkütlesinin arttığını; +4°C'den sonra ise azaldığını görüyoruz. Su en yüksek özkütle değerini +4°C'de alıyor. Bu durumda suyun hacmi nasıl değişir?





Suyun sıcaklığa bağlı olarak özkütle ve hacim değişim grafiklerini incelediğimizde suyun diğer sıvılardan farklı olarak sıcaklığı arttığı halde 0 – 4°C aralığında hacminin küçüldüğünü ve özkütlesinin arttığını görürüz. Bu sebeple +4°C'deen küçük hacim dolayısıyla en büyük özkütle değerine sahiptir. +4°C'den yüksek sıcaklıklarda ise diğer sıvılar gibi genleşerek özkütlesini azaltır.

Detaylı açıklama: Suyun sıcaklığı azaldıkça, su moleküllerinin hareketi de azalır. +4°C'desıcaklıkta, suyun moleküler hareketliliği yok olur. Çünkü su moleküllerini bir arada tutan hidrojen bağları öyle bir düzene girer ki; 0°C'deki buzun moleküler yapısını bir arada tutan hidrojen bağlarıyla neredeyse aynı seviyeye gelir. 4 dereceden suyun donma noktası 0 dereceye, su moleküllerinin artık birbirleri üzerinden hareket etmesi oldukça zorlaşır. Başka bir deyişle, su molekülleri hidrojen bağlarının moleküler arası etkileşimini daha fazla hissetmeye başlar. (Bir su molekülünün hidrojen atomlarıyla, diğer bir su moleküllerinin oksijen atomları arasında). Bu sayede düzenli kristal bir yapı düzenine girerek buzu oluştururlar. Buzun yapısında suya göre daha fazla boşluk vardır. Bu yüzden buzun özkütlesi, suya göre daha düşüktür.

http://www.newton.dep.anl.gov/askasci/gen99/gen99817.htm

Suyun bu özelliği sayesinde göllerin derinliklerinde suyun sıcaklığı neredeyse 4 derecedir. Hava sıcaklığı düştüğünde suyun üzerini buz kaplar. Bu buz kütleleri sayesinde altta kalan su sıcaklığını muhafaza eder ve göldeki canlıların yaşamasına olanak sağlar. Kuzey kutbunda da suda yüzen dev buz kütleleri görmemizin sebebi de budur.

http://van.physics.illinois.edu/qa/listing.php?id=1736

Sıvılarda genleşmeden katılarda genleşmeye geçiş:

Termometredeki sıvı genleşirken cam boru genleşmez mi? Katı maddeler de sıvılar gibi genleşir mi?

Gösteri Deneyi – Metal bilyeyi/topu nasıl metal çemberden geçiririz?

Durum: Metal bir top metal bir çemberden rahatlıkla geçmektedir. Metal topu ısıtırsak, çemberden geçer mi? *Öğrenciler tahminlerini sınıfta ifade ederler.*

Gözlem: Isıtılan metal top çemberden geçemez.

Açıklama: Isıtılan metal top her yönde genleşeceği için topun yarıçapı çemberin yarıçapından daha büyük olur.

SORU: Isıtılan metal topun çemberden geçebilmesi için neler yapılabilir?

Beklenen cevaplar:

Metal top soğutulur, bu sayede büzüşerek eski haline döner ve çemberden geçebilecek hale gelir.

Isıtılan metal topun yarıçapı çemberden büyük olduğu için, çember de ayrıca ısıtılarak genleştirilir. Bu sayede metal top çemberden geçebilir.

Bazı katı maddeler için genleşme katsayılarını inceleyelim.

Bazı katılar için ısıl genleşme katsayıları (20 ℃)	
Madde	**Katsayı (K^{-1})**
Alüminyum	23.0×10^{-6}
Bakır	16.7×10^{-6}
Demir	19.0×10^{-6}
Çelik	10.5×10^{-6}
Teneke (Tin) (25℃)	23.4×10^{-6}
Cam (25℃)	5.9×10^{-6}

- Sıvı maddelerle karşılaştırdığımızda katılardaki genleşme katsayıları arasında nasıl bir fark görüyorsunuz?

Sıvılarda genleşme miktarı katılara göre daha fazladır. Çünkü moleküller katılardakine göre sıvılarda daha serbest hareket edebilir. Ve sıcaklığın artmasıyla beraber moleküllerin hızlarında meydana gelen artış sebebiyle daha geniş bir hacmi kaplamaya başlarlar.

- Katı maddelerdeki genleşme durumunu yaşadığımız çevrede hangi olaylarda gözlemliyoruz?

Günlük hayattan örnek verilir.

Köprülerde genleşme derzleri (boşlukları) bırakılarak sıcak havalarda genleşme ve soğuk havalarda büzülmenin köprünün yapısını bozması engellenir. Tren yayları arasında boşluk bırakılması da bu duruma bir örnektir.

- Çürüyen dişlerimize dolgu yaptırırız. Yapılan dolgunun dişe zarar vermemesi için hangi özelliği ön planda tutulur?

Yiyecekleri sıcak ya da soğuk tükettiğimiz için sıcaklık farkından dolayı dişte meydana gelen genleşme ve büzülme olayını bozmayacak şekilde benzer ısıl genleşme ve büzülme katsayısı olan dolgu malzemeleri seçilir.

- Bazen dolaptan çıkardığımız bir kavanozun kapağını açmak çok zor hale gelir. Bunun nedeni nedir? Kapağı rahatça açmak için ne yapabiliriz?

Dolaba koyduğumuzda hem kavanozun camı hem de metal kapağı büzüşür. Ama bu büzüşme iki madde içinde farklıdır. Teneke, cama göre daha fazla büzüşür. Bu yüzden dışarı çıkarttığımızda kapağı çeviremeyiz. Tenekenin cama göre daha fazla büzüşüyorsa, aynı mantıkla teneke cama göre daha fazla genleşiyordur. Bu yüzden teneke kapağı bir süre ısıtarak (sıcak suya tutarak), kavanozu daha kolay açarız.

Termometredeki cam genleşir mi sorusunu artık cevaplayabiliriz. Bu termometrelerde cam, içine konulan sıvıdan çok daha az genleşir.

Katılarda genleşmeden gazlarda genleşmeye geçiş:

Peki, gazlarda genleşme miktarı katı ve sıvılara göre nasıldır? Moleküllerin hareketlerini düşünerek cevaplamaya çalışalım.

Moleküler arası kuvvetlerin oldukça az olduğu gaz halde, moleküller ve atomlar serbestçe hareket edebilmektedir. Isıtılan gaz moleküllerinin kinetik enerjileri artacağı için daha büyük bir alan kaplamaya başlarlar. Bu yüzden katı ve sıvılara göre daha fazla genleştiklerini söyleyebiliriz.

- Doğru sonuca ulaşabildik mi? Bir gözlem yaparak bunu deneyelim.

Günlük hayattan örnekler: Uçan balonlar, Mylar Balonu

Mylar balonu, lastik balonlar gibi şişirildiğinde gerilmez. Bu balonlar oda sıcaklığında helyum gazıyla doldurulur.

- Oda sıcaklığında şişirilmiş Mylar balonu soğutulursa ne gözlemlenir?

Balonun havası inmiş gibi olur. Oda sıcaklığına ise getirildiğinde balon tekrar eski halini alır.

- Bu durumdan nasıl bir çıkarım yapabiliriz?

Hava kaçırmadığına göre balonun içindeki gaz miktarı aynıdır. Ama hacmi azalmıştır. Yani sıcaklık düştüğünde hacmi azalmış, sıcaklığı arttığında ise gazın hacmi artmıştır. Biz bu durumları sırasıyla büzüşme ve genleşme olarak tanımlamıştık. Sıvı ve katıların genleşmesiyle karşılaştırdığımız da gazlardaki genleşme gözle görülebilecek kadar gözlemlenebilir. (10 derece sıcaklığı artan 1 litre gaz 34 mL genleşir.) Bu yüzden balonu gazla doldurduğumuz yerdeki sıcaklık düşükse ve balon oda sıcaklığında muhafaza edilecekse tamamen gazla doldurulmaz.

Epistemolojik Boyut - Bilginin Gerekçelendirilmesi: (Öğretmen Konuşması)

Epistemolojik tartışma soruları:

[Bilginin Gerekçelendirilmesi]1. Bazı bilgileri gözlem ya da deney yaparak gösteremediğimizde, kendi fizik bilgilerimizi kullanarak bir bilginin mantığını ortaya çıkarabilir miyiz?
[Bilginin Gerekçelendirilmesi]2. Fizik bilgilerimiz farklı durumları farketmemizi, mantıklı ve mantıksız durumları ayırt etmemizi nasıl sağlar?
[Bilginin Yapısı]3. Öğrendiklerimizle günlük hayatta gözlemlediklerinizin çeliştiği durumlar olabilir mi? Örnek verebilir misiniz?
[Bilginin Gerekçelendirilmesi]4.Öğrendiğiniz ya da önceden bildiğiniz bilgiler arasında tutarsızlık ya da çelişkiler olursa mantıklı bilgiye nasıl ulaşırsınız?

Bu sınıftan dışarı çıktıktan sonra belki günün sonuna kadar burada konuştuklarımızı hatırlayacaksınız. Düşünmeden ya da sorgulamadan aldığımız her bilginin kaderi unutulmaktır. Çünkü bu bilgileri işimize yaramayan bir eşyaymış gibi çantamıza koyuyoruz ve varlığını unutuyoruz. Ancak bir bilgi mantığını anladığımızda bizim olur. Mantığını anlamak için çoğunlukla akıl yürütme yolunu kullanırız. Yani rasyonel düşünce. Sahip olduğumuz bilgileri kullanarak problemleri ya da durumları açıklayabiliriz. Bazen de karşılaştığımız durumları kontrollü bir şekilde tekrar deneyerek bilgiye ulaşırız aynı bugün yaptığımız gibi. Gözlem yaparken ve sonucunda aslında bizim olan "yeni ve mantıklı" bilgiler üretiriz. Bu neden önemli? Evet, bizden önce fizikçiler gözlemlediğimiz pek çok durumu bilimsel olarak açıklamıştı. Ortada bilimsel bilgi var ama bizim değil. Peki bir bilgi nasıl bizim olur? Bunun bir yolu benzer durumlar yaratarak bilginin mantığını test etmektir. Yani bilimsel bilgiyi kendi yöntemlerimle sorgularım ve kendi bilgimi üretirim.

Aslında yaptığımız iş şu: Yaşadıklarınız, gözlemleriniz, önceden öğrendikleriniz sizin için bir mantık süzgeci oluşturur. Düşünmeden ezberliyorsanız bu süzgeci kullanmıyorsunuz demektir. Yani yeni bilgi sizin için anlamlı mı değil mi sorgulamıyorsunuz. Bu bilgiler ne yazık ki sizin olamıyor. Bu sadece duyduğunuz bir bilgi olarak kalıyor. Ancak mantık süzgecinizi kullandığınızda sağlam kuleler elde edersiniz. Tek yapmamız gereken düşünmek. Bana böyle bir bilgi sunulmuş, evet. Ama bu bilgi benim bilgilerimle örtüşüyor mu? Bir çelişki var mı? Sorgulamak zorundayız. Yoksa birbirinden kopuk yüzlerce bilgiyi hafızamızda tutmaya çalışırız. Halbuki öğrenmek bir eziyet değildir. Öğrenmek, verilen bilgiyi sorgulama ve kendimiz için anlamlandırma sürecidir.

Çelişki oluşuyorsa aslında yeni bilgiyle varolan kendi bilgilerimizi de sorgularız. Bilgilerimizin hepsi bilimsel bilgilerle paralel olmayabilir. Örneğin, ısı ve sıcaklık kavramlarını aynı kavramlar olarak birbirinin yerine kullanabiliyoruz. Geçen derste bunların farklı kavramlar olduğunu gördük. Ama günlük hayatta buna çok dikkat etmiyoruz. Sahip olduğumuz bilgileri değiştirmek her zaman kolay değildir. Sizi sevdiğiniz bir alışkanlıktan vazgeçirmeye çalışsak, direnç gösterirsiniz. Burada öğrendiklerinizle bilgilerinizi hemen değiştirebileceğinizi düşünebilirsiniz. Ama bilgilerimizi göründüğü gibi kolay takas edemeyiz. Bu yüzden sorgulamak, yeni bilgiyi anlamlandırmak zorundayız.

DERS PLANI-4 (Termometre Çeşitleri ve Sıcaklık Birimleri)

Sınıf: 9

Ünite: Isı ve Sıcaklık

Konu: Isı, Sıcaklık ve İç Enerji

Süre: 2 saat

Kazanım: 9.5.1.2.a. Kullanım amaçlarını göre termometre çeşitlerini karşılaştırarak sunar.

9.5.1.2.b. Kullanım amaçlarına göre sıcaklık birimlerini karşılaştırarak sunar.

9.5.1.3.b. Farklı sıcaklık birimlerinin ortaya çıkış nedenlerini açıklar.

Termometre çeşitleri:

Hayatımızda sıcaklığın önemi büyüktür. Bulunduğumuz ortamlardaki sıcaklık değişikliklerini bilmek, vücut sıcaklığımızı korumamız için bize ipuçları verir. Örneğin dışarı çıkacaksak nasıl giyineceğimize, hava durumunu takip ederek karar veririz. Bu yüzden sıcaklık insanlar ve diğer canlılar için oldukça önemlidir.

Yaşadığımız yerlerde sıklıkla kullandığımız termometre çeşitlerini inceleyelim.

Kendi vücut sıcaklığımız ölçmek için sıvılı termometreler kullanırız. Normal vücut sıcaklığımız 36-37^{o}C'dir. Hastalandığımız zaman bu sıcaklık 40^{o}C ve üzerine çıkabilir. Bu sebeple vücut sıcaklığını ölçmek için kullanılan sıvılı termometreler genellikle 34^{o}C ile 42^{o}C arasında ölçeklendirilir.

- "Vücut sıcaklığı ölçen bir termometreyle hava sıcaklığını ölçebilir miyiz?"
- Hava sıcaklığını ölçmek için kullanılan termometrelerin çok geniş bir aralıkta sıcaklığı ölçebiliyor olması gerekir. Örneğin kutuplarda hava sıcaklığı çok düşükken (-68^{o}C) çöllerde ise gün içerisinde sıcaklık çok yüksek olabilmektedir (70^{o}C). Bu yüzden vücut sıcaklığı ölçen bir termometre işimize pek yaramaz. Öyleyse nasıl bir termometre kullanmalıyız?

Sıvılı termometreler kullanılan sıvının donma ve kaynama sıcaklığı arasındaki sıcaklıkları ölçebilir. Örneğin laboratuvarlarda kullanılan cıvalı termometreler -10^{o}C ile 110^{o}C aralığında ölçeklendirilir. (Cıvanın donma sıcaklığı -39^{o}C'dir.) Bu laboratuvar için uygun olan sıvılı termometre kutuplardaki hava sıcaklığını ölçmek için uygun değildir. Bu yüzden daha düşük sıcaklıklarda sıvı halde bulunan maddeler örneğin alkol kullanılır. Alkol -115°C de katılaşır.

Oda sıcaklığını ölçmek için cıvalı termometreyi alkollü termometre yerine tercih ederiz. Çünkü alkol oda sıcaklığında gaz haline geçer.

- "Sıvılı termometrelerden başka ne tür termometreler vardır?"

Aşağıdaki tablo öğrencilere gösterilir.

Bazı termometre çeşitleri		
Termometre	**Ölçülen fiziksel özellik**	**Açıklamalar**
İdeal gaz	Sıvılaşan gazların basınç ve hacmi	
Cıva hazneli	Sıvının genleşme ve büzülmesi	Sıvı hal değiştirmezse kullanılabilir.
İkili metal şerit	İki metalin farklı genleşmesi	
Direnç	Elektriksel direnç	
Termoelektrik (Isıl Çift)	Farklı metaller arası elektriksel voltaj farkı	Sanayide en çok kullanılan termometre çeşididir.
Paramanyetik	Maddenin manyetik özelliği	Çok soğuk sıcaklıklarda kullanışlıdır.
Optik pirometre	Yayılan ışığın rengi	Çok yüksek sıcaklıklar için kullanışlıdır.

Gazlı termometreler laboratuarlarda hassas ölçüm yapmak için kullanılır. Gazlar moleküler yapılarından dolayı sıvı ve katı maddelere göre sıcaklık değişimlerinden daha çok etkilenir. Hassasiyet söz konusu olduğunda gaz termometreleri kullanılabilir.

Metal termometreler, metallerin erime noktasının yüksek olması sebebiyle, yüksek sıcaklık ölçümleri için fabrikalarda, fırınlarda, seramik atölyelerinde kullanılır.

Sıcaklığın yaklaşılamayacak kadar yüksek veya erişilmesi zor olan yerlerin sıcaklığını ölçmede pirometre kullanılır. Hastanelerde vücuda temas etmeden yapılan sıcaklık ölçümlerinde de kullanılmaktadır.

- Okuldaki laboratuarlarda genellikle alkollü ya da sıvılı termometre kullanılır. Eskiden cıvalı termometreler daha yaygın kullanılırdı. Fakat termometre kırıldığı zaman cıva sağlık açısından tehlike yarattığı için artık tercih edilmiyor. Sizce bu termometreler -273°C'den 2000°C'e kadar olan sıcaklıkları ölçmekte ne kadar etkilidirler? Bu sıcaklık aralığında hangi termometreleri hangi sıcaklıkları ölçmek için tercih edersiniz? *(Grup çalışması yapılabilir.)*

*F*arklı maddeler kullanarak yapılan termometreleri inceledik. Bu termometrelerde ölçeklendirme nasıl yapılır şimdi bunu inceleyelim.

Sıcaklık birimlerine geçmeden önce, "Sıcaklık ne zaman bir alet ile ölçülmeye başlandı?" biraz bilgi edinelim. *Bu kısım okutulabilir ya da öğretmen tarafından anlatılabilir.*

Termometre çeşitlerinden termometrelerin ölçeklendirilmesi ve sıcaklık birimlerine geçiş:

Bilim tarihinden örnek

Sıcaklık ne zaman bir alet ile ölçülmeye başlandı?: Termometreler

İlk termometreler 17. yüzyılda İtalyan Santorio Santorio, Galileo Galilei ve Giovanfrancesco Sagredo tarafından yapılmıştır. Bu termometreler Galileo'nun bilimsel yöntemi kullanılarak geliştirilmiştir. Bu termometreler içi sıvı dolu camdan yapılmıştır. Camın alt kısmı sıvının doldurulduğu haznedir ve buna bağlı bir ince boru bulunmaktadır. Çalışma prensibi: Sıcaklık arttığında, sıvı ince boruda yükselir, soğuduğu zaman ise sıvı cam borudan aşağıya inerek haznede birikir. Galileo termometresinde ölçeklendirme kullanmamıştı. Bu yüzden Galileo'nun sadece gözlem yapabildiğini söyleyebiliriz, ancak ölçüm yaptığı konusunda bir bilgi yoktur. Daha sonra, Sagredo termometresine 360 eşit parçadan oluşan bir ölçek eklemiştir. 360 parça olmasının nedeni ise dairenin 360 dereceye bölünebilmesini taklittir. Bu uygulamadan sonra sıcaklık birimleri **derece** olarak adlandırılmıştır.

İngiliz bilim insanı *Robert Hooke* (1635-1703) ilk defa **sabit olan** en düşük nokta olarak suyun donma noktasının kullanılmasını önermiştir. Danimarkalı *Ole Romer,* termometresinde 7,5 dereceyi suyun donma noktası, 60 dereceyi ise suyun kaynama noktası olarak işaretlemiştir. Bu termometrede insanın vücut sıcaklığı 22,5 dereceye sabitlenip suyun donma noktasının 3 katı olacak şekilde ayarlanmıştır. O zamanlar herkes kendi termometresini yaptığı için termometreler arası değişiklikler görülebiliyordu.

Ne var ki, normal vücut sıcaklığı ciddi bir termometrenin ihtiyacı olan sabit bir nokta değildi. İnsan söz konusu olduğunda "normal" kavramı farklılıklar gösterebilir. Farklı iki insanın vücut sıcaklıkları birbirinden farklı olmasına rağmen her biri sağlıklı kişiler olabilir. Hatta gün içinde bile vücut sıcaklığı değişir. Bu yüzden vücut sıcaklığını sabit nokta gibi düşünme fikri de suya düşmüş olur.

En uzun süre kullanılan sıcaklık ölçeği, Alman Fizikçi Daniel Gabriel Fahrenheit'ın (1686-1736) bir çalışmasının ürünüdür. Fahrenheit 28 yaşındayken sabit ölçümler alabilen birkaç termometre yaparak bilimsel çevreleri hayrete düşürmüştü. Çünkü o zamana kadar böyle bir şey hiç yapılmamıştı. İtalya'da yapılan termometreler tekrar tekrar aynı sonucu vermeyen sabit noktalara ayarlanmıştı. Bu yüzden 1650 yılında yapılan bir termometre 1651 yılında yapılan termometreye göre farklı sonuçlar veriyor; aynı şekilde Floransa'da yapılan bir termometreyle Venice'de yapılan bir termometre yine farklı sonuçlar veriyordu.

Fahrenheit bunun yerine 3 sabit noktası olacak şekilde ayarladığı termometresini 1724 yılında sunmuştur. Fahrenheit, termometresinin özelliklerini şu şekilde açıklar:

"Ölçeğin bölümleri 3 sabit noktaya dayanır ve bu noktalar şu şekilde belirlenir. Birincisi kalibre olmamış bölümde yani ölçeğin başladığı yerdedir ve buz, su ve amonyumklorit ya da deniz tuzu karışımıyla belirlenir. Termometre bu karışımın içine yerleştirildiğinde, termometredeki sıvı 0 derece işaretli noktaya düşer. Bu deney kışın yaza göre daha iyi çalışır.

"İkinci nokta, su ve buz karışımının üstte bahsedilen tuzlar olmadan elde edilir. Termometre bu karışıma yerleştirildiğinde, termometredeki sıvı 32. dereceye çıkar. Bunu donma noktası olarak isimlendirdim. Kışın, musluk suları ince bir buz tabakasıyla kaplandığında termometre sıvısı bu noktayı gösterir.

"Üçüncü nokta ise 96. derecedir. Alkol ağızda tutulduğunda ya da sağlıklı bir insanın koltuk altına damlatıldığında bu noktada genleşir."

Fahrenheit'ın ölümünden sonra bu sabit noktalar değiştirilmiş yerine ölçülebilir iki sabit nokta belirlenmiştir. 32^{o}F derece suyun donma noktasına ayarlanırken; suyun kaynama sıcaklığı 212 ^{o}F derece olarak en üst sabit nokta olarak belirlenmiştir. Fahrenheit termometresi 180 dereceye ayrılarak ölçeklendirilmiştir. (http://physics.info/temperature/)

1742 yılında İsveçli astronom ve fizikçi Anders Celsius (1701-1744) kendi sıcaklık ölçeğini geliştirmiştir. Meteorolojik gözlemler yapabilmek için bu termometreyi geliştirmiştir. Bu ölçek 100 eşit parçaya bölünmüş ve her bir parça Celsius derece olarak isimlendirilmiştir. Bu ölçek buzun erime sıcaklığı (0^oC) ve suyun kaynama sıcaklığı (100^oC) aralığını kapsar. Aynı zamanda santigrat sıcaklık ölçeği olarak da adlandırılır.

1848 yılında ise Kelvin termometresi, İrlandalı William Thomson (daha sonra Sir Lord Kelvin ünvanı verilen) tarafından bir maddenin düşebileceği en düşük sıcaklık değeri referans alınarak geliştirilmiştir. Bu sıcaklık Celsius termometresine göre -273.15^oC'tur ve Kelvin termometresinde mutlak sıfır kabul edilir. Bu yüzden -273.15^oC, sıfır Kelvin olarak belirlenir. Kelvin termometresi Celsius termometresine benzetilebilir. Kelvin termometresinde buzun erime sıcaklığı 273.15K ve suyun kaynama sıcaklığı 373.15K olarak belirlenmiştir. Kelvin sıcaklık biriminde derece işareti kullanılmaz. Uluslararası birim sisteminde sıcaklık birimi Kelvin olarak kabul edilmiştir.

Sorular

1. Okuma parçasında bahsedilen sıcaklık ölçekleriyle ilgili tabloyu dolduralım.

Sıcaklık Ölçeği	**Sembolü**	**Suyun donma sıcaklığı**	**Suyun kaynama sıcaklığı**
Fahrenheit	***^oF***	***32***	***212***
Celcius	***^oC***	***0***	***100***
Kelvin	***K***	***273.15***	***373.15***

2. Farklı sıcaklık ölçeklerinin ortaya çıkmasının nedeni nedir?

3. Günümüzde kullanılan bu üç termometrede de suyun donma ve kaynama sıcaklığı sizce neden referans noktaları olarak belirlenmiştir?

Öğrenciler bireysel olarak soruları cevaplarlar. Öğrencilerin cevapları sınıfta tartışılır.

- Siz de kendi sıcaklık biriminizi oluşturabilir misiniz? Nasıl?

Öğrencilerin tartışmaları sağlanır.

Epistemolojik tartışma sorusu:

[Bilginin Değişebilirliği]1. Sahip olduğunuz bilgiler, mantıklı olduğunu düşündüğünüz yeni bilgiler sayesinde değişiyor mu? (Gelişimde bir değişimdir.)

Epistemolojik Boyut: Bilginin Değişebilirliği (Öğretmen Konuşması)

Termometrelerin tarihteki gelişimi göz önüne alındığında bilim insanlarının benzer bilimsel yöntemler kullanarak ölçüm aletleri geliştirdikleri vurgulanır. Amacın hep daha güvenilir ve daha kesin bilgiye ulaşma çabası olduğuna değinilir.Ve bu örnekte bilimsel bilginin üst üste önceki bilgiler kullanılarak oluşturulduğuna değinilir. Bu şekilde bilginin tekrar tekrar yapılandırılabileceği ve de değişebileceğine dikkat çekilir. Öğrencilerin yeni öğrendikleri fizik bilgilerinin de önceki bilgilerinin üzerine anlamlı bir şekilde inşa edildiğini ve dolayısıyla gelişerek değiştiği söylenir.

DERS PLANI-5 (Birim Dönüşümleri ve Isı Birimleri)

Sınıf: 9

Ünite: Isı ve Sıcaklık

Konu: Isı, Sıcaklık ve İç Enerji

Süre: 2 saat

Kazanım: 9.5.1.3.a. Farklı ısı birimlerinin ortaya çıkış nedenlerini açıklar.

9.5.1.3.c. Isı (Kalori ve Joule) ve sıcaklık (^{o}C, ^{o}F, K) için birim dönüşümleri yapılır.

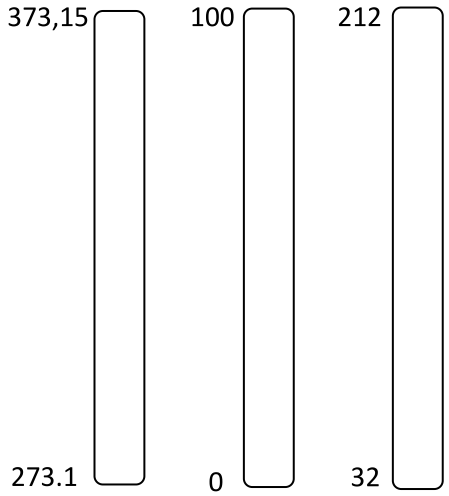
Epistemolojik Tartışma Soruları:
[Sabit Yetenek ve Hızlı Öğrenme] 1. Bu ünitenin başından beri öğrenmekte sıkıntı yaşadığınız bir konu oldu mu? Varsa bunlar neler?
2. Sıkıntı yaşadığınızda öğrenmek için çaba gösteriyor musunuz?
3. Sizce fiziği anlamak için özel bir yeteneğe sahip olmanız gerekiyor mu?

Sıcaklık birimlerinden ve birimler arası dönüşümleri:

Bir önceki derste neden farklı sıcaklık birimlerinin ortaya çıktığından bahsetmiştik. Dünyanın farklı yerlerinde farklı ölçü sistemleri kullanıldığı için, kullandıkları sıcaklık ölçekleri de farklılık göstermektedir. Örneğin ABD'de Fahrenheit sıcaklık birimi kullanılırken, pek çok Avrupa ülkesinde ve ülkemizde Celsius sıcaklık birimi kullanılmaktadır. Bilimsel araştırmalarda sıcaklık birimi genellikle Kelvin cinsiden ifade edilir. Bu yüzden farklı sıcaklık birimleri arasında dönüştürme yapmamız gerekebilir.

En basit dönüştürmeden başlayalım. Kelvin ve Celsius sıcaklık birimleri 100 eşit dereceden oluşur. Kelvin'in sıfır noktası Celsius ölçeğinde -273.15^{o}C olarak gösterilir. Buradan yola çıkarak: $T_K = T_C + 273.15$ şeklinde ifade edebiliriz.

Celsius ve Fahrenheit ölçeklerinde dönüştürme yapmak istersek, şöyle bir orantı kurarak bu işi başarabiliriz.



1. Celsius termometresi 100 aralıktan oluşurken, Fahrenheit termometresi 180 aralıktan oluşur. Bu da Celsius termometresindeki bir aralığın Fahrenheit termometresinde 1.8 aralığa denk olduğu anlamına gelir.

2. Fahrenheit derecesi 32'den başlarken Celsius derecesi 0'dan başlar.

Bu sebeple Celsius'dan Fahrenheit'a dönüşüm yaparken 32^{o}F eklenir.

1 Celsius derece, 32+ (**1**x1.8)= 33.8^{o}F'dır.

50^{o}C →32 + (**50**x 1.8) = 112^{o}F'dır.

Formülle gösterecek olursak:

$$\frac{T_X - Suyun\ donma\ sıcaklığı\ °X}{Suyun\ kaynama\ sıcaklığı\ °X - Suyun\ donma\ sıcaklığı\ °X} = \frac{T_c - 0°C}{100°C - 0°C}$$

$$= \frac{T_F - 32°F}{212°F - 32°F}$$

Aşağıda verilen sorular öğrenciler tarafından sınıfta çözülür.

Örnek Soru 1:

Bir sebze üreticisi serasında yetiştirdiği ürünleri İngiltere'ye ihraç edecektir. İletişim kurduğu firma yetkilisi, ürünlerin yetiştirilme sürecindeki seranın sıcaklık değerini hem Celsius hem de Fahrenheit cinsinden öğrenmek ister. Bunun üzerine üretici, serasındaki sıcaklığı bir termometre ile 20^{o}C olarak ölçer. Acaba bu sıcaklık değerinin Fahrenheit karşılığı nedir?

Çözüm:

Verilenler: Termometrede ölçülen sıcaklık değeri 20^{o}C'dir.

İstenilenler: 20 °C'nin Fahrenheit biriminde karşılığı nedir?

- Soruda kullanılacak formül ya da bilgiler:

$$\frac{T_c - 0°C}{100°C - 0°C} = \frac{T_F - 32°F}{212°F - 32°F}$$

- Sonuç:

$$\frac{20°C - 0°C}{100°C - 0°C} = \frac{T_F - 32°F}{212°F - 32°F} \quad \frac{\cancel{20°C}}{\cancel{100°C}} = \frac{T_F - 32°F}{180°F}$$

$$\frac{1}{5} = \frac{T_F - 32°F}{180°F} \qquad 180°F = 5T_F - 160°F$$

$$340°F = 5T_F \; ; \; T_F = 68°F$$

Oran-Orantı Yoluyla Çözme

20°C → 32 + (20x1,8)=68°F

Örnek Soru 2:

Evde sudan farklı bir sıvı kullanarak yaptığımız bir termometre, suyun donma sıcaklığını 20°X ve suyun kaynama sıcaklığını 140°X olarak göstermektedir. Bu verilerden yola çıkarak oda sıcaklığını kaç °X ölçeriz? Oda sıcaklığını 20°C alalım.

Çözüm:

Verilenler: Yaptığımız termometreye göre suyun donma sıcaklığı 20°X

Suyun kaynama sıcaklığı 140°X.

İstenilenler: 20°C'nin X derece biriminde karşılığı nedir?

Soruda kullanılacak formül ya da bilgiler:

$$\frac{T_X - Suyun\ donma\ sıcaklığı\ °X}{Suyun\ kaynama\ sıcaklığı\ °X - Suyun\ donma\ sıcaklığı\ °X} = \frac{T_c - 0°C}{100°C - 0°C}$$

Sonuç:

$$\frac{T_X - 20°X}{140°X - 20°X} = \frac{20°C - 0°C}{100°C - 0°C} \quad \frac{T_X - 20°X}{120°X} = \frac{\cancel{20°C}}{\cancel{100°C}}$$

$$\frac{T_X - 20°X}{120°X} = \frac{1}{5} \qquad 5T_X - 100°X = 120°X$$

$$5T_X = 220°X \; ; \; T_X = 44°X$$

Oran-Orantı Yoluyla Çözme:

X termometresi 140-20=120 aralıktan oluşur, Celsius ise 100 aralıktan. Yani Celsius derecesindeki 1 aralık X termometresinde 1.2 aralığa denktir. (120/100) X termometresi 20'den başlarken Celsius 0^oC'den başlar. Bu sebeple Celsius'dan X'e çevirirken 20^oX ekleriz.
20^{o}C → 20 + (**20** x1.2) = 20 + 24 = 44^oX

- Celsius sıcaklık biriminde 0 derece ne anlama gelir?

Hava durumunu incelediğimizde kışın sıcaklıklar eksi değerlere düşmektedir. Yani sıfırın altında da sıcaklık olduğunu biliyoruz. Bizim için 0^oC suyun donma, buzun erime noktasıdır. Matematikte kullanıdığımız, 0 ile aynı anlmada kullanılmamaktadır. Yani 0^oC bize sıcaklığın olmadığını söylemez. Başka bir değişle 0^oC'de ve altında hala moleküler seviyede hareketlilik söz konusudur ve hala maddenin ortalama kinetik enerji değeri vardır.

- Kelvin sıcaklık biriminde sıfır ne anlama gelir?

0 Kelvin teorik olarak maddenin moleküler hareketliliğinin sıfır olduğu nokta olarak tespit edilmiştir. Mutlak sıfır denmesinin nedeni de, 0 Kelvin'in sıcaklığın sıfır olduğunu göstermesidir.

Epistemolojik Boyut: Sabit Yetenek ve Hızlı Öğrenme (Öğretmen Konuşması)

Sorular öğrenciler tarafından çözüldükten sonra öğretmen öğrencilerin öğrenme süreçleri hakkında konuşur. Soruları çözmek için tek bir yöntem olmadığını gösterir. Konuları anlamlandırarak ve basamak basamak ilerleyerek fizikteki soruları çözebilecekleri, fizik konularını daha iyi anlayacaklarını vurgular.

- Sıcaklık ölçtüğümüz termometreler ve sıcaklık birimlerini bitirdiğimize göre artık ünitemizin önemli kavramlarından ısıya geri dönelim.
- Isıyı zihninizde nasıl canlandırıyorsunuz?

Öğrencilerin cevapları dinlenir… Bir madde gibi mi yoksa moleküler hareketliliğin iletimi şeklinde mi anlatıyorlar buna dikkat edilir.

Madde halinde olduğunu düşünüyorlarsa tartışma başlatılır.

Isı kavramının tarihsel gelişimi

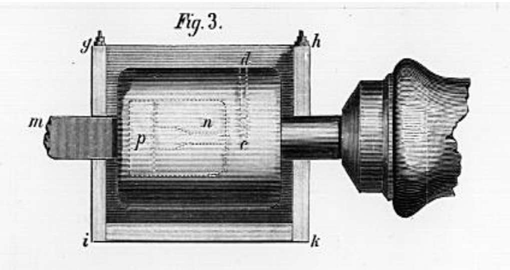
Isı Kavramının Tarihsel Gelişimi

1700'lerin sonuna gelindiğinde, Fahrenheit, Joseph Black ve diğer bilim insanlarının deneyleri sıcaklığın sistematik ve nicel olarak ölçülebilmesini sağladı. Ancak ısının nasıl aktığı konusunda net bir açıklama yapılamıyordu. Bu dönem, elektrik çalışmalarının ivmelendiği bir zamandı. Benjamin Franklin'in yaptığı uçurtma deneyinde üzerine yıldırım düşmesi sonucu elektriğin görünmeyen bir **akışkan** olduğunu savunmuştu.

Isı da elektrik gibi bir görünmeyen akışkan olabilir miydi? 1787 yılında, modern kimyanın kurucusu, Fransız bilim insanı Lavoisier, ısının da görünmeyen bir akışkan olduğunu düşünerek buna kalorik akışkan ismini verdi. Kalorik, Yunancada ısı anlamına gelen bir kelimeden türetilmişti.

O zamanlar için böyle bir akışkanın varlığı oldukça anlamlıydı – çünkü ısı sıcak bir cisimden soğuk bir cisme doğru akıyordu. Ve yapılan nicel deneylerle ısının korunan bir büyüklük olduğu ortaya konmuştu. Korunan bu büyüklüğün akışkan olması mümkündü. Kalorik teoriye göre bir maddenin katıdan sıvıya ve daha sonra gaza dönüşmesini şu şekilde açıklıyordu: Kalorik akışkan bir katının atomları arasında yayılır, atomlar arası var olan kuvvetin zayıflamasına neden olur. Katı eriyip sıvıya dönüştüğünde kalorik akışkan etkisini sürdürür dolayısıyla madde gaz haline geçer.

Kalorik teoriye göre; iki katı cisim birbirine sürtüldüğünde bir miktar kalorik yüzeye çıkar ve muhtemelen sürtülen maddenin küçük parçacıkları kalorik kaybeder ve ısı açığa çıkar. Kalorik teori doğru olabilir mi?



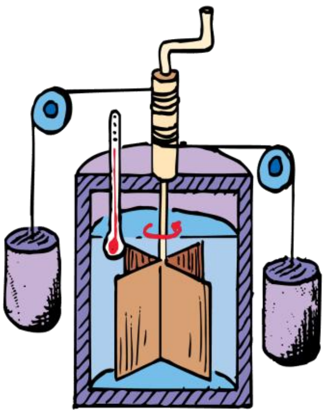
Kalorik teoriye ilk gerçek tepki Kont Rumford tarafından 1798 yılında yapılmıştır. Lavoisier'in ortaya koyduğu kalorik akışkanının gerçekten var olup olmadığını sorguluyordu. Şüpheciydi. Rumford, top fırlatma makinesi yapımında kullanılan malzemeleri incelemişti. Topun fırlatıldığı borunun yapılması için pirinç silindirin delgi aletiyle delinmesi gerekiyordu. Demir delgiyi döndürmek için gereken güç ise atlardan sağlanıyordu. Rumford, demir delgeçin silindir içerisinde ilerlerken sürtünmesi sonucu silindirin ısındığını farketti. Demir delginin pirinç üzerinde sürtünmesiyle ısı açığa çıkmıştı. Rumford delme sonucu çıkan artık kısımları dikkatle inceledi. Bu artıklar birebir silindirle aynı olan metalden olduğu, dolayısıyla kendilerinden hiçbir şey kaybetmediklerini düşündü. Yani ısı ortaya çıktığında maddesel bir kayıp yoktu.

Rumford ısı üretimini hesaplamak için bir deney düzeneği geliştirdi. Düzenek, içi su dolu dış ortamdan yalıtılmış bir kap ile kabın içine yerleştirilmiş bir pirinç silindirden oluşmaktadır. Pirinç silindiri delmek için silindir kendi etrafında döndürülmektedir. Rumford gözlemlerini şu şekilde yazmıştı:

"*Silindir dakikada 32 tur dönerken kısa bir zaman geçmesine rağmen silindirin dışına dokunurken elimi suya batırdığımda ısı açığa çıkmıştı ve bu, etrafı suyla çevrelenmiş silindirin hissedilebilir sıcaklığa ulaşmasından çok sonra olmamıştı.*

"Bir saatin sonunda, termometreyi suya koyduğumda, şimdiki sıcaklığının Fahrenheit ölçeğine göre 107 dereceye ulaştığını, yani sıcaklığının 47 derece daha yükseldiğini gördüm... İki saatin sonunda, suyun sıcaklığının 178^{o}F'a yükseldiğini buldum. 2 saat 20 dakikada sıcaklığın 200^{o}F olduğunu ve iki buçuk saat sonra suyun kaynadığını gördüm."

Rumford deneyinin sonucunda oluşan ısının ancak bir hareketliliğin sonucunda oluşabileceğinin altını çizmiştir. Bu modern anlamda ısıyı anlamak için aslında bir zemin oluşturuyordu. Ama biraz daha zamanın geçmesi ve başka bilim insanlarının çalışmalarının gün yüzüne çıkması gerekiyordu.



James Joule elektrik akımı geçen bir telin ısınması sonucu açığa çıkan enerjiyi hesaplamıştı. Kalorik teoriye göre bu durum şu şekilde açıklanıyordu: Pilde bulunan kalorik akışkan elektrik akımıyla birlikte tel üzerinde hareket ediyordu. Pil olmadan, belli bir mesafeden mıknatıs yardımıyla da telde elektrik akımı oluşturarak teli ısıtabildiğini gördü. Yani sistemde kalorik akışkan için bir kaynak yoktu.

Sonunda elektriksel bir aracıya ihtiyacın gereksiz olduğunu, ısının doğrudan bir kuvvetle üretilebileceğini düşündü. Bir dizi deney tasarladı. Yalıtılmış su dolu bir kaba kürekli çarkı yerleştirdi ve çıkrık yardımıyla döndürerek suyun çalkalanmasını sağladı. Çıkrığın dönmesiyle oluşan sürtünmenin kabı ısıtmasını sağladı. Makaraya yaklaşık 350kg (772 pound) kütle yerleştirmişti. 450g (1 pound) suyun 1 Fahrenheit derece yükselmesi için gereken ısı miktarı, 350 kg kütlenin 30.5cm (1 foot) düşmesi için gereken mekanik işe eşitti. Bu şekilde ısının mekaniksel denkliğini hesapladı. Sonuç olarak ısı ve mekanik iş rakamsal olarak denkti. Yapılan iş miktarı sayısal olarak ısı miktarına dönüştürülebiliyordu. 1847'de James Joule çalışmalarını bilimsel çevrelere sunmuştu.

Isı birimleri ve dönüşümleri:

James Joule'ün ısı ve iş denkliğini henüz sunmadan önce, ısının bir enerji türü olduğu henüz bilinmiyordu. Bu sebeple ısı için farklı enerji için farklı birimler kullanılıyordu. Isı için kalori birimi kullanılmaktaydı. Daha sonraki çalışmalarda kalorinin Joule cinsinden denkliğinin bulunması gerekmiştir.

- **1 kalori ne anlama gelir?** 1 kalori 1 gram suyun sıcaklığını 1 Celsius derece arttırabilmek için gereken enerjidir. Kalori birimi "cal" olarak gösterilir.
- **1 kalori ne kadar Joule'e denktir?**

5. ve 8. sınıfta ısının birimlerini kalori ve Joule cinsinden tanımlamış ve aralarındaki ilişkiyi

$$1\,cal = 4.18\,J$$

şeklinde öğrenmiştik. Başka bir ifadeyle

$$1\,J = 0.24\,cal\text{'dir.}$$

Fizik dersinin ilk ünitesinde vektör ve skaler büyülüklerden bahsetmiştik.

Hatırlatma: Sadece birim ve sayı belirtilmesi ile anlam kazanan büyüklüklere **skaler büyüklükler** denir. Anlam kazanabilmesi için, sayı ve birimin yanında yönün de belirtilmesi gereken büyüklüklere ise **vektörel büyüklükler** denir.

UYARI: Isı için sıcaktan soğuğa diyerek akış yönü belirtmemiz, vektörlerin sahip olduğu yön bilgisiyle aynı değildir. Kuzey, güney, doğu veya batı, ya da sağ sol tarzında bir yön ifadesi içermez.

Isı transfer edilen enerji olduğu için skaler bir büyüklüktür. Isı birimi türetilmiş bir büyüklüktür ve SI birimi Joule'dür.

Isı, transfer edilen enerjidir. Maddelerin karakteristik bir özelliği değildir. Sıcak olan cisimden/ortamdan soğuk olana doğru gerçekleşen bir enerji akışıdır. Bu enerji ancak transfer anında ortaya çıkar. Bu sebeple bir cismin veya ortamın ısısından bahsedemeyiz. Isı, iç enerjinin bir yerden diğerine geçişi olarak tanımlandığı için, hiçbir şey için "***ısısı var***" ya da "***ısı depolandı***" diyemeyiz. Bunun yerine **ısı bir yerden diğerine transfer edildi** deriz.

Epistemolojik Boyut: Bilginin Gerekçelendirilmesi (Öğretmen Konuşması)

Günlük hayatta yaptığımız gözlemlerin, ya da nasıl çalıştığını bilmediğimiz ama akıl yürüterek sonuca vardığımız durumlarda bazen kendimiz gerçekten uzak bilgiler üretebiliriz, Kalorik teori de olduğu gibi. Maddenin yapısı hakkında çok fazla bilginin mevcut olmadığı yıllarda bu tür teorilerin ortaya atılması şaşırtıcı değildir. Asıl şaşırtıcı olan yıllarca ısının bu şekilde davrandığını savunan bilim insanlarının, şüpheci yaklaşan bilim insanları tarafından deneysel sonuçlarla ikna edilerek savunulan teoriyi çürütmeleridir. Bizler de doğa ve doğada gerçekleşen olaylar hakkında gerçeğe yakın olmayan kavramalar üretmiş olabiliriz. Bu yüzden fizik dersinde verilen bilgilerle bu bilgilerimiz bir araya geldiğinde bilgilerimiz arasında çatışma durumu meydana gelir. Bu çatışmaları lütfen es geçmeyin, aksine üstüne giderek tartışın. Çünkü bu bilgiler doğru bilgiyi öğrendikten sonra bile sizin düşüncelerinizi etkileyebilir.

Epistemolojik Boyut: Bilginin Değişebilirliği (Öğretmen Konuşması)

Deney ve gözlemle ve aynı zamanda bilim insanlarının bakış açılarındaki farklılıkların bilimsel bilginin değişmesinde veya gelişmesinde nasıl rol oynadığı üzerinde konuşulur. Öğrencilerden bildikleri benzer örnekler varsa bu örnekleri derste paylaşmaları istenebilir. Bize sunulan bilgilerin ne kadar mantıklı olduğu veya doğruluğu üzerine tartışabiliriz. Bunun için rasyonel düşünce kadar deneyler de önemlidir. Buradan yola çıkarak öğrencilerin öğrendikleri fizik bilgilerinin mantığını test edebilmeleri için deney ve gözlem yapabilmeleri gerektiği vurgulanır. Her bir öğrencinin derste sunulan bilgiyi farklı yorumlayabildikleri ve aynı farkındalıkla yaklaşmadıklarına değinilebilir. Çünkü her birimiz kendimize has mantığımızla bilgilerin doğruluğunu test ederiz.

DERS PLANI-6 (Öz ısı – Q=m x c x ΔT)

Sınıf: 9

Ünite: Isı ve Sıcaklık

Konu: Isı, Sıcaklık ve İç Enerji

Süre: 2 saat

Kazanım: 9.1.5.4.Öz ısı ve ısı sığası kavramlarını açıklar.

a. Öz ısının maddeler için ayırt edici bir özellik olduğu vurgulanır.

b. Öğrencilerin farklı maddelerin öz ısılarını ısı-sıcaklık grafiklerinden hesaplamaları sağlanır.

c. Öğrencilerin öz ısıları farklı maddelerin sıcaklık değişimlerinin günlük hayattaki etkileri ile ilgili örnekler vermeleri sağlanır.

Epistemolojik Tartışma Sorusu:
[Bilginin yapısı]1. Sizin için fizikteki formüller ne anlam ifade ediyor?

Isı ve Sıcaklık Değişimi arasındaki ilişki: $Q = mc\Delta T$

- Bazı kaynaklar ısı ve sıcaklık değişimi arasındaki ilişkiyi $Q = mc\Delta T$ şeklinde, 9. sınıf fizik kitabımız ise $\Delta Q = mc\Delta T$ şeklinde ifade etmektedir. Bu formüllerden hangisinin mantıklı olduğunu nasıl bulabiliriz?

Bugün ısı ve sıcaklık değişimi arasındaki ilişkiyi incelemek için bir dizi deney ve gözlem yapacağız.

Deney 1(A): Isı ve Sıcaklık Değişimi Arasındaki İlişki Nedir?

Araç gereçler

- Su
- İspirto ocağı
- Bir cam beher
- 1 adet termometre
- Kronometre

Deneyin yapılışı

1. Cam beherin içerisine bir miktar su koyalım.

2. Suyun sıcaklığını termometre ile ölçelim tabloya kaydedelim.

3. Su dolu cam beheri ispirto ocağının üzerine yerleştirelim.

4. 2'şer dakika aralıklarla termometrenin gösterdiği değerleri tabloya kaydedelim.

5. Dakikalar arasında görülen sıcaklık değişimlerini hesaplayarak tabloya yazalım.

Ölçüm	Süre (dk.)	Sıcaklık (℃)	Sıcaklık Değişimi (℃)
1			
2			
3			
4			
5			
6			
7			

Sonuca Ulaşalım

1. Süre ilerledikçe suyun sıcaklığı nasıl değişti?

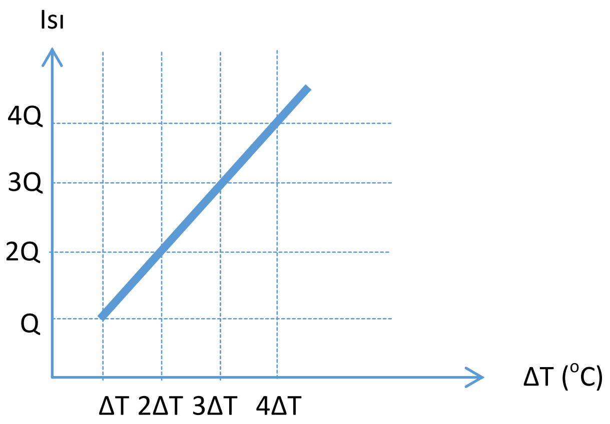
2. Verilen enerjinin sıcaklık değişimi ile ilişkisi nedir? Isı – sıcaklık grafiğini çizerek tartışalım.

Beklenen Cevaplar:

1. Eşit zaman aralıklarında ispirto ocağının eşit miktarda enerji verdiğini varsayarız. Dolayısıyla her aralıkta birbirine eşit sıcaklık değişimleri gözlemlenir.

2. Eşit zaman aralıklarında eşit sıcaklık değişimleri gözlemlendiğine göre, ısının büyüklüğü ve sıcaklık değişimi doğru orantılıdır.

Sıcaklık artışı eşit olduğu için, sıcaklık yerine sıcaklık değişimi kullanılabilir. Grafik şu hale gelir:



Bu grafik şu şekilde yorumlanır. Bir maddeye Q kadar ısı transfer edildiğinde ΔT kadar sıcaklık değişimi olur. Bir maddeye 2Q kadar ısı transfer edilirse, sıcaklık 2ΔT kadar artar. Bu grafikten yola çıkarak ısının sıcaklık değişimiyle doğru orantılı olduğunu buluruz. Isının sıcaklık değişimine oranının sabit olduğunu yine grafikten çıkarabiliriz.

SORU: Yaptığımız deneyde musluk suyu için bulduğumuz bu ilişki başka maddelerde geçerli midir?

Öğrencilerin tahminleri sınıfta dinlenir. Bu tahminler hipoteze çevrilir.

Hipotez 1: Isı ve sıcaklık değişimi arasındaki sabit oran farklı maddeler için aynıdır.

Hipotez 2: Isı ve sıcaklık değişimi arasındaki sabit oran farklı maddeler için farklıdır.

Öğrencileri gruplara ayırarak hipotezlerini test etmeleri için deney tasarlamalarını isteyelim.Öğrencilerin deney düzeneklerini kâğıt üzerinde planlamalarını isteyelim.

Deney 1(B): Farklı maddeler için Isı-Sıcaklık Değişimi Oranı Aynı Mıdır?

Araç gereçler

- Terazi
- Su
- Alkol
- Sıvı yağ
- Üç adet termometre

- Cam beher
- Üç adet özdeş deney tüpü
- Kronometre

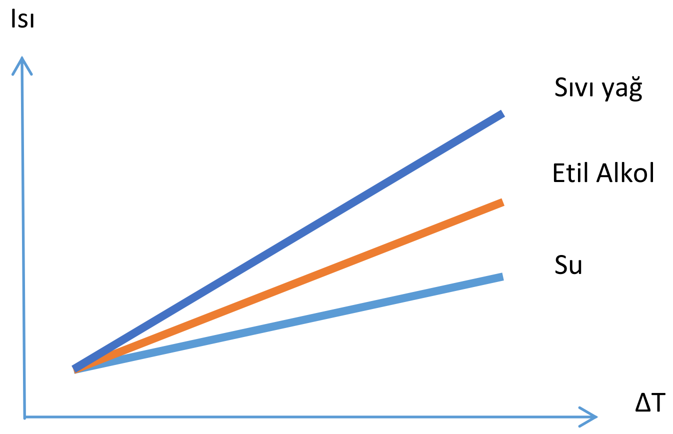
Deneyin yapılışı
1. Cam beheri sıcak su ile dolduralım.
2. Deney tüplerine eşit kütle ve sıcaklıkta su, alkol ve sıvı yağ koyalım.
3. Deney tüplerini dik olacak şekilde behere bantla tutturalım.
4. Tüplerdeki sıvılara termometre koyalım ve sıvıların ilk sıcaklık değerlerini ölçelim.
5. Belirli sürelerde termometre ile yaptığımız ölçümleri tabloya kaydedelim.

Sıcaklık (℃)	Su	Etil Alkol	Sıvı Yağ
İlk sıcaklık			
Tahminlerim			
1. Ölçüm			
2. Ölçüm			
3. Ölçüm			

Sonuca Ulaşalım
1. Tahminleriniz ve gözlem sonuçlarınız tutarlı mı? Farklılık varsa sebepleri ne(ler) olabilir?
2. Süre ilerledikçe sıvıların sıcakları nasıl değişti?
3. Sıvıları, sıcaklık artış miktarlarına göre büyükten küçüğe doğru sıralayınız.

Beklenen cevaplar
1 -2. Eşit miktarda verilen enerji sonucunda farklı sıvılarda farklı sıcaklık değişimleri gözlemlenecektir. Tek tek sıvılar incelendiğinde ise eşit sürelerde eşit miktarda sıcaklıklarının değiştiği gözlemlenir.
3. Sıvı yağ, etil alkol ve su.

3 sıvının ısı ve sıcaklık değişimi grafiğini bir grafik üzerinde çizdirelim.



Her bir sıvı için ısı- sıcaklık değişimi oranı farklıdır. Tek bir sıvıyı incelediğimizde ise ısı ve sıcaklık değişimi ilişkisinin su da olduğu gibi doğru orantılı olduğunu görürüz.

SORU: Isıtılan maddenin kütlesi değişirse ısı-sıcaklık değişimi oranı etkilenir mi?

Öğrencilerin tahminleri sınıfta dinlenir. Bu tahminler hipoteze çevrilir.

Hipotez 1: Isıtılan maddenin kütlesi değişirse, ısı ve sıcaklık değişimi arasındaki sabit oran değişmez.

Hipotez 2: Isıtılan maddenin kütlesi değişirse, ısı ve sıcaklık değişimi arasındaki sabit oran değişir.

Öğrencileri gruplara ayırarak hipotezlerini test etmeleri için deney tasarlamalarını isteyelim. Öğrencilerin deney düzeneklerini kâğıt üzerinde planlamalarını isteyelim.

Deney 1(C): Farklı kütlede bir madde için Isı-Sıcaklık Değişimi Oranı Aynı Mıdır?

Araç gereçler

- Su
- İspirto ocağı
- Bir ölçekli cam beher
- 1 adet termometre
- Kronometre

Deneyin yapılışı

1. Cam beheri 100 mL (~100 g) musluk suyu ile dolduralım. Sıcaklığı ölçüp tabloya kaydedelim.
2. Cam beheri ispirto ocağının üstüne yerleştirelim
3. Belirli aralıklarla termometrede okunan değerleri tabloya yazalım
4. İspirto ocağını kapatalım ve cam beherdeki suyun seviyesini 200 mL'ye (~200g) çıkaralım.
5. Cam beherdeki suyun sıcaklığını ölçelim ve ispirto ocağının üzerine tekrar yerleştirelim.
6. Belirli aralıklarla termometrede okunan değerleri tabloya yazalım.

Kütle (g)	Ölçüm No.	Süre (dk.)	Sıcaklık (℃)	Sıcaklık Değişimi (℃)
100g	1			
	2			
	3			
	4			
200g	1			
	2			
	3			
	4			

Sonuca Ulaşalım
1. 100g su ve 200g su için eşit sürelerde alınan sıcaklık değerlerini karşılaştıralım. Bir farklılık gözlemlediniz mi?
2. Suyun kütlesini değiştirdiğimizde ısı-sıcaklık değişimi oranı değişti mi?

Beklenen cevaplar:
1. Eşit zaman aralıklarını incelediğimizde 100g suyun sıcaklığı 200 g suya göre 2 kat artmıştır.
2. Suyun kütlesini değiştirdiğimizde ısı-sıcaklık değişimi oranı da değişti. Kütle ve sıcaklık değişimi ters orantılıdır.
Grafik çizdirilebilir.

SORU: Bu üç deneyin bulgularını toparlayacak olursak nasıl bir sonuca varırız?

1. Bir maddeye verilen enerji miktarı arttıkça sıcaklık değişimi doğru orantılı olarak artar.

$Q \; \alpha \; \Delta T$

2. Farklı maddeler için ısının sıcaklık değişimine oranı farklıdır.

$$\frac{Q}{\Delta T_1} = Sabit_1 \; ; \qquad \frac{Q}{\Delta T_2} = Sabit_2$$

3. Aynı maddenin farklı kütleleri için ısının sıcaklık değişimine oranı farklıdır. Kütle arttıkça sıcaklık değişimi azalır. Dolayısıyla kütle ve sıcaklık değişimi ters orantılıdır.

$$\frac{Q}{\Delta T} = m \times Sabit$$

Modelleme aktivitesinin ardından ulaştığımız matematiksel model:

$$\frac{Q}{\Delta T} = m \times Sabit; \quad Q = m \, x \, Sabit \, x \, \Delta T$$

Ortaya çıkan bu formülde sabit bir sayının ısı-sıcaklık değişimi oranına etki ettiğini görmekteyiz. Bu sabit değer, her madde için farklıdır dolayısıyla maddeler için ayırt edici bir özelliktir.

$$\frac{Q}{m \, \Delta T} = Sabit$$

Sabit değerin fiziksel olarak anlamı; 1 gram maddenin sıcaklığının 1℃ artması için gereken ısıdır. Bu sabit değer, **öz ısı** olarak tanımlanır ve “c” harfiyle gösterilir.

$$\frac{cal}{g \, ℃} = [Sabit]$$

SI birim sisteminde öz ısının birimi $\frac{J}{kg.℃}$ ‘dur.

Matematiksel model:

$$Q = m \times c \times \Delta T$$

Başta sorduğumuz sorunun cevabını bulmuş oluyoruz.

- Rasyonel düşünce ile de hangi formülün mantıksız olduğunu çıkarabilir miyiz?

Isının tanımını hatırlayacak olursak aktarılan enerji ısı olarak tanımlanmıştı. Öğrendiklerimizden yola çıkarak "Isı maddenin sıcaklığını değiştirmek için gereken enerji miktarıdır" diyebiliriz. *(Bu yarı doğrudur, çünkü hal değişimi esnasında sıcaklık değişmez. Bir sonraki derste bu tanımla tam doğru karşılığıyla değişitirlecektir.)* Aktarılan enerji olduğu için başta sıfır ısı aktarıldı sonra X kadar ısı aktarıldı, dolayısıyla sisteme X kadar enerji verilmiştir demek mantıksız hale gelmektedir. Çünkü ısı maddenin sahip olduğu bir özellik değildir. Maddenin ısısı diye bir kavram yoktur. Aktarılan enerji olduğu için ilk ve son ısı gibi ifadeler kullanamayız. Bu durumda ΔQ ifadesi mantıksızdır. Dolayısıyla kitaptaki formül yanlış verilmiştir.

9. sınıf kitabında verilen ısı-sıcaklık grafiği doğru verilmiş midir?

(*Tartışalım.*)

Özısı kavramını detaylı incelemeye geçiş:

Farklı maddelere ait öz ısı değerlerini inceleyelim. (Tablo verilir).

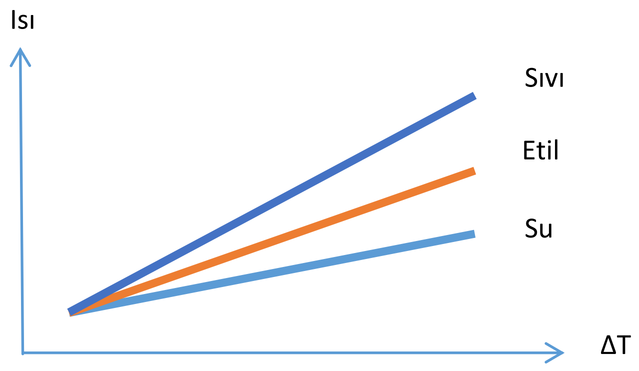
Madde	**c (cal/g. ℃)**
Hava (deniz seviyesinde)	0.24
Etil Alkol	0.58
Alüminyum	0.21
Asfalt	0.22
Tebeşir	0.18
Buz (0°C)	0.50
Demir	0.11
Kurşun	0.031
Cıva	0.033
Tuz (NaCl)	0.21
Kuru toprak	0.19
Yaş toprak	0.35
Kar	0.50
Teflon	0.28
Bakır	0.09
Saf su (20°C)	1.00

- Öz ısısı yüksek olan maddeleri inceleyelim. Öz ısısı düşük olan maddeleri inceleyelim. Bir maddenin öz ısısının düşük ya da yüksek olması ne anlama gelir?
- Deneyde kullandığımız su ve etil alkol için verilen değerler elde ettiğiniz grafikle uyuşuyor mu?
- Tablodaki maddelere eşit ısı verirsek, en fazla sıcaklık değişimi hangisinde gözlenir?

Beklenen Cevaplar:

Öz ısısı düşük olan maddeler: kurşun ve cıva, öz ısısı yüksek olan maddeler: saf su ve etil alkol. 1 gram saf suyun sıcaklığını 1 ℃derece arttırmak 1 g kurşun veya 1 g cıvaya göre daha fazla ısı gerektirir.

Suyun öz ısısı 1.00 cal/g ℃ etil alkolün öz ısısı ise 0.58 cal/g ℃ dır. Sonuç olarak grafikteki gösterimle bu veriler birbiriyle uyuşmaktadır.



En fazla sıcaklık değişimi öz ısı en düşük olan maddede gözlenir: Kurşun

Özısıdan ısı kapasitesine geçiş:

Öz ısı maddelerin 1g'ı için hesaplanan değerlerdir. Ancak kullandığımız maddeler farklı kütlelerde olabilir. Farklı miktarlardaki maddelerin sıcaklıklarını 1°C arttırmak için gerekli enerji aynı değildir. Bir maddenin farklı kütlelerdeki sıcaklığını 1°C arttırmak için gereken ısıya **ısı sığası** denir. C harfi ile gösterilir.

$$Q = m \times \underbrace{c \times \Delta T}$$

C: ısı sığası

$$C = m \times c; \quad [C] = g \times \frac{cal}{g\,°C}\ ; \quad [C] = \frac{cal}{°C}$$

şeklinde ifade edilir.

Öz ısı kavramını açıkladık ve sadece özısı ile bağlantısını verdik. Peki sizin için ne ifade ediyor ısı kapasitesi? Herhangi başka bir kavramla özdeşleştirebildiniz mi?

Tartışalım.

SORU: Isı sığası maddeler için ayırt edici bir özellik midir? Tartışalım.

Asfalt (0.22) ve demirin (0.11) öz ısı değerlerini kullanalım.

50 g asfaltın ısı sığası: C = 0.22 x 50 = 1,1 cal/ ℃

100g demirin ısı sığası: C = 0.11 x 100 = 1,1 cal/ ℃

İki farklı madde için ısı sığası aynı olabilmektedir. Bu yüzden ısı sığalarına bakarak maddeleri ayırt edemeyiz.

Epistemolojik Boyut: Bilginin Gerekçelendirilmesi (Öğretmen Konuşması)

Epistemolojik Tartışma Soruları:
[Bilginin Gerekçelendirilmesi]1. Sizce yaptığımız deneyin sonuçları mantıklı mıydı? Neden?
[Bilginin Gerekçelendirilmesi]2. Fizik dersinde ne amaçla deney yaptık? Deneyin öğrenmenize nasıl bir katkısı oldu?
[Bilginin Yapısı]3. Fizikteki formüller size ne anlam ifade ediyor?
[Bilginin Yapısı]4. Fizikte formülleri bilmek öğrenmenizde nasıl bir rol oynuyor? (Anlamlı bir şekilde ilişkileri görmeyi mi? Doğrudan ezberleyip matematiksel problemleri çözmeyi mi? vs.)

Deney yapmak bizlere farklı durumları gözlemleyebilmek için özgürlük sağlar. Bu şekilde kavramlar arası ilişkileri kontrollü bir şekilde deneyerek ortaya çıkarmak mümkündür. Kavramlar arası ilişkiler matematiksel olarak ifade edilebilir. Matematiksel ifadeler formüllerdir. Ama formülleri işlem yapmaktan ziyade kavramlar arası ilişkileri ifade etmek için kullanırız.

Formülleri kullandığımızda aslında matematiksel ifadenin mantıklı olup olmadığını test etmiş oluruz. Emin olduğumuz formülleri, farklı durumlarda yaptığımız çıkarımların mantıklı olup olmadığını test etmek için kullanırız. Amacımız sadece hesap yapmak değildir. Testlerde pek çok sorunun sadece matematiksel işlem yapabilme yeteneğinizi ölçtüğünü görüyoruz. Bu da bizde formüller fizikte ezberlenmesi gereken ifadelerdir düşüncesi oluşabilir. Formüllerin amacı bu değildir. Formüller birçok gözlem sonrasında farklı kavramlar arasındaki ilişkileri sade ve öz biçimde ifade etmek için kullanılır.

Formüllerin çıkış mantığını öğrendiğimizdeyse bu anlamsız ifadeler olarak formülleri ezberleme durumundan kurtulabiliriz. Zaten formülleri anlamlı kılan kavramsal olarak ne anlama geldiklerini yorumlayabilmektir.

Bundan sonraki sayfalarda hep kavramsal hem de epistemolojik boyutları aktive edecek sorular içermektedir. "Neleri Biliyorum?" ders öncesinde, "Neler öğrendim?" epistemolojik tartışmalardan sonra öğrenciler tarafından doldurulacaktır.

9. Sınıf Isı ve Sıcaklık Ünitesi (1)

Neleri biliyorum?

1. Önceki derslerde öğrendiğiniz ve günlük hayatta tecrübe ettiğiniz bilgiler ısı ve sıcaklık ünitesini anlamanızı nasıl etkileyecektir?

2. Enerji ünitesinde öğrendiklerim (örnek: enerji kavramı, enerjinin türleri gibi) ısı ve sıcaklık ünitesini anlamamda:

a. yararı olmayacaktır. Çünkü iki ünitenin konuları birbirinden farklıdır.

b. yararı olamayacaktır. Çünkü ________________________________

c. yararı olacaktır. Ama nasıl olacağını bilmiyorum.

d. yararı olacaktır. Çünkü _____________________________________

3. Günlük hayatta sıcaklık ve ısı kavramlarını hangi durumlarda ve ne için kullanırsınız? Örnek vererek açıklayınız.

9. Sınıf Isı ve Sıcaklık Ünitesi (1)

Neler öğrendim?

1. Bu derste öğrendiğim yeni kavramlar şunlardır:

Bu kavramları şu şekilde açıklarım:

2. Enerji kavramı ile ısı, sıcaklık ve iç enerji kavramları arasında ilişki var mıdır? Varsa, bu ilişkileri birer cümle ile ifade ediniz. Söz konusu ilişki fiziği öğrenmenizde nasıl bir rol oynar?

3. Günlük hayattan bildikleriniz fiziğin öğrenmenizde nasıl bir rol oynuyor?

4. Doğru olarak öğrendiğinizi düşündüğünüz bilgileriniz değişebilir mi? **Evet** / **Hayır**

Cevabınız evet ise; "Kendi bilgilerim değişir çünkü:…" cümlesini,

Cevabınız hayır ise; "Kendi bilgilerim değişmez çünkü ..." cümlesini tamamlayınız.

9. Sınıf Isı ve Sıcaklık Ünitesi (2)

Neleri biliyorum?

1. Bir maddenin sıcaklığı artarsa, kinetik enerjisi hakkında ne söylenebilir?

2. Moleküller arası etkileşimi çizerek nasıl gösterirsiniz?

Şekil 1. Düşük sıcaklıkta maddenin molekülleri arasındaki etkileşim.

Şekil 2. Daha yüksek sıcaklıkta maddenin molekülleri arasındaki etkileşim.

3. Farklı sıcaklıklardaki iki cisim temas ettirilirse, tahminen neler gözlemlersiniz?

4. Günlük hayatta yaptığınız gözlemler bu soruları cevaplamanıza yardımcı oldu mu? Olduysa, bu gözlemlerden birini örnek olarak yazınız.

5.Günlük hayattan bildiklerimiz fiziğin öğrenilmesinde nasıl bir rol oynuyor?

6. Size sunulan bir bilginin veya bir soruya verilen cevabın mantıklı olup olmadığına nasıl karar verirsiniz?

Deneyelim – Isı Alışverişi Ne Zaman Biter?

Araç gereçler

İki adet plastik bardak

Soğuk ve sıcak su

Pipet ya da ince boru

Mandal

İki adet termometre

Cam macun ya da oyun hamuru

Deneyin yapılışı

1. Plastik bardakların tabanlarına yakın bir yerden birer küçük delik açalım.
2. Plastik bardakları birleştirecek şekilde pipetin uçlarını deliklerden geçirelim.
3. Pipetin deliklerden girdiği uçlarını oyun hamuruyla sıkıştıralım.
4. Pipeti ortasından bir mandal ile sıkıştıralım.
5. Plastik bardaklara eşit miktarda birine soğuk diğerine sıcak olmak üzere su koyalım.
6. Kaplardaki suların başlangıç sıcaklıklarını termometre ile ölçerek tabloya kaydedelim.
7. Mandalı çıkaralım ve belirli aralıklarla termometreleri gözlemleyip verileri kaydedelim.

Kap	İlk Sıcaklık (°C)	1dk (°C)	2dk (°C)	3dk (°C)	4dk (°C)	5dk (°C)	6dk (°C)
1.							
2.							

Sonuca ulaşalım

Aldığımız verileri kullanarak aşağıdaki soruları cevaplayalım.

- *Birinci kaptaki suyun sıcaklığı nasıl değişti? Neden?*
- *İkinci kaptaki suyun sıcaklığı nasıl değişti? Neden?*
- *Kaplardaki suların son sıcaklıkları ne oldu? Neden?*

Kontrol Edelim – Bu Simülasyon Doğru Çalışıyor mu?

1. Aynı sıcaklıktaki demir parçası ve tuğlayı temas ettirdiğimizde:
a. Demir parçasının sıcaklığı ________________.
b. Tuğlanın sıcaklığı ________________.
Çünkü ____.
Şimdi simülasyonda deneyelim. Simülasyon doğru çalışıyor mu? Evet / Hayır

2. Suyla aynı sıcaklıktaki demir parçası su dolu kaba konulduğunda:
a. Demir parçasının sıcaklığı ________________.
b. Suyun sıcaklığı ________________.
Çünkü ____.
Simülasyon doğru çalışıyor mu? Evet / Hayır

3. Suyla aynı sıcaklıktaki tuğla su dolu kaba konulduğunda:
a. Tuğlanın sıcaklığı ________________.
b. Suyun sıcaklığı ________________.
Çünkü ____.
Simülasyon doğru çalışıyor mu? Evet / Hayır

4. Kaptaki suyu kaynatana kadar ısıtalım. Sonra içine demir parçasını koyalım. Bu durumda:
a. Demir parçasının sıcaklığı ________________.
b. Suyun sıcaklığı ________________.
Çünkü ____.
Simülasyon doğru çalışıyor mu? Evet / Hayır

5. Demir parçasını ısıtalım. Tezgahta duran tuğla ile temas ettirelim. Temas ettirdikten sonra:
a. Demir parçasının sıcaklığı ________________.
b. Tuğlanın sıcaklığı ________________.
Çünkü ____.
Simülasyon doğru çalışıyor mu? Evet / Hayır

9. Sınıf Isı ve Sıcaklık Ünitesi (3)

Neler öğrendim?

1. Bu derste öğrendiğim yeni kavram(lar):

Bu kavram(lar)ı şu şekilde açıklarım:

2. Bu derste yaptığımız deneyin amacı neydi? Çıkarımlarınızla birlikte yazınız.

3. Bu derste yaptığımız deneyin konuyu anlamama katkısı **oldu** / **olmadı**.

Çünkü;

9. Sınıf Isı ve Sıcaklık Ünitesi (4)

Neleri biliyorum?

1. Hangi termometre çeşitlerini biliyorum?

2. Termometreler nasıl çalışır?

3. Termometrelerle ilgili başka neler biliyorum?

4. Hangi sıcaklık birimlerini biliyorum?

5. Termometrelerle ilgili tecrübelerim termometrelerin yapısını anlamamda nasıl bir rol oynayabilir?

Termometreler

1. Bugün üzerinde konuştuğumuz sıcaklık ölçekleriyle ilgili tabloyu dolduralım.

Sıcaklık Ölçeği	**Sembolü**	**Suyun donma sıcaklığı**	**Suyun kaynama sıcaklığı**
Fahrenheit			

2. Farklı sıcaklık birimlerinin ortaya çıkmasının nedeni nedir?

3. Günümüzde kullanılan bu üç termometrede, suyun donması ve kaynaması sizce neden referans noktaları olarak belirlenmiştir?

4. Öğrendiğiniz bilgileri kullanarak, yeni bir sıcaklık birimi ortaya çıkarabilir misiniz? Nasıl?

9. Sınıf Isı ve Sıcaklık Ünitesi (4)

Haydi Düşünelim!

1. Fizikte bugün bilinenler gelecekte değişebilir mi? **Evet** / **Hayır**

Cevabınız evet ise; Fizik bilgileri nasıl değişebilir?

Cevabınız hayır ise; Fizik bilgileri neden değişmez?

2. Kendi bilgilerim değişebilir mi? **Evet** / **Hayır**

Cevabınız evet ise; "Kendi bilgilerim değişir çünkü:..." cümlesini,

APPENDIX O

RAW DATA

CLASS	GENDER	METHOD	AGE	PPHYSCG	PREPPEQ	PREHTAT	POSTPPEQ	POSTHTAT
3	1	1	15	77,75	105	13	93	22
3	1	1	15	71,75	103	40	93	38
3	1	1	15	77,75	106	42	107	43
3	1	1	15	71,75	106	35	109	34
3	2	1	14	78,25	99	27	103	33
3	1	1	15	73,25	96	18	84	25
3	2	1	14	79,00	93	22	92	34
3	2	1	14	77,75	118	25	108	33
3	2	1	14	70,25	101	13	91	23
3	2	1	15	74,25	109	29	108	43
3	1	1	15	75,50	106	20	106	26
3	1	1	15	60,50	103	28	118	37
3	2	1	15	59,50	92	33	100	27
3	2	1	15	67,50	115	22	100	28
3	1	1	15	75,25	104	25	109	42
3	1	1	14	68,54	103	26	103	30
3	1	1	14	68,75	100	21	118	41
3	1	1	14	56,00	106	32	109	18
3	1	1	15	63,50	100	20	106	25
3	2	1	15	67,25	96	28	104	24
3	2	1	15	84,00	78	16	83	30
3	2	1	15	70,50	90	31	82	37
3	2	1	14	71,00	103	25	98	34
3	1	1	15	85,25	107	28	104	29
3	1	1	15	50,75	90	25	87	41

3	2	1	15	70,00	90	24	87	31
3	2	1	15	59,25	85	37	82	39
3	2	1	14	76,50	103	22	109	31
3	1	1	15	70,75	101	13	76	17
3	1	1	15	57,00	95	37	90	17
1	2	2	15	70,50	97	24	104	38
1	2	2	15	69,00	118	48	122	59
1	1	2	15	75,61	106	30	111	56
1	1	2	15	71,25	116	35	99	43
1	1	2	15	76,25	90	30	102	39
1	1	2	15	86,00	105	25	107	44
1	1	2	15	67,75	101	14	111	24
1	1	2	15	68,50	104	14	96	31
1	1	2	16	51,00	118	25	121	50
1	2	2	15	76,25	104	26	90	23
1	1	2	15	76,50	110	25	113	42
1	1	2	15	73,75	113	22	118	33
1	1	2	15	72,00	105	41	109	41
1	1	2	15	71,25	109	26	120	43
1	2	2	16	82,25	100	32	105	16
1	2	2	15	56,75	78	13	89	20
1	2	2	15	74,00	104	35	100	47
1	2	2	15	78,00	121	17	103	23
1	1	2	14	59,00	100	39	116	48
1	1	2	15	79,25	115	14	121	26
1	1	2	15	76,75	114	35	101	38
1	1	2	16	86,25	99	25	106	44
1	2	2	15	72,75	93	12	112	31
1	2	2	15	76,50	112	43	109	51
1	2	2	16	68,00	96	20	105	47
1	2	2	15	65,00	111	24	121	39
1	2	2	16	85,00	103	38	105	46
1	2	2	15	80,25	104	34	108	39
1	1	2	15	68,25	100	13	83	25
1	1	2	14	70,50	101	25	106	27
1	1	2	15	65,00	103	19	106	29
1	1	2	15	70,50	94	26	97	51
6	1	3	15	67,00	115	22	126	42
6	1	3	15	81,25	109	13	116	43
6	2	3	15	65,25	93	10	109	30

6	1	3	15	71,25	98	23	101	20
6	1	3	15	82,75	101	36	107	50
6	1	3	15	65,50	99	15	106	58
6	2	3	16	75,75	93	25	113	40
6	1	3	16	75,25	115	20	116	48
6	1	3	15	88,50	110	28	120	45
6	1	3	15	67,50	86	18	88	34
6	1	3	15	75,25	111	23	113	54
6	1	3	15	70,50	103	29	114	41
6	1	3	15	74,75	115	27	108	61
6	2	3	15	61,00	102	22	105	29
6	2	3	15	78,25	97	23	114	31
6	1	3	15	61,25	100	14	116	17
6	1	3	15	72,25	109	30	107	69
6	1	3	15	66,00	97	23	87	46
6	1	3	15	70,00	98	20	100	49
6	2	3	16	69,75	104	19	111	35
6	2	3	15	87,00	106	34	97	45
6	2	3	15	69,25	111	20	114	47
6	1	3	15	82,50	101	14	85	26
6	2	3	15	53,50	88	17	102	37
6	2	3	14	76,50	81	30	108	50
6	2	3	15	66,25	83	19	86	35
2	1	2	15	73,50	87	38	105	49
2	2	2	15	61,50	100	15	100	31
2	1	2	15	78,00	98	16	91	34
2	2	2	14	73,75	111	28	108	41
2	1	2	15	76,50	92	23	114	37
2	1	2	15	77,00	105	34	105	48
2	1	2	15	80,25	113	26	100	43
2	2	2	15	79,00	101	29	88	47
2	1	2	16	82,75	106	20	105	37
2	2	2	15	82,50	103	20	113	36
2	1	2	15	75,50	96	41	103	47
2	1	2	16	71,50	99	28	86	30
2	2	2	14	85,25	105	22	122	46
2	1	2	14	59,00	116	20	116	38
2	1	2	15	79,00	109	33	101	44
2	1	2	15	78,75	97	26	96	43
2	1	2	16	77,25	98	20	103	36

2	1	2	15	67,25	108	21	103	45
2	1	2	15	84,00	99	20	97	34
2	2	2	14	74,00	100	26	103	46
2	1	2	14	77,00	104	20	113	32
2	1	2	15	80,50	95	31	100	36
2	1	2	15	75,50	109	32	119	50
2	1	2	15	80,25	91	35	92	44
2	1	2	15	69,75	92	29	90	31
2	2	2	15	66,25	102	32	107	41
2	1	2	16	70,00	107	31	108	36
2	2	2	14	70,75	90	12	87	12
5	2	3	16	73,00	117	13	121	47
5	2	3	15	78,75	123	23	122	47
5	1	3	15	87,75	107	35	115	54
5	1	3	15	67,50	99	35	96	30
5	1	3	14	66,00	114	14	107	34
5	1	3	15	68,00	97	32	86	50
5	1	3	14	81,25	78	41	88	52
5	2	3	15	50,00	94	24	103	27
5	2	3	15	83,25	94	29	95	40
5	2	3	16	72,25	112	26	114	58
5	1	3	15	73,00	102	24	106	39
5	1	3	15	77,00	100	25	106	40
5	1	3	15	85,00	94	26	101	47
5	2	3	15	73,00	100	31	98	52
5	2	3	15	88,25	119	38	120	52
5	1	3	15	63,75	108	18	89	25
5	2	3	15	79,00	102	37	101	55
5	2	3	14	82,00	98	36	113	57
5	1	3	15	70,75	106	17	108	47
5	1	3	15	74,50	96	41	103	27
5	2	3	16	70,50	110	15	119	45
5	1	3	14	81,50	103	30	120	42
5	1	3	14	91,50	94	41	101	54
5	1	3	14	84,25	96	27	86	37
5	1	3	15	63,75	116	27	110	36
5	2	3	15	69,75	122	24	125	38
5	1	3	15	75,25	84	18	92	53
5	2	3	15	79,25	104	26	101	50
5	1	3	14	82,25	98	25	111	50

5	1	3	15	79,75	94	23	104	40
5	1	3	15	77,75	83	26	102	42
4	1	1	15	73,75	109	20	113	16
4	1	1	15	82,75	103	26	110	33
4	1	1	15	71,75	101	37	105	28
4	2	1	14	73,75	99	16	102	27
4	2	1	15	74,75	104	42	106	35
4	2	1	15	65,75	104	30	99	28
4	2	1	15	64,50	110	30	94	34
4	1	1	15	73,75	110	36	114	27
4	1	1	15	74,50	102	20	110	21
4	1	1	15	85,00	111	29	106	32
4	1	1	15	83,00	113	17	103	18
4	2	1	15	68,75	86	30	91	17
4	1	1	15	74,50	103	40	98	25
4	1	1	15	70,50	101	28	113	25
4	1	1	14	77,50	109	22	97	29
4	2	1	15	64,50	110	23	122	43
4	1	1	15	74,25	94	26	89	17
4	1	1	15	67,50	102	25	84	35
4	1	1	15	80,00	106	29	100	19
4	2	1	15	59,25	90	24	88	17
4	1	1	15	75,75	119	22	94	32
4	1	1	15	75,00	121	27	117	26
4	2	1	15	75,75	113	26	124	36
4	2	1	15	70,25	115	15	116	23
4	1	1	15	87,00	113	32	102	28

APPENDIX P

KEYWORDS

- Epistemology
- Epistemological beliefs
- Epistemological understanding
- Epistemic cognition
- Epistemic instructional activities
- Epistemological activities
- Epistemological interventions
- Domain-specific epistemological beliefs
- Measurement of epistemological beliefs
- Personal epistemology
- Explicit epistemological interventions
- Scientific epistemology
- Scientific inquiry
- Explicit and implicit interventions
- Physics
- Physics achievement
- Heat and temperature

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PUBLICATIONS

International (Papers)

1. Oktay, O. & **Eryurt, K.** (2012). How high school students represent the image of scientists in their minds. *Procedia: Social and Behaviorial Sciences*, *46*, p. 2482-2486.

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