DESCRIPTIVE STUDIES OF THE RELATIONS BETWEEN PERSONAL EPISTEMOLOGY AND SELF-REGULATED LEARNING

A Dissertation

by

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ABSTRACT

In my dissertation, I have examined the relations between students' personal epistemologies and self-regulated learning. I have conducted three independent studies for my three-article dissertation. The first study is a meta–analytic research of the relations between personal epistemology and self-regulated learning. I analyzed 40 published articles in the literature and computed an overall effect size for the reported relations between personal epistemology and self-regulated learning. I also examined the roles of the moderator factors (i.e., culture, age, sex, and subject area) on those relations. The meta-analysis revealed a small but statistically significant mean effect size (r=.24 under fixed effects model, and r=.22 under random effects model). The moderator analyses revealed that although students' grade level did not statistically significantly predict the relations under fixed- and random-effects models, the effects of culture, sex, and subject area on the relations were statistically significant.

For my second study, I collected quantitative data at a high school in Turkey to explore the relations between the students' personal epistemologies and self-regulated learning. Two-hundred-nine high school students at the school in Turkey participated in the study. Results from the structural equation modeling (SEM) showed that students' personal epistemologies predict both their motivation and meta-cognitive strategies to learn physics.

For my third study, I employed a case study in order to explore high school students' personal epistemologies in school science practice in a STEM charter school located in South Central United States. For this study, I observed nine students in a

physics class and conducted individual and group interviews with them over six weeks. I audio recorded students' conversations in class. Results showed that the students hold naïve beliefs about the nature of scientific knowledge and knowing. The students viewed scientific theories as ideas or thoughts that needed to be tested. In their view, a school science experiment had either a correct or an incorrect answer.

The three studies I conducted and report in this document help us better comprehend how personal epistemology is related to self-regulated learning and to design instruction to help students' understand the nature of scientific knowledge.

DEDICATION

This dissertation is dedicated to my beloved parents, Halil and Selma Alpaslan. I would like to dedicate this work to my wife, Fatma Alpaslan and my son, Erdem Batu Alpaslan.

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Finally, thanks to my mother and father for their encouragement and to my wife for her patience and love.

NOMENCLATURE

CFA	Confirmatory Factor Analysis
EBQ	Epistemic Beliefs Questionnaire
MSLQ	Motivated Strategies for Learning Questionnaire
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Modeling

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CHAPTER I

INTRODUCTION

Current vision for science teaching and learning requires students to develop critical thinking and problem solving skills along with some basic understanding of scientific knowledge. In the 21st century, students learning science are expected to (a) generate and evaluate scientific explanations and evidences, (b) understand the nature of scientific knowledge, and (c) participate productively in technological and scientific discourse (Duschl, 2008; National Research Council [NRC], 2007; Sandoval, 2005). This expectation highlights the importance of learners' personal epistemologies towards scientific knowledge. One's personal epistemology plays a major role in her critical thinking and problem solving skills (Hofer, 2008). Beliefs in scientific knowledge and its generation may have direct impact on how one interprets the scientific knowledge provided and puts into practice during decision making (Deng, Chen, Tsai, & Chai, 2011; Ryder & Leach, 2000).

Studies which address students' epistemic perspectives on scientific knowledge have pointed out that students develop epistemic perspectives on public scientific knowledge as a consequence of their interactions with science in school and society (Elby & Hammer, 2010; Hofer & Pintrich, 2002; Leach, 2006). Typically, at schools theoretical ideas are presented to the students as an accumulation of facts (Sandoval, 2005; Sandoval & Reiser, 2004). This leads most students to develop a naïve view of scientific knowledge (Driver, Leach, Millar, & Scott, 1996). Students see that the best way to learn science is to memorize the applications of scientific procedures and formulas (Hammer, 1994; Lee, Johanson, & Tsai, 2008; Sandoval & Reiser, 2004). However, very few students develop a sophisticated understanding of scientific knowledge that recognizes science as a process of building and revising models and theories (Driver et al., 1996; Hammer, 1994; Smith & Wenk, 2006).

Although the influence of personal epistemology in human cognition is well documented in psychological studies, in science education research personal epistemology has been studied only over the last decade (Yang & Tsai, 2012). Examining students' personal epistemologies is useful for three reasons in science education. First, understanding of scientific knowledge is viewed as a statistically significant component of understanding science, and thus as an outcome of science education (NRC, 2007). Second, students' ideas about scientific knowledge may influence their interpretations of the result of a practical task or understanding the logical structures behind teachers' explanations (Leach, Millar, Ryder, & Sere, 2000). Lastly, examining students' personal epistemologies might determine how science curriculum contributes to students' understanding of scientific knowledge.

Literature Review Summary

A growing body of research provides evidence that personal epistemology plays an important role in students' learning, including motivation, argumentation, problem-solving, achievement, decision-making process, source choices, and skills of critical thinking (Elby & Hammer, 2010; Feucht & Bendixen, 2010; Hofer & Pintrich, 1997; 2002; Kittleson, 2011; Nussbaum, Sinatra, & Poliquin, 2008; Sandoval, 2005; 2009; Sandoval & Cam, 2010; Wu & Tsai, 2011). Studies in science education have reported that naive learners are more likely to memorize science concepts (Hammer, 1994; Tsai, Ho, Liang, & Lin, 2011). Although some dimensions may not be correlated to scientific reasoning, sophisticated learners on justification and development of knowledge tend to have high-scientific reasoning skills (Wu & Tsai, 2011). Similarly, sophisticated learners are more willing to collaborate with others in teams (Hogan, 1999).

Studies report that students' personal epistemologies may directly and indirectly influence their scientific practices (Havdala & Ashkenazi, 2007; Sandoval, 2005). Students viewed the purpose of science as finding the right answer out about the world (Sandoval & Morrison, 2003). Students did not recognize the role and quality of evidence in building scientific theories (Smith & Wenk, 2006). Students had difficulties in identifying relationships between variables, differentiating evidence from information sources, and using data to develop convincing evidence (Wu & Wu, 2011).

Some researchers have examined students' epistemologies within the context of their scientific practices. The underlying assumption that guided these studies was that knowledge is socially constructed and so the students' scientific epistemologies might be constituted through situated interaction (Kelly, MacDonald, & Wickman, 2012; Yang & Tsai, 2012). In this view, students construct and justify knowledge through social interaction in a community (Kelly, 2008). Students' dissenting positions in group decisions represented a way of understanding the differential influence of individual contributions to the group interpretations (Kelly, Crawford, & Green, 2001). Each student's epistemic perspective contributes to the group's knowledge construction and mutual agreement (Sandoval & Reiser, 2004).

Personal epistemology has been linked to students' thinking and learning in many ways including conceptual change learning, directing their perception and attention to particular features of information, and strategy use (Patrick & Pintrich, 2001). A naïve belief about the certainty and simplicity of knowledge leads the learner to look for a simple answer for the given task: however, a sophisticated learner engages in a deep learning process and critical thinking to complete the given task (Muis, 2007; Muis & Franco, 2009).

Rationale for Proposed Papers

Research in both science education and the learning sciences has contributed to our understandings of students' ideas about the nature of science knowledge. Researchers in both areas have suggested that epistemological research should be extended the following ways:

- Studies of epistemology should be focused on students' scientific practices (Elby & Hammer, 2010; Sandoval, 2005; 2009) because students learn from their practices of science.
- Studies of epistemology should be undertaken via naturalistic studies (Elby & Hammer, 2001; Kelly et al., 2012; Yang & Tsai, 2012) to examine how context influences ideas about science;
- Studies of epistemology should combine epistemology from psychological and social perspectives in the context of science (Kelly & Crawford, 1997; Kelly et al., 2012; Sandoval, 2009) because science is a social practice.

- Studies of epistemology should pay attention to domain-specificity and analyzing complex interplays among personal epistemology and learning approaches (Yang & Tsai, 2012).

In my first study, I conducted a meta–analytic study of the relations between personal epistemology and self-regulated learning. Using a meta-analytical approach, I determined the level of relations between the students' personal epistemologies and self-regulated learning strategies (effect size) and how that relationship varies in moderator effects such as culture, sex, age, and subject area. In my second paper, I proposed determining the relationship between physics-related personal epistemologies and self-regulated learning skills among Turkish high school students, and the role of relationship on their physics achievement. Adapting Muis's (2007) theoretical model, I constructed a model to explain the relationships among the personal epistemologies, self-regulated learning skills, and academic achievements of the Turkish high school students. In my third paper, I explored high school students' personal epistemologies in school science practice in South US. Examining the personal epistemologies in scientific practice is of importance to determine the contributions of the curricular and social contexts to the students' personal epistemologies. I utilized Cobb's and his colleague's (2001) interpretive framework that allows the researcher to analyze students' practices from the social and psychological perspectives. Studying students' personal epistemologies from both perspectives within one study may contribute to our understanding of personal epistemology in classroom settings.

CHAPTER II

PERSONAL EPISTEMOLOGY AND SELF-REGULATION LEARNING: A META-ANALYTIC REVIEW

Researchers have been interested in the role of individuals' beliefs in their learning processes. Studies focusing on personal epistemology and self-regulated learning have assumed that both are closely linked to each other (Hofer, 2008; Moschner, Anschuetz, Wernke, & Wagener, 2008; Pintrich, 2002). These studies have consistently demonstrated statistically significant relationships between the students' personal epistemologies and self-regulated learning. In the present study, I wanted to examine the relationship between the personal epistemologies and self-regulated learning from the primary school level through college level, and how this relationship is differentiated by moderator variables (e.g., culture, age, subject area, and sex). A meta-analytic review of studies concerning personal epistemology and self-regulated learning help us know the overall statistical power of studies.

Recently, researchers have begun associating personal epistemology with self-regulated learning. Some researchers (e.g., Hofer & Pintrich, 1997) stated that personal epistemology served as goals that guide self-regulated learning. Other researchers (Bromme, Pieschl, Stahl, 2010; Muis, 2007) pointed out that personal epistemology is likely to shape learners perceptions of tasks and therefore how the tasks are approached. Although the theoretical models exist to explain how personal epistemology associates with self-regulated learning, it is important to know how empirical studies support the relationship between personal epistemology and self-regulated learning. Therefore, I believe that taking a closer look at the strength of the relationship between personal epistemology and self-regulated learning may better guide the future studies. Moreover, meta-analysis enabled me to explain the variation by including the moderator effects, such as, culture, sex, age, and subject area that underpin the theories of personal epistemology and self-regulated learning (e. g., Hofer, 2008; Zimmerman, 2008). For example, Hofer (2008) states that research in the relationship between personal epistemology and self-regulated learning may not neatly replicate in other cultures. Including the studies conducted in different cultures, the meta-analysis results enabled me to determine the level of difference among the cultures. In the literature, no meta-analytic study dealing with personal epistemology and self-regulated learning has been reported up to date. The present study addresses this gap.

Literature Review

Personal epistemology is defined as what individuals believe about what counts as knowledge, and how knowledge is constructed and evaluated (Hofer, 2008; Hofer & Pintrich, 1997; 2002; Schommer, 1990). Since Perry's (1970) work, many attempts have been made to organize personal belief research. The complexity of personal epistemology research led to many different models on how to organize the research. These models can be put into two groups (a) the developmental nature of epistemic thinking (King & Kitchener, 2004; Kuhn, 1991; Perry, 1970), and (b) multi-dimensional structure of personal epistemology (Hammer & Elby, 2002; Hofer & Pintrich, 1997; Schommer-Aikins, 2002).

In the developmental nature of epistemic thinking models, personal epistemology is viewed as worldviews (e.g., dualist, relativist). This perspective suggests that personal epistemology is a cognitive construct that progresses along a predictable developmental path, driven by a process of cognitive equilibrium (Feucht & Bendixen, 2010; Hofer & Pintrich, 1997; 2002). In this perspective, personal epistemology develops through a sequence of stages (Sandoval, 2009). Although various stages for the development of personal epistemology are proposed, common views are that naïve individuals tend to see knowledge as static and an accumulation of separate facts. If any change in one's personal epistemology occurs- it has to move from naïve views through more sophisticated views.

The multi-dimensional structure of personal epistemology views personal epistemology as a construct that consists of different dimensions, rather than unitary. In this perspective, individuals may have different beliefs about the different facets of knowledge and knowing. On the one hand, according to Schommer-Aikins (2002), personal epistemology is a system of more-or-less interdependent beliefs about the knowledge and learning and consists of five dimensions, including the structure of knowledge, the stability of knowledge, the source of knowledge, the ability to learn, and the speed of learning. On the other hand, Hofer and Pintrich (1997) asserted that the dimensions of personal epistemology are dependent on each other. Hofer and Pintrich also specified personal epistemology in four dimensions including the certainty of knowledge, the simplicity of knowledge, the justification of knowledge, and the source of knowledge.

Self-regulated learning is defined as a process in which individual students actively monitor and control their own motivation, cognition, and behavior toward the successful completion of academic tasks (Butler & Winne, 1995; Pintrich, 2002; Winne, 1995; Zimmerman, 2008). According to Zimmerman (2008), self-regulated learning refers to approaching educational tasks with confidence, diligence, and resourcefulness. Many models have been made to organize self-regulated learning research (e.g., Pintrich, 2002; Winne & Hadwin, 1998; Zimmerman, 2000). Although terminology varies from one model to another, models of self-regulated learning typically have four phases or processes: (a) forethought (Zimmerman, 2000), the definition of the task (Winne & Hadwin, 1998), and the goal orientation (Pintrich, 2002), (b) monitoring, (c) control, and (d) reaction and reflection (Muis, 2007). In the first phase, the learner may set up goals for learning tasks. In the second phase, metacognitive awareness of various aspects of the learning process is activated. In the third phase, controlling processes and regulating learning are activated. In the fourth phase, the learner may show various types of reflections and reactions about the learning event (Muis, 2007).

Some researchers have proposed theoretical models to explain the relationship between personal epistemology and self-regulated learning. According to Hofer (2000), students' personal epistemologies relate to their goals that determine engagement in learning, strategy use, and comprehension monitoring. Muis (2007) specified that the relations between personal epistemology and self-regulated learning are reciprocal and discipline-specific. Muis (2007) also stated that personal epistemology serves as inputs to metacognitive processes and as standards in the task definition phase of self-regulation. Research on personal epistemology has demonstrated that students' beliefs about knowledge and knowing are related to their learning strategies (Koksal, 2011; Moschner et. al., 2008, Muis & Franco, 2009).

Potential Moderator Effects

I have identified several potential moderator variables that the previous studies have reported, relating to the relationship of personal epistemology and self-regulated learning.

Age. Younger students may have difficulties in applying cognitive and metacognitive strategies (Zimmerman, 1990). Paris and Winograd (1999) asserted that the development of children's metacognition continues during schooling from 5 to 16 years. Zimmerman and Martinez-Pons (1990), for instance, found that 11th graders reported a higher level of mathematical and verbal self-efficacy than 5th graders. Also, Hofer (2008) stated that individuals' beliefs about knowledge develop with age and education. Thus, variation in personal epistemology may be a function of age (Buehl, 2008). For example, Driver et al. (1996) studied scientific views of students aged 9, 12, and 16 and found that younger students reported naïve beliefs than did older students.

Culture. Studies identified that the structure of Asian students' beliefs is different from the students sampled from the U.S. (Hofer, 2008). As cultural norms play a crucial role on an individual's construction of his/her own personal epistemology, studies that sampled participants in different countries may report the different level of relationship (Hofer, 2008). Moreover, different educational systems affect the personal epistemology and self-regulated learning, and consequently the relationship between the two. For instance, Purdie, Hattie, and Douglas (1996) found that Australian students reported greater use of self-regulated learning strategies than Japanese students.

Sex. Sex appears to play a role in personal epistemology and self-regulated learning. For instance, Neber and Schommer-Aikins (2002) found that highly gifted girls' science-related motivational beliefs were less positive than those of boys. Similarly, Elder (2002) found that girls showed more sophisticated beliefs in the source of knowledge than did boys.

Subject area. Students may hold different epistemological beliefs about hard versus soft sciences (Buehl & Alexander, 2006). For example, Hofer (2000) found that students viewed scientific knowledge to be more certain than knowledge in the discipline of psychology. Students' learning strategies may differ from one course to another (Pintrich, 1995). Wolters and Pintrich (1998) found that 7^{th} and 8^{th} grade students reported greater use of cognitive strategies in social studies than in mathematics.

Research Questions

Considering the moderator effects described above, two guiding questions were posed to analyze the relationship between personal epistemology and self-regulated learning:

1. What is the overall effect size of the studies that have been conducted to determine the level of relationship between personal epistemology and self-regulated learning?

2. How do moderator variables including sex, country, subject area, and grade affect the level of relationship?

Methods

List of Variables

Personal epistemology and self-regulated learning strategies are the variables in this study. I used any study dealing with personal epistemology from both developmental and multi-dimensional perspectives. For self-regulation learning strategies, the literature provides a large number of strategies, ranging from simple reading to more advanced strategies including synthesizing knowledge. To be consistent with the previous meta-analytic studies in self-regulated learning (e.g., Dignath and Buttner, 2008; Dignath, Buttner & Langfelt, 2008) I focus on the following self-regulated learning strategies:

a) *Motivational strategies:* These strategies refer to motivational aspect of using cognitive and metacognitive strategies including goal orientation, task value, control beliefs, self-efficacy, and test anxiety (Dignath et al., 2008; Pintrich, 1995).

b) *Cognitive strategies:* Cognitive strategies are defined as the treatment of the learned information. Cognitive strategies including elaboration, rehearsal, and organization are domain and task specific (Pintrich et al., 1991).

c) *Metacognitive strategies:* These are strategies a higher level than the cognitive strategies. Meta-cognitive strategies refer to cognition about cognition. These strategies include self-reflection, planning, and monitoring (Winne & Hadwin, 1998).

d) *Management strategies:* Management strategies are used to enhance the learning environment and to create the optimal learning conditions. These strategies include help-seeking, collaborative learning, and effort management (Pintrich et al., 1991).

Data Collection

I collected potential data sources via keyword searches of the PsychINFO, Eric, Dissertation Abstracts databases, Google Scholar and examinations of the reference lists of studies. Sixteen words describing personal epistemology and self-regulated learning were used: *personal epistemology, epistemic belief, epistemological beliefs, beliefs, meta-cognition, learning strategies, self-regulation, self-monitoring, help-seeking, goal orientation, self-efficacy, cognition, task value, peer learning, effort management, and test anxiety.*

Coding procedure. I coded each data source using standardized coding sheets. This information includes: correlations between personal epistemology and self-regulated learning, and sub-scales, reliability values of the instruments, the type of subject area (e.g., Chemistry), and sample characteristics including sex, country, and age.

Selection criteria. I used several criteria to include potential studies in this meta-analytic study.

1. *Purpose of the study*. I included studies that focused on the relationship between personal epistemology and self-regulated learning, and, if that relationship is shown to exist, what influence the relationship had on achievement. I excluded interventional studies that were outside the scope of the study. Studies that focused on only one dimension of personal epistemology and self-regulated learning were included.
2. *Reporting.* Studies were included if the inter-correlation among subscales was presented. Any study was excluded if the inter-correlation among subscales cannot be calculated into Pearson correlation. I also excluded studies that did not report any subscale or reported only statistically significant correlation, not all correlations.
3. *Publication type.* Since it is difficult to obtain unpublished papers, only studies published in English in peer-reviewed journals and as ERIC document (conference papers) were included in the study.

Data Analysis Methods

Computing effect size. Personal epistemology and self-regulated learning is a multivariable construct, which was in most cases measured by several constructs. In terms of personal epistemology, studies employed different theoretical models whose dimensions do not overlap each other. To be able to investigate the relation between personal epistemology and self-regulated learning, I followed these steps: First, Pearson r values were transferred to Fisher's z score. Then, for each self-regulated learning strategy, I computed the average value of the Fisher's z score (Corey, Dunlap, & Burke, 1998). That yielded an average z score of the correlation between the self-regulated learning strategy and personal epistemology. Next, Fisher's z scores were transferred back to Pearson r. Finally, self-regulated learning strategies were grouped according to the recorded dimension. As for the reliabilities, if the studies that did not report overall reliabilities of measurements, I computed it, as described by Willson (1982), by using reliabilities of each subscale and inter-correlation between each subscales in unweighted case of the number of item.

To compute effect size, I used Pearson correlation within variables. In case the studies do not report overall Pearson correlation, I calculated the average correlations following the steps described above, if inter-correlation among the subscales of variables was reported. I calculated the effect size for the studies that regressed variables, as described by Libsey and Wilson (2001). To make corrected effect size, I included the reliabilities of variables into the calculation. I took as 1.0 value of reliability if a study did not report its measurements' reliability values. When aggregating the effect sizes across the studies, I weighed the effect sizes of the studies by the number of participants, as the effect sizes from studies with different sample sizes do not estimate the level of relationship with the same precision (Dignath & Buettner, 2008).

Fixed-and random-effects models. Fixed effects model refers to the assumption that sampling error is due solely to differences among participants in the study on the one hand (Cooper, 2010). On the other hand, random effects model views "studies as containing other random influences, including differences in teachers, facilities, community economics, and so on" (Cooper, Robinson, & Patall, 2006, p.16). Rather than choosing a single effect model, I chose to apply both effects models to my analysis. I conducted all my analyses twice, under fixed and random effects models once. By doing so, I could examine the effects of different models on the outcomes of the analysis and make my interpretation on the effect of moderator variables in the effect size distribution (Cooper et al., 2006). Figure 2.1 represents the funnel plot representation of the effect sizes from the sampled 45 studies.

I used multiple ANOVAs to examine the interaction of categorical moderator variables (e.g., grade level) on the relationship, and regression analysis for continuous moderator variables. I put studies into groups as the following criteria:

Age. Most studies did not report age means. Thus, I categorized studies by the level that studies targeted such as, university, high school (9th to 12th grade), and elementary (1st to 8th grade).

Culture. I used the country of origin of the study as indicator of the culture. Since studies were conducted in different countries, I categorized the studies into two groups: (a) Western culture (countries in Europe, Australia, and North America) and Eastern Culture (countries in Asia).

Sex. I used the percentage of the female participants in the study. By doing so, I obtained a continuous variable.

Subject area. Biglan (1973) classified academic disciplines into two groups as hard science and soft science. Based on Biglan's (1973) classification of academic disciplines, I categorized students' majors into three groups as: (a) hard sciences including physics, science, and math etc., (b) soft sciences including education, psychology, history etc., and (c) mixed sciences indicating participants' majors in both hard and soft sciences. I categorized studies at high school and elementary levels into the mixed sciences unless the study focused on the particular subject area. Some studies focused on elementary students' scientific beliefs or science-related strategies (e.g., Chen, 2012). I put these studies into the hard science group, not mixed group.

Results

General Characteristics of the Studies Included in the Meta-analysis

A total of forty-five studies from forty articles, which met the eligibility criteria, were included in the meta-analysis. These sampled studies were drawn from a variety of student populations from elementary level through college level. The samples were drawn from 15 countries: the United States, Canada, Norway, Hong Kong, Taiwan, Germany, Turkey, China, Fiji, Italia, Belgium, India, Indonesia, Iran, and Greece. Of these studies, %47.6 in North America, %16.6 in Europe, and 35.7 in Asia, and %2.3 in Australia were conducted. The mean age of participants was 17.9 years. Fifty-nine percent of the participants was female.

One hundred and thirty effect sizes arose from these 45 studies resulting from 40 articles. Dignath et al. (2008) discussed that an effect size value that differs greatly from the distribution of all effect sizes may be misleading the results in the research area and it influences the meta-analytic analysis in a spurious way. Lipsey and Wilson (2000) recommended excluding such an extreme effect size in the analysis if it differs from the mean effect size more than three standard deviations. I looked at the funnel plot of the effect sizes and located an extreme effect size (with an E.S. value of .66). I excluded this effect size (with a value of .66) from the analysis. Figure 1 represents the funnel plot of the effect size illustrating the distribution of the effect sizes before the elimination.

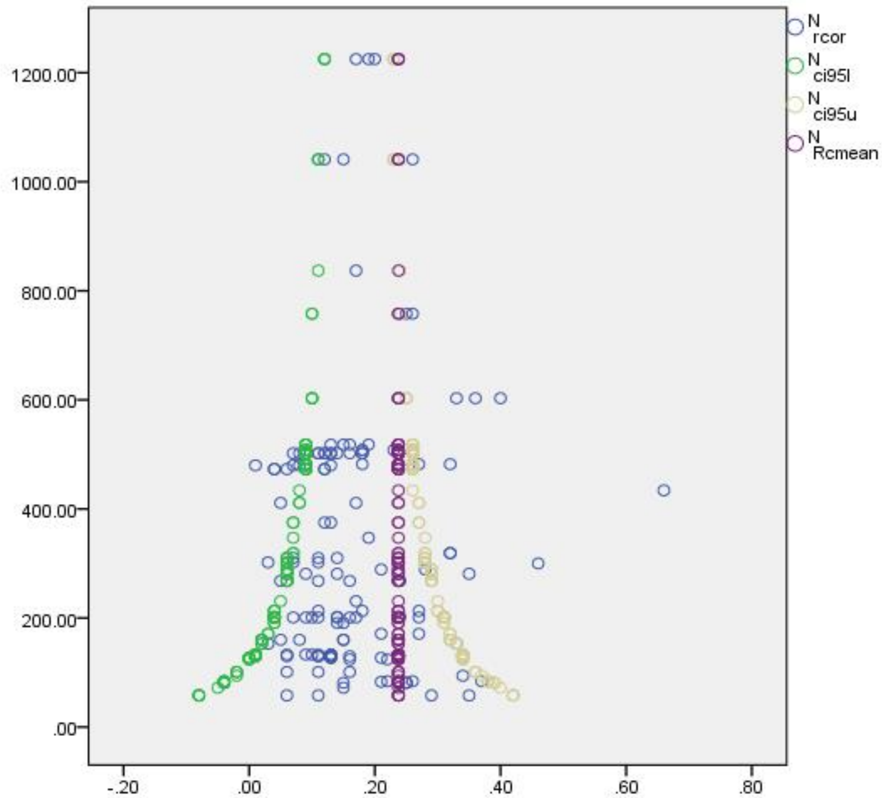

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Figure 2.1: The funnel plot of the effect sizes

After eliminating the extreme effect size, the overall distribution comprised 129 effect sizes. Of these effect sizes, 22 cognitive strategies effect sizes, 17 meta-cognitive strategies effect sizes, 12 management strategies effect sizes were reported (See Table 2.1). Most effect sizes focused on the relation between personal epistemology and motivation strategies. Fourteen studies reported the overall effect size.

Table 2.1
Summary of study and effect size characteristics

Self-regulated learning strategies	n=129 (effect size)	N= 45 (studies)
Cognitive strategies	22	13
Meta-cognitive strategies	17	15
Motivational strategies	64	24
Management strategies	12	7
Overall strategies	14	14
Publication year	M= 2008.95 (S.D.= 3.51)	
Sample size	M= 342.70 (S.D.=250.53)	

Mean effect sizes were computed, underlying the assumption of fixed effects model and random effects model. In the fixed effects model, the weighted overall effect size, "r" was .24 with a standard error .012. In the random effects model, the weighted overall effect size, "r" was .22 with a standard error .026. In the random effects model the standard error value was higher, which led the confidence intervals to be wider. Since the confidence intervals for fixed and random effects models do not include zero (Dignath et al., 2008), the mean effect sizes are statistically significant (See Table 2.2). Also, I conducted the Q homogeneities test to compare the observed variance to that expected from sampling error (Cooper, 2010). I found a statistically significant difference, which indicates the heterogeneity of the effect sizes (Q (128) =635.7, p<.01).

Table 2.2
Mean effect sizes

	Mean E.S.(S.E.)	-95% CI	+95% CI
Fixed effects model	.24 (.012)	.21	.27
Random effects model	.22 (.026)	.17	.27
Random effects var. com. (*v*)			.016

Relationship between Moderator Variables and Effect Sizes

The influence of the aforementioned moderator variables (age, culture, subject area, and sex) on the effect size variability is presented.

Age. Age was defined as a moderator effect that may influence the level of relationship between variables. Since most studies were clustered in college level and that were not continuous within themselves by age, I categorized the sampled studies into levels as university, high school, and elementary so that I was able to include studies that did not report the mean value of the participants' ages (See Table 2.3).

Table 2.3
Summary of study and effect size characteristics by age

Age (grade level)	n=129 (effect size)	N= 45 (study)	Mean sample size
University	85	31	M= 311.5 (SD=193.0)
High School (9^{th} to12^{th})	20	7	M= 418.5 (SD=350.6)
Elementary (1^{st} to 8^{th})	24	7	M=361.5 (SD=249.8)

I computed mean effect sizes for each group, underlying the assumption of fixed effects model and random effects model as described by Lipsey and Wilson (2001). A categorized inspection of the school level data revealed a weighted overall mean effect size of 0.23 for elementary school (ranging from -.02 to .47), 0.22 for high school (ranging from -.04 to .50), and 0.24 for university level (ranging from .06 to .40) under fixed effects model (See Table 2.4). Under random effects model, I found the weighted mean effect size as .22 for elementary level, .20 for high school level, and .22 for university level. In both instances the absolute value of the difference between the correlations was quite small.

Table 2.4
Summary of mean ES in fixed-random effects models by age

	Fixed effects model			Random effects model		
Age	E.S.(S.E.)	-95% CI	+95% CI	E.S.(S.E.)	-95% CI	+95% CI
University	.24 (.008)	.23	.26	.22 (.016)	.19	.25
High School	.22 (.013)	.19	.24	.20 (.033)	.14	.27
Elementary	.23 (.013)	.21	.26	.22 (.031)	.16	.28
Q-between (Q_b)			3.32(p>.05)			.20 (p>.05)

I compared the effect sizes for the different categories as described by Lipsey and Wilson (2001). In fixed effects model, comparing the effect sizes for the different outcome categories revealed no statistically significant differences between all categories (Q_b = 3.32, p>.05). Likewise, I found that there is no statistically difference between all categories in random effects model (Q_b =.20, p>.05). Non-significant value of Q_b under fixed and random effects models indicates that as a moderator factor, participants' age does not explain the variation of the effect sizes, except the effects beyond that associated with the sampling error.

Culture. I chose the country where the study was conducted as the indicator of its culture. Next, I categorized the studies into two groups as (a) Western culture including studies that have been conducted in the North America, Australia, and Europe, and (b) Eastern culture including studies that have been conducted in Asia. The studies analyzed in this paper were conducted in 15 different countries. The cultural variations between each country would not be easy for me to identify and document. Hence, I categorized the countries as being a more representative of the Western culture versus being a more representative of the Eastern culture. Table 2.5 represents the effect size distribution by Eastern versus Western cultures. As Table 2.5 shows, twice the more studies were conducted in the Western culture than the studies conducted in the Eastern culture.

Table 2.5
Summary of study and effect size characteristics by culture

Culture	n=129 (effect size)	N= 45 (studies)	Mean sample size
Western	91	30	M= 314.7 (SD=188.0)
Eastern	38	15	M= 385.8 (SD=350.9)

I calculated the mean effect sizes for each culture group, underlying the assumption of fixed and random effects models (See Table 2.6). Under fixed effects model, the weighted overall mean effect sizes are 0.25 for the Western culture (ranging from -.04 to .50), and 0.22 for the Eastern culture (ranging from -.02 to .46). Under random effects model, I found the weighted mean effect size as 0.23 for the Western culture, and 0.19 for the Eastern culture. In both instances the absolute value of the difference between the correlations was quite small.

Table 2.6
Summary of mean ES in fixed and random effects models by culture

	Fixed effects model			Random effects model		
Culture	E.S.(S.E.)	-95% CI	+95% CI	E.S.(S.E.)	-95% CI	+95% CI
Western	.25 (.008)	.23	.27	.23 (.016)	.20	.26
Eastern	.22 (.009)	.20	.24	.19 (.023)	.14	.24
Q_b		5.58(p<.01)			1.24 (p>.05)	

I compared the effect sizes for the different categories. In fixed effects model, comparing the effect sizes for the different outcome categories revealed a statistically significant difference between the categories (Q_b = 5.58, p<.05). However, I found that there is no statistically significance difference between the categories in random effects model (Q_b =1.24, p>.05). A statistically significant value of Q_b under fixed effects model indicates that the culture is a significant contributor to the variation in the effect size.

However, under random effects model, the culture does not explain the variation in the effect sizes. Cooper (2010) argued that if the analysis is significant under fixed effects model but not under random effects model, this indicates that "the findings relates only to what past studies have found but not necessarily to the likely results of a broader universe of similar studies"(p.201). The present study's findings suggest that "culture" explains the variation in the effect sizes for the past studies. However, the same claim-- that the culture explains the variations in the effect sizes-- is not valid for the studies that are not included in the present study.

Subject area. The sampled studies were conducted in various subject areas including physics, business, education, psychology, history, and math. To able to investigate the effect of the subject area on the effect sizes, I categorized the effect sizes into three groups as (if the target sample coming from or the study focused on the particular subject area) a) hard sciences that used to define academic areas perceived as being more scientific or accurate (e. g. physics), b) soft sciences that used to define social science academic areas (e. g. education), and c) mixed that included participants from hard and soft science areas. And I put the studies at elementary and high school levels into the mixed group unless the study focused on any particular subject area. Table 2.7 represents the effect size distribution by subject area. Table 2.7 shows that, most of the studies analyzed in this paper have been conducted in the hard sciences.

Table 2.7
Summary of study and effect size characteristics by subject area

Subject area	n=129 (effect size)	N= 45 (studies)	Mean sample size
Hard sciences	57	20	M= 271.2 (SD=54.1)
Soft sciences	29	11	M= 312.4 (SD=175.7)
Mixed sciences	43	14	M=415.6 (SD=451.5)

I computed the mean effect sizes for each "subject area" group under fixed- and random effects models (See Table 2.8). Under fixed effects model, the weighted overall mean effect sizes are 0.19 for hard sciences (ranging from -.02 to .47), .32 for soft sciences (ranging from -.04 to .46), and .26 for the mixed science category (ranging from .05 to .50). Under random effects model, I found the weighted mean effect size as 0.19 for hard sciences, 0.26 for soft sciences, and 0.22 for the mixed science category.

Table 2.8
Summary of mean ES in fixed and random effects models by subject area

	Fixed effects model			Random effects model		
Subject area	E.S.(S.E.)	-95% CI	+95% CI	E.S.(S.E.)	-95% CI	+95% CI
Hard sciences	.19 (.008)	.17	.21	.19 (.020)	.15	.23
Soft sciences	.32 (.014)	.29	.35	.26 (.030)	.20	.32
Mixed sciences	.26 (.010)	.24	.28	.22 (.023)	.17	.27
Q_b			74.8(p<.01)			6.19 (p<.05)

I compared the effect sizes for the different categories. In fixed effects model, comparing the effect sizes for the different outcome categories revealed statistically significant differences between the categories (Q_b (2) = 74.8, p<.01). Also, I found that there is a statistically significant difference between the categories in random effects model (Q_b (2) =6.19, p<.05). A statistically significant value of Q_b under fixed- and random effects models reveals that the subject area can account for the variation in the effect sizes. Again, in both instances the absolute value of the difference between the correlations was quite small.

Sex. To able to investigate the influence of students' sex on the effect size distribution, I used the percentage of female students in the study, which yielded a continuous variable of the female. To estimate the influence of students' sex on the effect size variance, I applied a series of meta-analytic approaches under fixed and random effects models. First, I adopted the general approach described by Cheung (2008) in Mplus 6, which is an innovative way to integrate fixed, random, and mixed effects models of meta-analysis to SEM. Although this approach worked well with the available data under fixed effects model, it did not fit with the available data in random effects model. Therefore, in random effects model I used the traditional weighted regression method described by Lipsey and Wilson (2001) to estimate the parameters. Table 2.9 represents the parameters in the traditional and the SEM approaches.

Lipsey and Wilson (2001) suggested that the standard error (SE) value should be adjusted and then the correct assessment of statistical significance should be tested in the regression analysis for the meta-analytic purposes. I computed the corrected SE values for fixed and random effects models, and found z-test values as 17.9 and 14.9, respectively.

The traditional regression analysis revealed that in fixed effects model the percentage of female students is statistically significantly related to the effect size distribution (R^2= .08, *t* (female) = 17.9., *p* <.01). The standardized coefficient (β =-0.28) indicates that approximately 8% of the variance of the effect size can be explained by the percentage of female participants in the studies. The direction of the relationship is negative, which means that the more female participants in the sample, the lower is the effect size obtained. Traditional regression analysis resulted identical with the SEM analysis (See Table 2.9).

Table 2.9
Results of the traditional meta-analytic regression analysis by sex

	Fixed effects model			Random effects model		
	β	SE (β	β(stand.)	β	SE β	β (stand.)
Sex	-0.51 (-.50)	.03** (.01)	-0.286*(-0.28*)	-0.20	.014**	-0.233*

Note: Numbers in parenthesis show the parameters obtained from SEM approach.
*: p <.01
**: Corrected SE values.

In random effects model, the relation between the percentage of female students and the effect size is statistically significant but the strength of the relation is low (β =-0.23). This value indicates that approximately 5% of the variance of the effect size can be explained by the percentage of female participants in the studies (R^2= .05, t (female) =

14.9, p<.01). The adjustment on the variance in random effects model can account for obtaining a small beta coefficient. Again, the direction of the relation between the percentage of the female participants and the effect size is negative.

Conclusion

The present meta-analytic study investigated 45 studies for the relationship between personal epistemology and self-regulated learning strategies from elementary level through college level. The results of the present study are discussed below.

Overall Effect Size of the Studies

The findings of this meta-analytic study have important implications not only for research on the relationship between personal epistemology and self-regulated learning, but also on the general literature regarding the determinants of and predictors of these on college academic performance. The result of this meta-analysis shows that personal epistemology is positively related to self-regulated learning strategies. The analysis is based on 129 effect sizes from 45 studies and revealed a weighted average effect size of .24 under fixed effects model and .22 under random effects model. This meta-analytic study suggests that the relationship between personal epistemology and self-regulated learning strategies is moderate. Moreover, 5% (R^2=.05) of the variation in self-regulated learning strategies can be explained by personal epistemology. These results should be considered in future studies.

Age and the Relationship

Under fixed and random effects model, the results of this meta-analytic study have shown that the relationship between personal epistemology and self-regulated learning is positive for all age levels. I found that under fixed effects model, the weighted average effect size of the relationship was .23, .22 and .24 for elementary, high school and university levels, respectively. The magnitude of the weighted average effect size under random effects model was .22, .20 and .22 for elementary high school and university levels, respectively.

In addition to the main finding, the meta-analytic analysis revealed that the moderate relationship between personal epistemology and self-regulated learning strategies was not statistically significant in fixed and random effects model. The previous studies in personal epistemology and self-regulated learning reported that age is a function of development in personal epistemology and self-regulated learning strategies (Beuhl, 2008; Hofer & Pintrich, 1997; Driver et al., 1996). The results of this meta-analytic study suggest that even when students get mature, motivation and behaviors of self-regulated learning that are constructed by their personal epistemology remain the same.

Culture and the Relationship

The result of this meta-analytic study has shown that under fixed and random effects model the relationship between personal epistemology and self-regulated learning is positive for the Western and Eastern cultures. Under fixed effects model, the weighted average effect size is .25 for the Western culture and .22 for the Eastern culture. Under random effects model, I found that the weighted average effect size is .23 for the Western culture and .19 for the Eastern culture.

In addition to these findings, the meta-analytic investigation yielded different results under fixed and random effects model. I found that the relationship between personal epistemology and self-regulated learning is statistically different across the cultures under fixed effects model. Yet, that relationship is not statistically significant under random effects model. This result suggests that culture explains the variation that the past studies have reported so far in the relationship between personal epistemology and self-regulated learning; yet, this variation cannot be generalizable to future studies.

Overall, the results of the meta-analytic study suggest that greater levels of the Western students' self-regulated learning strategies are explained by their personal epistemologies than those in the Eastern culture countries. This difference across cultures can be explained by the reported strategies that students used. The stereotypical view among the students in Eastern culture countries is that knowledge is something handed down by someone in authority (Purdie et al., 1996). The students in the Eastern culture countries reported that they were more likely to use rote learning strategies (Yumusak, Sungur, & Cakiroglu, 2007). Also they were less likely to seek help from others than students in Western culture countries (Yumusak et al., 2007). The students in the Eastern culture countries were less likely to use management strategies, like collaboration (Dahlin & Watkins, 2000). This may lower the relationship between the personal epistemology and self-regulated learning. Another explanation for the observed variation across the cultures is the instruments that were used. The instruments to measure students' epistemic beliefs and self-regulation learning were developed first in the U.S. and then translated into other languages and used in other countries (Hofer, 2008). In future studies it is suggested that researchers in other countries should use instruments developed by the native speaker researchers of the target country.

Subject Area and the Relationship

This meta-analytic study has shown that under fixed and random effects model the relationship between personal epistemology and self-regulated learning is positive for all subject areas. Under fixed effects model, the weighted average effect size is .19, .32, and .26 for hard sciences, soft sciences, and mixed sciences, respectively. Under random effects model, I found that the weighted average effect size is .19, .26, and .22 for hard sciences, soft sciences, and mixed sciences, respectively.

In addition to these findings, the meta-analytic review revealed that the relationship between personal epistemology and self-regulated learning strategies is statistically significant across subject areas under fixed and random effects models. This result suggests that the subject area explains the variation in effect sizes of the relationship between personal epistemology and self-regulated learning strategies.

The results showed that in soft sciences personal epistemologies predict students' self-regulated learning strategies more than they predict in the hard sciences. This difference in the mean averaged effect size across the subject areas can be explained by the difference in the content of the subject areas. Hard sciences are viewed more paradigmatic than soft sciences since "the content and methodologies employed are more idiosyncratic" (Muis, Bendixen, & Haerle, 2006, p.10). This difference between the hard versus soft sciences may lead students to view the knowledge in the hard sciences more certain, and dependent on the theoretical explanations and rules than the knowledge they view in the soft sciences (Buehl & Alexander, 2005; Hofer, 2000; Schoenfeld, 1989). Consequently, students in the hard sciences may employ more structured and rote learning strategies than in soft science.

Students' Sexes and the Relationship

The present meta-analytic review found that the percentage of female students is statistically significantly related to the effect size distribution under fixed effects model (β =-0.28, t (female) = 17.9., p <.01) and random effects model (β =-0.23, t (female) = 14.9, p<.01). The analysis also revealed that approximately 8% and 5% of the variance in the effect size were explained by the percentage of female participants under fixed effect model (R^2= .08), and random effect model (R^2= .05), respectively. The direction of the relationship is negative, indicating that the more female participants in the sample the lower is the effect size obtained.

The role of the students' sex on personal epistemology and self-regulated learning has been studied in multiple lines of works (Hofer, 2000; Baxter Magolda, 1992). Some studies have found that the students' sex plays an important role to shape their personal epistemologies and self-regulated learning strategies (e.g., Hofer, 2000) whereas some others did not report any variation in terms of students' sex (e.g., Buehl, 2002). The negative relationship between the percentage of female students and the effect size can be explained by the expectations from females. Following Perry's (1970) early research with almost all-male student sample in personal epistemology, Belenky and her colleagues (1997) worked on all-female student sample in their research and proposed an epistemology they labeled "women's ways of knowing (WWK)." The substantive studies on WWK reported that girls were more likely to report a connected approach (paying more attention to understand the object of attention) to knowing. In these studies, boys reported “a separate approach” (an approach that views “knowing” different from “the known” by putting their own feelings and values aside, and adopting a neutral perspective) (Clinchy, 2002; Galotti, Drebus & Reimer, 1999). In addition to this difference in ways of knowing, in social environments girls are more often expected to obey the social rules than boys. In turn, this might discourage girls to have sufficient practice and encourage them to regulate their behaviors and emotions (Davis, 1995).

Implications/Limitation of the Findings

This meta-analytic study has certain limitations. First, I included only published studies in English in peer-reviewed journals. Published studies are more likely to report statistically significant results, which may indicate a publication bias (Cooper, 2010). Including the non-significant results, which are usually not published, might lower the averaged effect size. Therefore, I encourage scholars to submit well-done studies for publication, even when results are not statistically significant.

Second, during the analysis, I found that the studies on personal epistemology and self-regulated learning strategies have most often used university level students (85 of 129 effect sizes and 31 of 45 studies). Very little research on personal epistemology and self-regulated learning includes elementary (seven of 45 studies) and high school students (seven of 45 studies). As a limitation relating to the effect of students’ age on the relationship, this should be taken into consideration. More studies with younger students are recommended.

Whether personal epistemology and self-regulated learning are domain general or domain specific is a recent discussion (Muis et al., 2006). There is evidence that students may have different beliefs and/or strategies across the disciplines (Hofer, 2000; Buehl et al., 2002). The results of this meta-analytic study support the notion that the motivation and behavioral aspects of self-regulated learning that are constructed by the students' personal epistemologies vary across the hard versus soft sciences. It should be noted that because I grouped the studies as hard, soft, and mixed sciences, any attempt to generalize this study's findings, and conclusions to all science disciplines in hard sciences or soft sciences should be approached with caution. The relationship between personal epistemology and self-regulated learning may vary across disciplines in hard science or soft science. There is evidence that high school students viewed knowledge in physics more certain and unchanging than knowledge in biology (Tsai, 2006). Furthermore, some argue that students' personal epistemologies are task and context dependent (Elby & Hammer, 2010; Sandoval, 2009). Therefore, future studies on personal epistemology and self-regulated learning should focus on the task or discipline specific nature of personal epistemology and self-regulated learning.

Lastly, in this study, I analyzed 129 effect sizes in which they were nested in 45 studies. Because the average number of effect sizes per study is 2.87, fixed effects model has some dependencies because of being in the same study. As a limitation of this study, in the analysis, I made the assumption that these dependencies would not significantly influence the variation with only 2 or 3 effect sizes for per study. Although Cheung (2013) suggests a methodology for multiple effects per study, it has not been validated and requires knowledge of the correlation between effect sizes within the study that is simply not known.

CHAPTER III

EXPLORING THE RELATIONSHIP BETWEEN HIGH SCHOOL STUDENTS' PHYSICS-RELATED PERSONAL EPISTEMOLOGIES AND SELF-REGULATED LEARNING IN TURKEY

Both personal epistemology and self-regulated learning play an important role in students' learning in general. The former refers to students' ideas about knowledge and knowing (Hofer, 2004). The latter is defined as a process in which students actively regulate their own motivation, cognition, and behavior towards the successful completion of academic tasks (Winne, 1995).

Personal epistemology is viewed as a starting point for learning about the nature and development of science knowledge in the classroom (NRC, 2007). Students' ideas about knowledge and knowing guide their actions towards the acquisition of knowledge (Hofer, 2001; Muis, 2007). In this view, students' personal epistemologies may relate to their self-regulated learning to learn physics. Understanding the function of personal epistemology on students' self-regulated learning may help the educator more effectively teach physics concepts.

Students' age may play an important role on the development of personal epistemology and self-regulated learning (Buehl, 2008; Paris & Winograd, 1999; Zimmerman, 2000). At early ages, students develop general personal epistemology that represents an amalgamation of their general personal epistemology; for example, science-related personal epistemology which indicates students' general ideas about scientific knowledge and knowing (Muis et al., 2006). When students enter high school, they are more likely to be exposed to some changes in the level and the specificity of content. One of the changes that the students are exposed to is a division within a specific academic discipline; for example science as physics, chemistry, and biology and so on. Students at high school level then start developing more specific beliefs across domains; for instance, ideas about physics knowledge versus ideas about biology knowledge (Muis et al., 2006). However, studies concerning personal epistemology and self-regulated learning have most often been conducted at university level and the high school science major students have been the subjects of few studies (Muis et al., 2006). Therefore, there is a need to determine the relationship between the personal epistemologies and the self-regulated learning with high school science students who just start developing ideas and self-regulated learning strategies in physics (Moschner et al., 2008). Furthermore, domain specificity is viewed as another factor that influences students' personal epistemologies (Hofer, 2000; Muis et al., 2006) and self-regulated learning (Pintrich, 2002). I believe that it is helpful to determine how physics-related personal epistemologies correlate to students' motivation and meta-cognitive processing to learn physics.

Theoretical Model

Research has reported that students' personal epistemologies are correlated to their self-regulated learning strategies (Hofer, 2004; Zimmerman, 2008). Personal epistemology can affect students' thinking in many ways, for example, directing their perception and attention to particular features of information (Patrick & Pintrich, 2001). Some researchers have proposed a theoretical model to explain the relationship between personal epistemology and self-regulated learning. According to Hofer (2001), students' personal epistemologies relate to "the goals and standards that determine engagement in learning, depth of processing, and comprehension monitoring" (p.370). In this view, for example, a learner who has a naïve view about the source and justification of knowledge uses learning strategies that are different from a learner with a sophisticated view. A naive learner relies on only one source such as the textbook; a sophisticated learner tends to look for different sources, monitors epistemic claims, weighs evidence, and evaluates authorities.

Muis (2007) proposed a theoretical model to describe how personal epistemology can facilitate or limit facets of self-regulated learning. Her model assumes the relationship between personal epistemology and self-regulated learning is reciprocal and discipline-specific. Consistent with Winne and Hadwin's (1998) and Pintrich's (2000) models on self-regulated learning, Muis specifies four propositions corresponding to four phases of the self-regulated learning to explain the relationship between personal epistemology and self-regulated learning:

(a) *Personal epistemology is one component of the cognitive and affective conditions on task definition:* In the first phase of self-regulated learning, students activate the perceptions of the task, context, and knowledge of the task. According to Muis (2007), personal epistemology is one component of cognitive and affective conditions and a key element to task definition and forethought. Personal epistemology helps students define the conditions of the task.

(b) *Personal epistemology influences goal standards students set:* In the second phase of self-regulated learning, students set goals to pursue by a particular strategy or a set of strategies. Muis proposes that students' personal epistemologies facilitate or constrain facets of self-regulated learning by relating to the goals for the task (Muis, 2007). Consistent with Hofer and Pintrich (1997) ideas, Muis asserts that personal epistemology might function as implicit theories that can induce particular types of goals for learning, including mastery or performance oriented goals.

(c) *Personal epistemology translates into epistemic standards that serve as inputs to metacognition:* Students' epistemological views predict how students understand the complexity of the problem, the certainty of knowledge and how they evaluate the evidence (Kuhn, 2000). According to Hofer (2004), personal epistemology relates to metacognitive process for any task by influencing epistemological standards that the student sets for any learning task. These standards serve as pertinent information during the metacognitive monitoring (Muis, 2007).

(d) *Self-regulated learning may play a role in the development of personal epistemology.* Many theorists agree that self-regulated learning is a cyclical construct that information produced any phase can feed into the same phase or other phases (e.g., Muis, 2007; Winne & Hadwin, 1998; Pintrich, 2000). Furthermore, Zimmerman (2000) proposed that during the self-reflection in self-regulated learning, feedback obtained from prior learning experience is used to evaluate adjustments to goals, strategy choice, etc. for subsequent efforts. Consistent with these ideas, Muis posits that as the reciprocal relationship is in the nature of the model, any information from any phase or component can provide information back into other components.

Literature Review

It has been reported that personal epistemologies are correlated to students' skill and attitudes for learning science. Some researchers have suggested that personal epistemology directly and indirectly predicts students' achievement in science (Koksal, 2011; Yilmaz-Tuzun & Topcu, 2008). Stathopoulou and Vosniadou, (2007) studied how students' physics-related personal epistemologies are correlated to their achievement in Newtonian dynamics content. Participants were seventy-six 10th grade students in Athens, Greece. Participants were divided into two groups as low- and high-epistemological sophistication based on their responses to a personal epistemology questionnaire (Greek Epistemological Beliefs Evaluation Instrument for Physics [GEBEP]). Participants were asked to answer the Force and Motion Conceptual Evaluation test comprising 43 items. ANOVA analysis revealed that there was a statistically significant difference between the groups ($t=5.2$, $p<.001$). Students in the sophisticated group achieved higher scores ($M=18.94$, $SD=10.91$) than the students in the naïve group ($M=9.0$, $SD=4.07$) in the Newtonian test. Naïve beliefs regarding the certainty of knowledge and viewing scientific knowledge as unchanging have been reported to be negatively correlated with the skill to interpret controversial evidence (Kardash & Scholes, 1996).

In addition to personal epistemology, self-regulated learning plays an important role in science learning. Research has documented the importance of students' self-regulated learning on their achievement in general and particularly in sciences (Bandura, 1997; Pintrich & De Groot, 1990). For instance, students with high self-regulated learning have demonstrated higher levels of involvement, effort, and consistency on academic tasks than those who were low self-regulated learners (Eilam et al., 2009; Zimmerman & Martinez-Pons, 1988). Self-regulated learning consists of two components; motivational orientation and learning strategies (Pintrich, 2002). Motivational orientation refers to the students' goals and value beliefs about a course and their beliefs about their skill to achieve in the course (Zimmerman, 2008). Learning strategies includes cognitive and meta-cognitive strategies that students use during a task (e.g., rehearsal, critical thinking; Pintrich, 2002).

Motivational dimensions (e.g., task value, goal orientation) of self-regulated learning are essential to lead the students to use learning strategies effectively (Koksal, 2011). Mastery-oriented students, for example, are more highly motivated to learning, and use deeper cognitive strategies (Wigfield & Cambria, 2010). Likewise, metacognitive dimensions of self-regulated learning are recognized as important to learning in general and science in particular (NRC, 2007). Metacognitively active students can decide how to use resources effectively, and make judgments about the outcomes and learning (Sungur, 2007). Yumusak et al. (2007), for example, studied to determine the contribution of self-regulated learning to Turkish high school students' achievement in biology. Participants were 519 tenth grade (214 girls) students in Turkey. The Turkish version of the MSLQ adapted by Sungur (2004) (81 items) was administered to the students. A 20-item biology achievement test was developed and administered. For the validation of the instrument, Confirmatory Factor Analysis (CFA) was conducted (Root Mean Square Error of Approximation [RMSEA] < .10). The reliability coefficient of the instruments ranged from .50 to .85. Multiple regression analysis revealed that 10% of the variation on students' achievement was explained by motivational beliefs (R=0.32, F=9.623, $p<.05$). Extrinsic goal orientation and task value statistically significantly predicted students achievement ($p<.005$), but others not ($p>.05$). Metacognitive strategies accounted for 9% of the variation on the students' achievement (R=0.29, F=5.299) and statistically significantly related to achievement ($p<0.05$).

Muis and Franco (2009) empirically tested Muis's (2007) hypothesis. Participants were 201 educational psychology students at a Canadian university. Three instruments were administered to the students (a) Discipline-Focused Epistemological Beliefs Questionnaire (Hofer, 2000; 27 items), (b) Achievement Goals Questionnaire (Elliot & McGregor, 2001; 12 items), and (c) a short version of MSLQ (Pintrich et al., 1991). The students' final grades in an educational psychology course were used as their achievement score. SEM resulted in a good fit with data (RMSEA= .05). From position 2, the belief of certainty of knowledge was correlated to extrinsic goal orientation (β =0.29). From positions 3 and 4, students' goal orientations were statistically significantly related to students' self-regulated learning strategies. For instance, intrinsic goal orientation predicted the use of rehearsal (β=0.82), critical thinking (β=0.72) meta-cognitive self-regulation (β=0.97). Also, students' self-regulated learning strategies statistically significantly predicted their achievement. For example, rehearsal, meta-cognitive self-regulation, and critical thinking strategies predicted achievement (β=0.14, β=0.69, and β=0.29, respectively).

Research concerning students' personal epistemologies and self-regulated learning has suggested that both constructs are domain-specific (Hofer, 2000; Muis et al., 2006; Tsai, 2006; Pintrich, 2002). Students' beliefs about knowledge and knowing are influenced by their experience and content knowledge within the domain (Tsai, 2006). For example, Hofer (2000) found that students viewed knowledge in science more certain and unchanging than in psychology. Even within science, students may have different views about knowledge across scientific disciplines; for example, physics versus biology. Tsai (2006), for example, found that high school students viewed knowledge in physics more certain and unchanging than in biology. Similarly, Wolters and Pintrich (1998) pointed out that motivation and self-regulated learning relies on context and domain under study. For the relationship between personal epistemology and self-regulated learning, Buehl and Alexander (2006) found varying relationships between domain-specific epistemic beliefs and dimensions of motivation, cognitive strategy use, and domain-specific achievement among math and history students.

Despite the existence of the theoretical model, there is a need to collect evidence to determine the strength of the relationship and the effects of domain sensitivity on this relationship. Therefore, the purpose of the proposed study is to examine the relationship between physics-related personal epistemology and self-regulated learning and how these two constructs can account for achievement in physics.

Research Questions

1. What proportion of variance in the level of physics achievement is explained by physics-related personal epistemology and self-regulated learning in Turkish high school students?
2. To what extent do the dimensions of personal epistemology express the motivational strategies that students use in physics in Turkey?
3. To what extent do the dimensions of personal epistemology predict the cognitive and meta-cognitive strategies that students use in physics in Turkey through the mediation of motivational strategies?
4. To what extent does the hypothesized SEM fit the data obtained from students in Turkey?

Methods

Participants and Data Collection

In this study convenience sampling was used (Creswell, 2007). Bursa, a metropolitan city located in the northwestern Anatolia, was chosen because of its convenience to the researcher. Bursa is the fourth most populous city in Turkey (with a population of 2.7 million in 2013) and one of the most industrialized metropolitan centers in the country. All high school students located in Bursa Province in Turkey were identified as the target population of the present study. However, the Office of the Turkish Ministry of Education in Bursa allowed one public school for this study's data collection. Therefore, the students from that public high school in Bursa were identified as the study participants. The school was located in the city center and had 780 students at the time the data were collected. The students in the school were moderate achievers and socio-economically diverse.

Data were collected from the school in May 2013. In my introduction to the students, I first explained the study's purpose and the students' rights as study participants. Students were invited to participate in the study and asked to take the parental permission forms home for their parents to review and consent. A week after the students returned the parental permission form the data collection instrument was given out to the students in the classrooms by their classroom teachers. Their teachers explained the study purpose and the participants' rights once again. Next the classroom teachers reviewed the directions to complete the questionnaire. Students who had their parental forms signed and volunteered to participate completed the questionnaires. The participants were given an hour to complete the instruments. A total of 209 (109 female, 100 male) students were involved in the study. Of these 209 students, 79 were at 9th grade, 57 were at 10th grade, and 73 were at 11th grade.

Instruments

In this study, I sought to empirically test Muis's (2007) model. Therefore, I chose the following questionnaires because (a) they are adaptable to the domain of physics, (b) they nicely capture the facets of the two constructs (personal epistemology and self-regulated learning) Muis (2007) stated, and (c) they have been validated in Turkey.

Epistemic Beliefs Questionnaire (Conley et al., 2004). This questionnaire consists of 26 items to measure students' views about (a) the source of knowledge--to what degree students view knowledge as transmitted from external sources to internally constructed (5 items), (b) the certainty of knowledge--to what degree students believe that knowledge is certain versus fluid and tentative (6 items), (c) the justification of knowledge---the degree to which students evaluate knowledge and use evidence (9 items), and (d) the development of knowledge--to what degree learners believe that knowledge is an accumulation of facts or a system of related constructs (6 items). Ozkan (2008) has adapted the questionnaire items from English into Turkish. The Turkish version of the questionnaire was used and validated in some recent studies in Turkey (Kurt, 2009; Ozkan & Tekkaya, 2011). Kurt (2009) reported, for instance, the reliability of EBQ with 1557 middle and high school students as .59 for the source of knowledge, .59 for the certainty of knowledge, .83 for the justification of knowledge, and .61 for the development of knowledge. Since the purpose of the present study is to identify students' personal epistemologies in physics, I replaced the words "science" and "scientists" with 'physics" and "physicists." The English version of the questionnaire used in this study is in Appendix B. The items in the certainty of knowledge and the source of knowledge dimensions were reversed so that higher scores represented more sophisticated beliefs.

Motivated Strategies for Learning Questionnaire (MSLQ). The original version of MSLQ consists of 81 items in 15 dimensions. The MSLQ is a world-wide questionnaire. It was developed by Pintrich, Smith, Garcia, and McKachie (1991) to measure students' self-regulated learning in any domain. The MSLQ has been translated into and adapted for Turkish by Sungur (2004) and used by other researchers (Yumusak et al., 2007; Ozsoy & Ataman, 2009). A short version of the MSLQ was used in this study so that the scales corresponded to the ones Muis (2007), and Muis and Franco (2009) reported. The following scales were included in the instrument: *intrinsic goal orientation*-- to what degree the student views participating in a task for curiosity, and mastery (4 items), *extrinsic goal orientation*--to what degree the student views participating in a task for grades, rewards, and evaluation by others (4 items), *rehearsal*--how often the students used strategies involving reciting or naming items from a list to be learned (4 items), *elaboration*--how often the students use strategies helping herself building internal connections between items to be learned (6 items), *organization*--how often the student uses strategies that help selecting appropriate information and also construct among the information to be learned (4 items), *critical thinking*--to what degree students report applying previous knowledge to new situations in order to solve problem or make critical decisions (5 items), and *metacognitive self-regulation*--to what degree students report the awareness, knowledge, and control of cognition (12 items; Pintrich et al., 1991). Yumusak et al. (2007) reported the reliability of the sub-scales of the MSLQ with 519 high school students as .64 for intrinsic goal orientation, .54 for extrinsic goal orientation, .66 for rehearsal, .75 for elaboration, .68 for organization, .78 for critical thinking, and .77 for meta-cognitive self-regulation. Because the purpose of the present study is to identify students' self-regulated learning strategies in physics, the items translated by Sungur (2004) adapted to physics by changing "biology" words with 'physics" words. The English and the Turkish versions of the items used in this study are in Appendix C and D. Two items in the metacognitive self-regulation scale were negatively worded, so these items were reversed before a student's score was computed.

Achievement in physics. The students' physics grade at the end of the semester in which the study took place was taken as their physics achievement. The physics grade comprised the results of three mid-term exams that equally contributed to the final course grade. The students' final course grades ranged from 1 (failed) to 5 (excellent), with a mean of 3.32 and a standard deviation of 1.10. The students' final grades were obtained from the schools.

I conducted the preliminary analyses including CFA and inter-item reliability analysis, to establish the validity of the instruments. Byrne (2010) suggests CFA is suitable when the instrument has been fully developed and its factor structure has been validated. The instruments that were used in this study met these criteria. Using Mplus 6, CFAs were conducted for the EBQ and the MSLQ with the full sample of high school students (N = 209).

I used Hu and Bentler's (1999) model fit criteria with two fit indices to evaluate the model fit; (a) the Comparative Fit Index (CFI) values around .90 or the RMSEA values around .08 point out a moderate fit of the data to the model, and (b) CFI values greater than .95 or RMSEA values less than .06 are indicative of a good fit. The CFA analysis for the EBQ resulted with χ^2 (290, N=209) =658.77, p<.001, Standardized Root Mean-Square Residual (SRMR) =.07, RMSEA =.078, CFI =.80. These results pointed out that the model was not fit with the expected level. Cabrera-Nguyen (2010) suggested using absolute cut-off values of .30 for factor loading. This step ended with deleting two items, item 19 (.25 of factor loading) and item 20 (.28 of factor loading). I rerun CFA analysis for EBQ. The new CFA resulted in a good model fit, χ^2 (243, N=209)=407.30,

p<.001, SRMR =.057, RMSEA =.057, CFI =.90. I also examined Cronbach's alpha for reliability, ranging from .67 to .85 which indicates an acceptable value. Table 3.1 presents two example items for each factor (one with the highest factor loading, and one with lowest factor loading), and Cronbach's alpha values.

Table 3.1
Results of CFA and of reliability analysis for EBQ

	Example item	FL	α
EBQ			
Source			.67
	Whatever the teacher says in physics class is true.	.75	
	If you read something in a physics book, you can be sure it is true.	.45	
Certainty			.80
	Physicists pretty much know everything about physics; there is not much more to know.	.90	
	Physics knowledge is always true.	.46	
Justification			.85
	Ideas about physics experiments come from being curious and thinking about how things work.	.69	
	It is good to have an idea before you start an experiment.	.58	
Development			.78
	Some ideas in physics today are different than what physicists used to think.	.67	
	New discoveries can change what physicists think is true.	.53	

Note: FL: Factor loading

As MSLQ consists of two different subscales, motivational subscale (MS) and learning strategy subscale (LSS), I conducted a separated CFA analysis for each subscale. The results of CFA for MSLQ-MS were in a good model fit, χ^2 (19, N=209)= 16.14, p=.65, RMSEA =.000, CFI =1.00 (See Table 3.2). CFA for MSLQ-LSS resulted with a value of, χ^2 (382, N=209) =1100.84, *p*=.000, RMSEA =.091, CFI =.89. These results pointed out a moderate fit of the data to the MSLQ-LSS (Table 3.2).

Table 3.2
Results of CFA and of reliability analysis for MSLQ

Dimensions	Example item	FL	α
Intrinsic M.			.68
	The most satisfying thing for me in this physics course is trying to understand the content as thoroughly as possible.	.81	
	In physics class, I prefer course material that really challenges me so I can learn new things.	.40	
Extrinsic M.			.74
	If I can, I want to get better grades in this physics class than most of the other students.	.85	
	Getting a good grade in this physics class is the most satisfying thing for me right now.	.49	
Rehearsal			.71
	I make lists of important terms for this course and memorize the lists.	.82	
	When studying for this physics class, I read my class notes and the course readings over and over again.	.62	
Elaboration			.83
	I try to relate ideas in this subject to those in other courses whenever possible.	.86	
	I try to apply ideas from course readings in other class activities such as lecture and discussion.	.59	
Organization			.74
	I make simple charts, diagrams, or tables to help me organize course material.	.80	
	When I study the readings for this physics course, I outline the material to help me organize my thoughts.	.56	
Critical th.			.84
	I treat the course material in this physics course as a starting point and very to develop my own ideas about it.	.80	
	I often find myself questioning things I hear or read in this physics course to decide if I find them convincing.	.63	
MSR			.80
	I try to change the way I study in order to fit the course requirements and instructor's teaching style.	.89	
	When studying for this physics course I try to determine which concepts I don't understand well.	.60	

I attempted to improve model fit by adding or removing items and paths as suggested from the modification indices (Brown, 2006) and Wald tests but the fit did not improve. Therefore, all indicators remained in the model and they were used in the full SEM. Cronbach's alpha values for all variables in MSLQ, ranging from .71 to .84, indicate an acceptable value for reliability.

Data Analysis

To answer the research questions, I used the SEM, using MPLUS 6 software which allowed me to compute the indirect effect among scales. One advantage of using the SEM is that it provides for the direct estimation of all specific paths in the model (Kline, 2011). Furthermore, the SEM allows for overall test of the fit of a particular model to observed data (Kline, 2011). I used Maximum Likelihood estimation procedure for the estimation of the model in this study.

Figure 3.1 represents the proposed model of the relationship between students' personal epistemologies and self-regulated learning strategies. The proposed model and the relationship between the variables are based on Muis' (2007) theoretical model. Solid lines in Figure 3.1 denote the positive relations between variables. After the model was run, the model fit as well as the modification indices were examined. Based on the modification indices, I put an inter-correlation between scales if the theoretical model allowed.

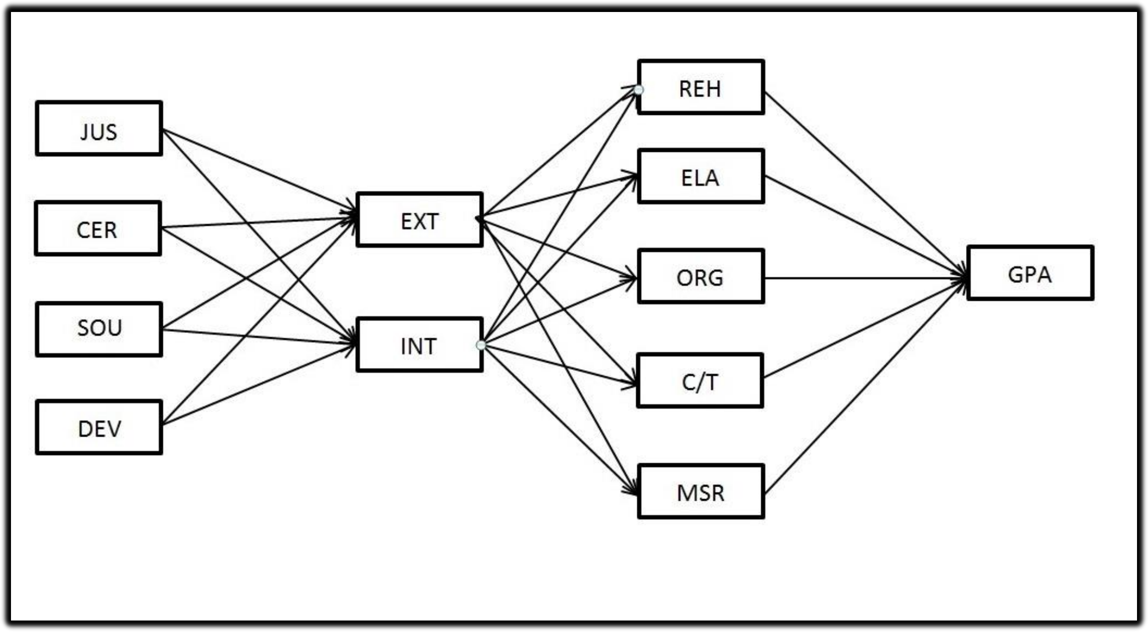

Figure.3.1: The hypothesized model.
Note: JUS, justification of knowledge, CER, certainty of knowledge, SOU, source of knowledge, DEV, development of knowledge, EXT, extrinsic motivation, INT, intrinsic motivation, REH, rehearsal, ELA, elaboration, ORG, organization, C/T, critical thinking, MSR, meta-cognition for self-regulation.

Results

The purpose of this study was to investigate the relationship between physics-related personal epistemology and self-regulated learning, and how these two constructs could account for achievement in physics. Academic performance was measured using students' final physics course grade. Personal epistemology dimensions of source, certainty, justification, and development were measured using EBQ. The self-regulated learning constructs of motivation, cognition, and meta-cognition were measured by using MSLQ.

Descriptive Statistics

I computed the mean, the standard deviation, the skewness and the kurtosis value for each variable in this study. The mean scores and standard deviations were to give insight about the students' personal epistemologies. As can be seen in Table 3.3, the results of the descriptive statistics indicated that the students' personal epistemologies generally were between moderate and sophisticated in a five-point scale (1 for naïve, 3 for moderate, and 5 for sophisticated personal epistemology). The source of knowledge dimension had the highest mean value (M=3.8, SD=1.23), whereas the justification of knowledge dimension had the lowest mean value (M=3.2, SD=1.11).

Table 3.3
Descriptive statistics for the variables

Subscales	Mean	SD	Skewness	Kurtosis
EBQ				
Justification [a]	3.2	1.11	-0.87	0.12
Certainty [a]	3.6	1.31	-0.73	-0.61
Source [a]	3.8	1.23	-0.21	-0.81
Development [a]	3.7	1.08	-0.76	0.14
MSLQ				
Intrinsic motivation [b]	4.7	1.31	-0.64	0.07
Extrinsic motivation [b]	5.2	1.71	-0.43	-0.88
Rehearsal [b]	5.2	1.13	-0.77	0.47
Elaboration [b]	4.7	1.87	-0.48	-0.73
Organization [b]	5.1	1.73	-0.46	-0.60
Critical thinking [b]	4.9	1.89	-0.58	-0.73
Meta-cognitive self- regulation [b]	4.0	1.86	-0.04	-0.98
GPA [a]	3.3	.1.10	-0.21	-0.61

Note: SD: standard deviation

[a] 1-5 point scale
[b] 1-7 point scale

As seen in Table 3.3, the mean value of students' motivational beliefs indicated that the students' motivational beliefs towards physics were between moderate and high in a seven-point scale (1 for low motivation, 4 for moderate motivation, and 7 for high motivation). Although the extrinsic motivation had a higher mean value than the intrinsic motivation, the difference between both values was quite small. Among the cognitive and meta-cognitive strategies, rehearsal strategy with a mean value of 5.2 (SD=1.13) seemed to have the highest mean value, whereas the meta-cognitive strategy had the lowest mean value (M=4.00, SD=1.86).

I also examined the normality of the variable scores. Kline (2011) suggested the skewness and the kurtosis values should not exceed an absolute cut-off value of 3.0 for skewness and 10.0 for kurtosis. The normality values ranging from -0.87 to 0.04 for skewness and from -0.98 to 0.07 for kurtosis for all variables were well within these ranges. Table 3.4 presents correlations among all variables.

Table 3.4
Correlation matrix

	Subscale	1	2	3	4	5	6	7	8	9	10	11
1	Justification											
2	Certainty	.16*										
3	Source	.09	.32**									
4	Development	.14	.27**	.28**								
5	Extrinsic mot.	.10	.19**	.33**	.29**							
6	Intrinsic mot.	.14*	.25**	.23**	.21**	.40**						
7	Rehearsal	-.06	.19**	.16*	.29**	.42**	.26**					
8	Elaboration	.01	.13	.18**	.17*	.60**	.33**	.36**				
9	Organization	.06	.13	.19**	.26**	.36**	.19**	.65**	.23**			
10	Critical thinking	.10	.09	.25**	.23**	.47**	.22**	.45**	.32**	.29**		
11	MSR	.15*	.15*	.26**	.21**	.24**	.24**	.37**	.19**	.34**	.10	
12	GPA	.19**	.12	.08	.13	.18*	.24**	.21**	.21**	.14*	.14*	.16*

MSR: Meta-cognition for self-regulation
*. p<.05
**. p<.01

Structural Equation Modeling

In this study, SEM via Mplus 6 was used to answer the aforementioned research questions. The model displayed in Figure 3.1 was tested. Coefficients for the direct causal pathways were calculated and presented in Figure 3.2. In Figure 3.2, for graphical simplicity I only included statistically significant estimates.

Research Question 1: What proportion of variance in the level of physics achievement is explained by physics-related personal epistemology and self-regulated learning in Turkish high school students?

According to the results presented in Figure 3.2, the model was able to successfully explain 11.6% of the variance in students' physics achievement. This can be considered a good result because 11.6% of variance in students' physics achievement can be accounted for by students' physics-related personal epistemologies and self-regulated learning strategies. Also, the model explained 45% of the variance in elaboration, 47% in critical thinking, 28% in rehearsal, and 14% in organization.

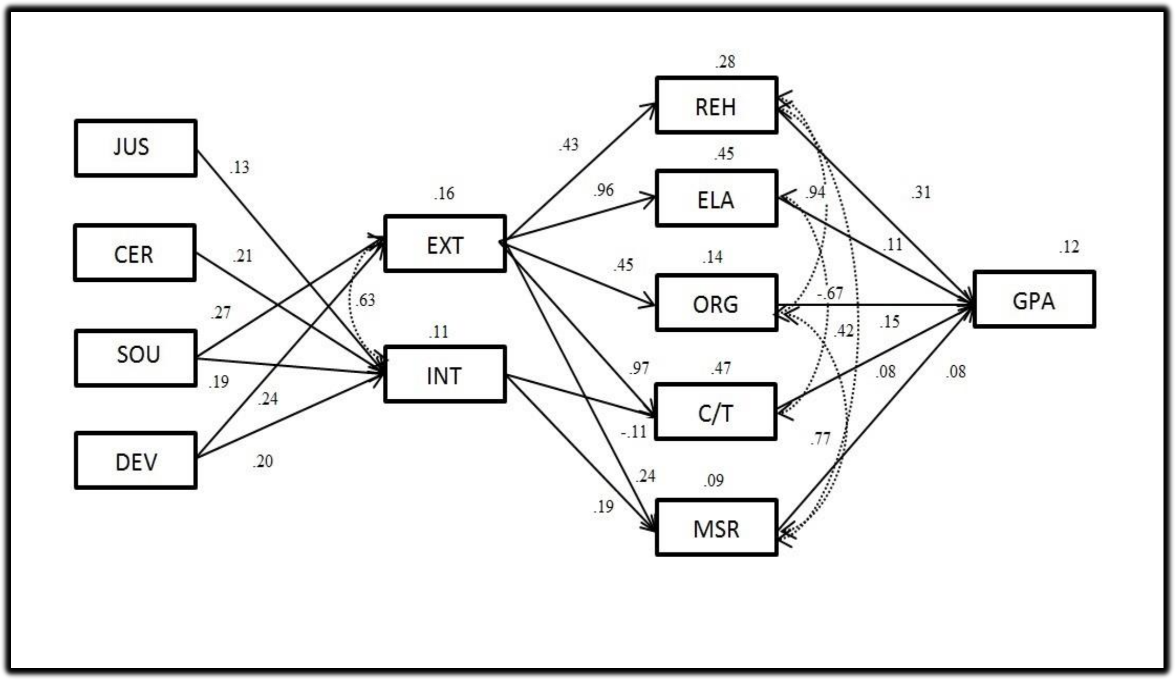

Figure 3.2: The final SEM.
Note: Dashed lines denote the paths that were added after examining modification indices.

Research Question 2: To what extent do the dimensions of personal epistemology express the motivational strategies that students use in physics in Turkey?

Examination of the path coefficients revealed that the source of knowledge would explain statistically significant variance in extrinsic motivation. The positive value of the estimated path coefficients (β = 0.27, p < .001) indicates that the more sophisticated belief in the source of knowledge dimension was related to greater levels of performance-related motivation to attain an outcome. Belief in the development of knowledge also accounted for statistically significant variance in extrinsic motivation (β

= 0.24, $p < .001$), indicating that the more sophisticated belief in the development of knowledge was related to greater levels of extrinsic motivation. However, the justification and the certainty of knowledge dimensions did not account for statistically significant variance in students' extrinsic motivation (β= 0.006, non-statistically significant [ns], and β= 0.007, ns, respectively), suggesting that belief in the justification and the certainty of knowledge dimensions are unrelated to outcome-oriented motivation.

The certainty of knowledge would explain statistically significant variance in intrinsic motivation. The positive value of the estimated path coefficients ($\beta = 0.21$, $p < .001$) indicates that the more sophisticated belief in the certainty of knowledge dimension was related to greater levels of intrinsic motivation. Belief in the development of knowledge dimension also accounted for statistically significant variance in intrinsic motivation ($\beta = 0.20$, $p < .001$), with the positive sign of the path coefficient indicating that more sophisticated belief in the development of knowledge was related to greater levels of intrinsic motivation.

The relationship between extrinsic motivation and rehearsal strategy was also statistically significant and positive (β= 0.43). This indicates that the more students had performance oriented motivation, the more they used memorizing strategies. Also, extrinsic motivation was positively related to the students' elaboration (β= 0.96, p<.001), organization (β= 0.45, p<.001), critical thinking (β= 0.97, p<.001) and meta-cognition for self-regulation (β= 0.24, p<.01) strategies. These results suggested that when students engaged in a particular cognitive strategy, they were more likely to choose the strategy that works best for the performance outcome. Because students' GPA constitutes an important part of their score at the Undergraduate Placement Examination (UPE), which is a required test to be able to attend a higher institution in Turkey, the UPE may account for why students were more extrinsically motivated and chose strategies for the performance outcome. Intrinsic motivation was positively related to the meta-cognitive strategies (β= 0.19, p<.01), implying that when the students had curiosity or interest to engage in a particular task of learning physics, they were more likely to control their cognition.

Another relationship that came out from the analysis was the profound positive effect of rehearsal strategies on students' academic achievement (β= 0.31, p<.001). This result suggests that students who had used more rehearsal strategies to learn physics received higher score in the tests at the semester. Organization strategies accounted for statistically significant variance in academic achievement (β= 0.15, p<.01), with the positive sign of the path coefficient indicating that the more frequently students organized the information during a particular learning task, the higher the GPA they obtained at the end of the semester. In addition to these, elaboration, critical thinking, and meta-cognition for self-regulation strategies were statistically significantly related to students' academic achievement.

Research Question 3: To what extent do the dimensions of personal epistemology predict the cognitive and meta-cognitive strategies that students use in physics in Turkey through the mediation of motivational strategies?

The mediation role of motivational strategies between students' physics-related personal epistemology and their self-regulated learning strategies was tested by examining the total indirect effect of personal epistemology on the self-regulated learning strategies. In addition, I examined the total effect coefficients through each motivational strategy. Table 3.5 represents the path coefficients from personal epistemology to each self-regulated learning strategy through intrinsic and extrinsic motivations.

Analysis revealed statistically significant effects of personal epistemology on the self-regulated learning strategies. Beliefs in the source and beliefs in the development of knowledge dimensions accounted for statistically significant variance in rehearsal strategies through extrinsic motivation (β = 0.117, p < .001, and β = 0.106, p <.01, respectively). This indicated that the more sophisticated beliefs in the source and the development of knowledge dimensions were related to greater levels of rehearsal strategies through students' performance-oriented motivation.

Table 3.5
Indirect effects from personal epistemology to cognitive strategies

	REH		ELA		ORG		C/T		MSR	
	EXT	INT	EXT	INT	EXT	INT	EXT	INT	EXT	INT
Justification	.023	.005	.052	.008	.024	.007	.060	-.014	.013	.024
Certainty	.025	.008	.056	.013	.026	.012	.063	-.022	.014	.039
Source	.117*	.007	.263*	.011	.122*	.010	.303*	-.020	.066*	.035
Development	.106*	.008	.236*	.012	.110*	.011	.273*	-.021	.059	.037

Again, the source and the development of knowledge dimensions would explain statistically significant variance in elaboration strategies through extrinsic motivation. The positive values of the estimated path coefficients ($\beta = 0.26$, $p < .001$ and $\beta = 0.24$, $p < .001$, respectively) indicate that the more sophisticated belief in these dimensions was related to greater levels of elaboration strategies, which help students store information by internal connection through extrinsic motivation.

Beliefs in the source and beliefs in the development of knowledge dimensions accounted for statistically significant variance in organization strategies through extrinsic motivation ($\beta = 0.122$, $p < .001$, and $\beta = 0.110$, $p <.01$, respectively). This indicated the more sophisticated belief in these dimensions was related to greater levels of organization strategies, which help students select appropriate information and connections among information through extrinsic motivation. Moreover, the source and the development of knowledge dimensions would explain statistically significant variance in critical thinking strategies through extrinsic motivation ($\beta = 0.303$, $p < .001$ and $\beta = 0.273$, $p < .001$, respectively). This suggested that the more sophisticated belief in these dimensions was related to greater levels of critical thinking strategies, which students apply previous knowledge to new situation to made decision, through extrinsic motivation.

Again, the source of knowledge dimension would explain statistically significant variance in meta-cognitive strategies through extrinsic motivation ($\beta = 0.066$, $p < .05$). This suggested that believing the multiple sources of knowledge was related to a more frequently use of strategies, including controlling and monitoring cognition, through extrinsic motivation. Yet, the justification and the certainty of knowledge dimensions did not account for statistically significant variance in any self-regulated learning strategies that students use.

Research Question 4: To what extent does the hypothesized SEM fit the data obtained from students in Turkey?

The model was originally developed to explain the data. The first model was run. This model showed poor fit of the data, $\chi 2$ (37, N=209) =243.62, p<.001, SRMR =.100, RMSEA =.112, CFI =.73. Then, the modification indices were examined. Based on the modification indices, I put an inter-correlation between (a) intrinsic and extrinsic motivations, (b) rehearsal and meta-cognition for self-regulation, (c) rehearsal and organization, (d) elaboration and critical thinking, and (e) organization and meta-cognition for self-regulation. These correlations were also conceptually reasonable: for example, students may organize information to use rehearsal strategy. These inter-correlations were showed with dashed lines in Figure 2.

Overall, the fit statistics for the second model revealed that the second model fit with the data obtained from the students in Turkey quite well. More specifically, the chi-square statistic $\chi 2$ (32, N=209) =62, p< .0011 was statistically significant. This indicated that although the model did not fit the data well, the chi-square/df ratio smaller than 2 indicates an adequate fit (Tabachnick, & Fidell, 2007). However, this result can be deceiving since this statistic is actually influenced by the large sample size used in this study (Kline, 2011). It has been suggested that this significance level is more likely to be the product of the sample size than a product of the actual fit of the models and therefore should be interpreted with caution (Bryne, 2010). A value of .96 for CFI was slightly higher than .95, and the Tucker–Lewis index (TLI) also equaled .92. These values supported the fit of the data to the second model since these values were equal or higher than .90. As for the fit index of the RMSEA and the SRMR, both showed a very good fit since their values equaled .057 and .049 respectively, which were lower than .06.

Conclusion and Implications

In this study, I empirically tested Muis's (2007) hypothesis that students' personal epistemologies predict their goal orientations and cognitive and meta-cognitive strategies they use in a physics course in Turkey.

The results of this study provide evidence for Muis's (2007) theoretical model. Also the results of this study are consistent with Muis and Franco (2009) that tested the Muis's theoretical model with the Canadian educational psychology undergraduate students. Hofer and Pintrich (1997) hypothesized that students' ideas about knowledge and knowing are related to their achievement goals that they set for a learning task. Muis (2007) also proposed that personal epistemology facilitates or constrains facets of self-regulated learning by influencing the goals for the task. The results of this study are consistent with Muis and Franco's (2009) findings that students' personal epistemologies predict students' achievement goals. Muis and Franco (2009) reported that students who viewed knowledge as simple and certain (the development of knowledge) were more likely to adopt an extrinsic motivation. If students believe that knowledge is certain and simple, which indicates there is a well-defined standard to evaluate how much one knows; then students are more likely to adopt an extrinsic (performance-oriented) motivation. On the contrary, learners with more sophisticated views on the certainty and the development of knowledge are more likely to adapt an intrinsic oriented motivation. Consistent with Muis and Franco (2009) and the predictions from Muis's hypothesis, in this study I found that students who viewed physics knowledge as tentative (β=0.21) and complex (β=0.20) adapted intrinsic goal orientations towards learning physics. Also the results of this study shown that students who viewed knowledge as complex (β =0.24) developed extrinsic goal orientation towards learning physics. This can be explained by the fact that students' physics GPA influences their scores at the UPE which is discussed later.

Muis (2007) hypothesized that a learner who has naïve views on the justification and the source of knowledge is more likely to adapt an extrinsic goal orientation because she believes that authority figures make the decisions and evaluate what one knows. Muis and Franco (2009) reported that the students who believed knowledge is personal are more likely to adapt an intrinsic goal orientation, than those who adapt extrinsic goal orientation. Consistent with their results, in this study I found that the students who believed evidence is required to evaluate the physics claims (β =0.13) and the knowledge is internally constructed (β =0.19) were more likely to possess intrinsic goal orientations towards learning physics. Also the analysis revealed that the students who viewed the knowledge as internally constructed (β =0.27) possessed extrinsic goal orientations towards learning physics. Again, this can be explained by the fact that the students' physics course grades have a slight impact on their overall university entrance score. In the Turkish educational system, the high school students' GPAs (out of 100) are multiplied by 0.6, and added to the scores they receive in the national university entrance exam.

The previous studies reported that students' goal orientations related to their use of rehearsal, elaboration, organization, critical thinking and meta-cognitive self-regulation (Elliot & McGregor, 1999; Yumusak et al., 2007). Muis (2007) hypothesized that students' achievement goals predict the types of learning strategies they use in phase 3 of self-regulated learning. I tested this hypothesis examining if students' achievement goals predict students' self-regulated strategies in learning physics. Consistent with previous research (Muis & Franco, 2009; Pintrich, 2000), the findings of this study indicated that students' intrinsic and extrinsic goal orientations predicted their self-regulated learning strategies in physics.

The study results showed a positive correlation between extrinsic goal orientation and rehearsal strategies that students used. This relationship can be explained by the fact that the traditional physics instruction at schools is mostly about teaching how to use formulas in physics problems (Redish & Steinberg, 1999; Meltzer, 2002). Students describe that mastering in physics includes knowing how to use formulas in physics problems (Redish & Steinberg, 2002). This view might have led the students who were extrinsically motivated to choose rehearsal strategies more often in order to perform better at the physics exams. From the self-regulatory perspective, this notion is important because it indicates how task definition predicts self-regulated learning strategies (Muis, 2007; Muis & Franco, 2009; Pintrich, 2000). The relationship between the use of rehearsal strategies and the academic achievement was positive, indicating that the more often the students used the rehearsal strategies the higher the final course grade they received in physics. This result is inconsistent with Yumusak et al.'s (2007) study with the high school biology students in Turkey. One possible reason for this inconsistency is the differences in assessing the students' academic achievement. Yumusak et al. used a constructivist test to measure students' achievement in biology whereas I used students' final course grades, which included the grades from three exams. Overall, this result suggests that the different use of surface processing strategies is helpful for academic performance in physics.

Muis (2007) hypothesized that students' personal epistemologies relate to their cognitive and meta-cognitive strategies through goal orientation. The results of this study indicated that students' cognitive and meta-cognitive strategies were related to their personal epistemologies through goal orientations. I found that the students who viewed knowledge as internally constructed reported the use of elaboration strategies more often. Similarly, the use of critical thinking strategies were indirectly predicted by students' views that physics knowledge is evolving. Yet, the indirect relations of the justification and the certainty of knowledge to the cognitive and meta-cognitive strategies were not statistically significant. This can be explained by the fact that the motivational goals of the students in this study were dominated by performance-oriented motivation, which is less likely to be adapted by the students who have sophisticated views on the justification and the certainty of knowledge.

Even though in this study a number of predictions from Muis's (2007) hypothesis were supported, some relationships in her theoretical model were not statistically significant or were in the reverse direction. Accordingly, I focus my discussion and the limitation of the study on two particular results of this study: the dominance of the extrinsic motivation, and the strong relationship between rehearsal strategy and academic achievement.

Dominance of extrinsic motivation among the students in this study may be due to a fact that students' GPA from physics course constitutes an important part of their score at the UPE test. Therefore, the students in this study may be more extrinsically motivated to obtain a good grade. Consequently, their cognitive and meta-cognitive strategies may be selected based on what strategy works better for a good grade. In addition to this, as a limitation of this study, the study data were collected in May when students were about to take their final exam at the physics course. Any attempt to generalize the findings of this study should be approached with caution.

An underlying assumption on Muis's theoretical model is that the relationship between personal epistemology and self-regulated learning is reciprocal and domain-specific. In terms of domain-specificity, Muis et al. (2006) argued that hard science (e.g., physics) is viewed as more paradigmatic than soft science as "the content and methodologies employed are more idiosyncratic" (p.10). The structure of physics, for example, is well defined and includes more technical terms that are more tightly structured (Muis et al., 2006). Consistent with this view, the previous studies in students' ideas about learning physics reported that learning physics means effectively memorizing how to use formulas (Ehrlich, 2002; Sin, 2014). One possible reason is the assessment methods in physics and how students view physics achievement. Some students believe that “studying historical and real-life examples will not be rewarded, and formulas will appear on the test” (Elby, 1999, p.53). Consistent with this, rehearsal was the most often used strategy by the students in this study (M=5.2). However, frequent use of surface-processing strategies (e.g., rehearsal) discourages students to attain conceptual understanding in physics and fails them in constructivist assessments in Turkey (Hammer, 1994; Yumusak et al., 2007). Due to the difference in contexts, there is a need for more studies on the relationship between personal epistemology and self-regulated learning in physics for the generalizability of the theoretical model and its implications.

CHAPTER IV

HIGH SCHOOL STUDENTS' PERSONAL EPISTEMOLOGIES AND SCHOOL SCIENCE PRACTICE

Personal epistemology is defined as what individuals believe about what counts as knowledge, how individuals come to know, and how knowledge is constructed and evaluated (Hofer, 2008; Hofer & Pintrich, 1997; 2002; Schommer, 1990). Personal epistemology influences how students make meaning, solve problems, and learn strategies (Hammer, 1994; Hofer, 2001; 2008; Sandoval, 2005). In science education, an understanding of how scientific knowledge is constructed would provide powerful tools for thinking and reasoning to the citizens in everyday life and for decision making in democratic societies (Sandoval, 2005). Therefore, examining students' personal epistemologies helps us understand how students resolve competing knowledge claims, evaluate new information, and make fundamental decisions (Hofer, 2001).

Some researchers have argued that students' personal epistemologies are tacit, complex, and require an intensive focus (e.g., Kelly, 2008; Sandoval, 2005). Cultural, curricular, and social contexts are considered as important elements interweaving students' personal epistemologies (Sandoval 2009; Kelly et al., 2012). To shed light on the complexity of students' personal epistemologies, some researchers have suggested examining students' school science practices (Elby & Hammer, 2010; Sandoval, 2005; 2009).

Students' practices in school science may reflect their tacit beliefs about the nature of knowledge, the methods by which knowledge is produced, and how it is evaluated (Metz, 2011; Sandoval, 2009). However, there are few studies that have examined students' personal epistemologies through students' school science practices (Metz, 2011, Yang & Tsai, 2012). How the ideas about the nature of scientific knowledge are interpreted in the social and cultural contexts in schools are critical. It is questionable whether or not the curricular context in schools positively supports students' ideas about the nature of scientific knowledge.

Two perspectives have been used to examine individuals' epistemologies. One perspective is psychological, which views epistemology or beliefs in knowledge as personal, empirical, and contingent (NRC, 2007; Kittleson, 2011). The other perspective is social, which views the beliefs in knowledge as situational and context-dependent (Kelly et al., 2012; Yang & Tsai, 2012). The studies that consider both of these perspectives are rare. Investigating students' personal epistemologies from these two perspectives at the same time will help us draw a better picture of the students' ideas about scientific knowledge.

Literature Review

Researchers have characterized personal epistemology in different theoretical models. Most of the models appear to view epistemology as a sequence of developmental stages. In these models, common views are that naïve individuals tend to see knowledge as static and an accumulation of separate facts, and if change occurs, it has to move from naïve views through more sophisticated views (e.g., Perry, 1970, Kuhn, 1991). A few researchers characterized personal epistemology as multi-dimensional and dependent on context (e.g., Hammer & Elby, 2002; Hofer & Pintrich, 1997).

Hofer and Pintrich (1997) draw upon personal epistemology as the basis of key aspects identifiable across psychology and philosophy. They define personal epistemology as epistemic theories in four identifiable dimensions. The first two dimensions relate to the nature of knowledge: (a) *the certainty of knowledge* is focused on the perceived stability and the strength of supporting evidence, and (b) *the simplicity of knowledge* describes the relative connectedness of knowledge. The other two dimensions describe the process of knowing: (c) *the justification of knowledge* explains how individuals proceed to evaluate and warrant knowledge claims, and (d) *the source of knowledge* is either that knowledge resides as an external source or is constructed by learners.

A growing body of research has addressed high school students' personal epistemologies in science. Most students at high school level view that all scientific knowledge can be attainable (Yang, 2004). Students believe that scientific knowledge can be wrong or right and only experts can tell the correctness of information (Yang, 2005). Wu and Tsai (2011) found that students might not be able to apply their relevant knowledge in their decision-making on the socio-scientific issue (SSI) and still tend to make intuitive decisions. Similarly, students might not be able to recognize the importance of evidence in evaluation of theories (Thoermer & Sodian, 2002).

The multidimensional model of personal epistemology outlined by Hofer and Pintrich (1997) has framed empirical studies of personal epistemology at high school level (e.g., Bekiroglu & Sengul-Turgut, 2011; Tsai et al., 2011; Wu & Tsai, 2011). Of these, a few studies investigated students' personal epistemologies in the domain of physics. For example, Bekiroglu and Sengul-Turgut (2011) studied if high school students' general epistemological beliefs were different from their personal epistemology in the domain of physics. Fifteen ninth-grade students completed two open-ended questionnaires that mapped their personal epistemologies in sciences in general and in physics in particular. Results showed that most of the students' (87%) epistemological views towards general science and towards physics were identical. Their views were reported as either low-level or medium-level. More specifically, the students viewed physics knowledge as certain and coming from an external source (either scientists or teachers).

Although several studies did not explicitly focus on personal epistemology in science education, they provided insight into students' ideas about scientific knowledge. For instance, Driver et al. (1996) examined age-related trends of students' views (aged 9, 12, and 16) on the purposes of scientific work, the nature and status of scientific knowledge, and the notion of science as a social enterprise. Driver et al. found that students aged 16 tended to mention empirical testability as a criterion for a question to be scientific more than younger students (χ^2 (2, 700) = 8, 98, p < .001). Relation-based reasoning was the most common among the students aged 12 and 16. They concluded students use different forms of reasoning across different situations.

Interviews and surveys are the most popular instruments to probe students' personal epistemologies from the psychological perspective in science education research. However, often the questions asked in interviews and surveys are about the nature of scientific knowledge in general and they are decontextualized and abstract (Samarapungavan, Westby, & Bodner, 2006). For instance, the Nature of Science Interview (Smith & Wenk, 2006) asks such questions as "what do you think the goal of science is" (p. 778). Some researchers argue that it may be misleading to attribute a particular stance to an individual (Hammer et al., 2005). Furthermore, there is evidence that students' epistemic reasoning is inconsistent across contexts (Driver et al., 1996; Leach et al, 2000; Sandoval & Cam, 2010). For instance, Leach et al. (2000) investigated whether students' epistemic reasoning is consistent across different kinds of questions. Students were asked to respond to two written items that consisted of multiple statements addressing epistemological issues (e.g., relationships between scientific theories, empirical data, and the design of investigation). In terms of consistency of students' reasoning across the two items, no evidence was found. Similarly, Sandoval and Cam (2011) examined young children's epistemic judgments of the causal justification types. Students were asked to choose a justification type (authoritative vs. evidentiary) among many for a causal claim, and explain why. Of 26 students, 15 chose the evidentiary justification in at least three of four stories; four chose the evidentiary; and one never chose the evidentiary justification in all four stories. These results suggested that a student can have a naïve view (choosing authoritative justification) or a sophisticated view (choosing evidentiary justification) across items. These studies suggested that students' epistemologies are complex, and multiple data sources should be used to probe students' personal epistemologies (Driver et al., 1996; Leach et al., 2000; Sandoval, 2005; 2009).

Researchers who studied epistemology as social practice asserted that characterizing students' epistemology requires paying attention to both students' personal epistemologies and the way in which the context interact with individuals. Elby and Hammer (2001) argued that research should be focused on the way in which context influences characterization of personal epistemology. For example, they argue that even if scientific knowledge is constructed by humans, in some contexts it is possible for scientists and students to see scientific knowledge as discovered in Nature. They assert that it is possible for some students to believe that scientific knowledge is about discovering objective truths in some contexts such as the Earth is round. Second, epistemic sophistication is viewed in the surveys as believing certain generalization that scientific knowledge is tentative. They argue that the view that scientific knowledge is tentative does not apply equally to all scientific knowledge. For example, it would barely be a tentative view that the Earth is round rather than flat. Hammer and Elby (2002) suggested that researchers should focus on the ways in which students view and use scientific knowledge in their practices of science.

Paralleling Hammer and Elby's (2002) point, some researchers argue that social and cultural contexts influence individuals' ways of thinking and acting (e.g., Kelly et al., 2012; Sandoval, 2005; 2009). In this view, knowledge and issues regarding knowledge are socially constructed (Kelly, 2008). Therefore, rather than paying more attention to the individual consciousness, examining epistemology should focus on the inter-subjectivity processes of a community (Kelly et al., 2012). This implies that epistemic actions of community practice depends on the individual's mind and the reflection of the other members of the community.

A few researchers examined students' epistemologies in practices of science (e.g., Hammer & Elby, 2003; Rosenberg et al., 2006; Sandoval & Reiser, 2004; Kittleson, 2011). The research revealed that students' epistemic approach is fragmented and localized in particular situations (Sandoval & Reiser, 2004). For example, Rosenberg et al. (2006) studied how epistemic knowledge played a role in the students' approach to an activity in terms of epistemic resources. Segments of the students' discussion revealed that students' epistemic resources can be categorized as coherence rather than pieces. There were also shifts from one segment to another in the students' sense of what constitutes knowledge. Students' discussion showed several local (depends on the context) coherences. These studies support Hammer and his colleagues' argument that the stability of an individual's epistemic stance can depend on the context, social or material.

A call for more naturalistic studies of personal epistemology has been made by several scholars (Sandoval, 2005; 2009; Elby & Hammer, 2001; 2010; Yang & Tsai, 2012). In this call, analyzing the discourse of the student and constructed artifacts was suggested (Sandoval, 2005; 2009). In this view knowing is an adaptive process that organizes an individual's experiential world within a social setting (Kelly et al., 2012). There is evidence, for example, that what students report in a survey or an interview about science is different from what the students do in science learning activities (Leach, 2006; Kelly, 2008; Wickman, 2004). Furthermore, students' epistemic perspectives contribute to the group's knowledge construction (Sandoval & Reiser, 2004). Taking into consideration both social and psychological perspectives on students' practices of science will shed light on our comprehension of students' personal epistemologies in classroom settings.

Research Questions

1. What are the characteristics of students' physics-related personal epistemologies in scientific practices?
2. In what ways are students' personal epistemologies mobilized in school science practices?
    a) In what ways are students' personal epistemologies mobilized in a teacher directed classroom (lecturing)?
    b) In what ways are students' personal epistemologies mobilized in laboratory activities?

Methods

Research Setting and Participants

In this study, I utilized an instrumental single case study with qualitative methods to explore students' physics-related personal epistemology in school science practices. Merriam (2009) defines a case study as "an intensive, holistic description and analysis of a single entity, phenomenon, or social unit" (p. 46). For a study to be a case it should be a bounded system that the researcher finites the participants or the timeline of the study (Stake, 2005). In this study the physics classroom at a charter school is considered as a bounded system by place in which the students participate in inquiry activities and time covering inquiry activities on two subject topics.

This study was conducted at a charter school, located an urban area at the South Central United States, which is defined as "publicly funded, nonsectarian school that operates under a written contract, or charter from an authorizing agency such as a local or state board" (Texas Education Agency, 2006, p.312 Cited in Sahin, Ayar & Adiguzel, 2014). The students at the school came from low-socio-economic status; the percentage of students who qualified for free or reduced lunch was 55%. The student population of the school was kindergarten to high school. When the study took place, a total of eleven students at 11^{th} grade enrolled in physics course with one teacher. Students at the school performed well on the state assessment program which ranked among the top 25% in the state for science at high school level.

The teacher in this study, Mr. Bryan (pseudonym), has four years of teaching experiences and has been working at the school for four years. He held a Bachelor of Physics degree. When the study was being conducted, he was teaching the physics course (5 hours), SAT Enrichment, and Pre-Calculus courses (a total of 10 hours).

There were eleven students in Mr. Bryan's eleventh grade physics class. Of eleven students, a total of nine students (3 girls, and 6 boys), with ages ranging from 16 to 18 years, consented to participate in all portion of the study. Two students declined to participate in the study. Two students identified themselves as Hispanic, two as African American, and five as White.

During the six weeks data collection, the topics covered in this physics class included a force and motion laws unit without force of friction (10 hours), Newton's laws of motion including force of friction (5 hours), and work-energy theorem and energy transformation and conservation of energy (10 hours). Instructional activities included Mr. Bryan's presentation of topics and whole class problem-solving activities. A total of 15 hours was devoted to instructional activities. Laboratory activities included pendulum bob experiment, motion without friction using motion detectors, motion with friction with the spring, the conservation of energy experiment, and gravitational acceleration. A total of 10 hours was devoted to laboratory activities.

The instructional activities and laboratory activities were implemented in the same classroom. During laboratory activities the students worked in groups of two or three students. The students were assigned to groups by Mr. Bryan and worked with the same students during my data collection. Group 1 consisted of Student 1 and Student 3. Group 2 consisted of Student 2 and Student 4. Group 3 consisted of Student 6 and Student 9. Group 4 consisted of Student 5, Student 7, and Student 8. Group 1 and Group 2 worked at the same desk during the activities.

Data Collection Methods

In this study, I used multiple data collection methods including formal and informal interviews, audio-recording of inquiry activities, field notes, lab reports, and the collections of documents and artifacts. I observed the classroom activities in person over six weeks. Audio-recordings of the inquiry activities and interviews were the primary data sources. I conducted interviews with the nine students to have an initial idea about their understanding of the nature of scientific knowledge. Interviews were conducted by using a semi-structured interview protocol in Appendix E. Interview questions were based on research on dimensions of personal epistemology and the nature of science (Hammer, 1994; Tsai, 1998; Kittleson, 2011; Hofer & Pintrich, 2002). The interviews included the following prompt questions: Do you think that scientific knowledge about [physics subject that being covered] in textbooks (teachers and scientists) is always true? What is a theory? After scientists have (had) developed a theory, does the theory ever change? What kind of change may occur in the development of science? How and why? Do you think your friend should reach the same results that you found in your experiment? (scientists, too). How do you know this equation or etc.? [showing a formula from the textbook)] If you had to teach this equation to someone, how would you do that?

Also, I conducted post-activity group interviews at the end of inquiry activities. During the inquiry activity, students might not verbally speak any dimension of personal epistemology, and this would lead to some part of the personal epistemologies being left out. Therefore, the purpose of the post-activity interview was to enter into students' perspectives about the activity (Patton, 1990). The post-activity interviews included, for example, the following prompt questions: How do you prepare for the activity? How do you define the purpose of the activity? Do you think that there is anything that you find for sure in your activity? What do you do when your results do not match the expected results from the theory? How do you draw conclusions from the experiment? Interviews were audio-recorded and transcribed.

Audio-recording of students' practices of science was another primary data source. It was used to capture students' conversations during the activity. The language is a key to capturing students' ideas about the nature of scientific knowledge (Kelly & Crawford, 1997; Lemke, 1990). Thus, I placed a voice-recorder device on each desk (a total of four voice-recorders) where students' voices were clear and distinguishable. All lessons (a total of 25 class sessions) were audio-recorded and transcribed. During this time, I observed the classes and took field notes. Also, artifacts constructed by students were suggested as important to characterize students' personal epistemologies (Sandoval, 2009). I collected students' lab reports or any artifacts they constructed at the end of the activity.

Data Analysis Methods

One of the purposes of the study is to analyze students' personal epistemologies in practices of science from both psychological and social perspectives. For this purpose, I utilized Cobb, Stephan, McClain, and Gravemeijer (2001)'s "interpretive framework" to analyze data from both social and psychological perspectives. The interpretive framework has been developed by Cobb et al. (2001) to analyze students' practices in mathematics classroom. The interpretive framework has also been used by mathematics education researchers to describe the socio-mathematical norm of a classroom community (McClaim & Cobb; 2001), the identity students develop (Cobb et al., 2009), and elements of mathematical practices (Stephan et al., 2003). In science education research, some researchers have employed the interpretive framework to analyze students’ interest (Dohn, 2011), representation in science (Danish & Enyedy, 2009), and socio-chemical norms in chemistry classroom (Becker et al., 2013).

According to Cobb et al. (2001), practices can be seen as cultural practices that are “emergent phenomenon rather than an already-established- ways of reasoning and communicating” (p.121). The interpretive framework consists of two dimensions: (a) social perspective and (b) psychological perspective. Social perspective, inspired by socio-cultural theory (e.g., Lave, 1998; Rogoff, 1997) refers to “ways of acting, reasoning, and arguing that are normative in the entire classroom community” (p. 118). Psychological perspective, inspired by constructivism and theories of intelligence (Pea, 1992) is “the nature of individual students' reasoning or, in other words, his or her particular ways of participating in those communal activities” (p.119). In this analytical framework, the social and the psychological perspectives are dependent on one another. Thus one cannot exist without the other, and vice versa, so that each forms the background for the other.

Kelly (2008) argues that investigating epistemology of students’ school science practices requires shifting from examining epistemology from the perspective of individual consciousness to examining epistemology as it arises from the inter-subjective processes of a community. The interpretive framework, then, can be used as an analytic tool since it captures both the psychological and social aspects of students’ personal epistemologies in school science practices. In the interpretive framework, “the social aspect brings to the fore normative taken-as-shared ways of talking and reasoning”; the psychological perspective brings to the fore the diversity in ways of participating in these taken-as-shared activities (Cobb et al., 2001, p.119).

The analysis of the psychological perspective is to view the teacher and students as a group of individuals who engage in acts as they interpret and respond to each other's actions. From a psychological perspective, I viewed personal epistemology as the individual's experiences of epistemology associated with his or her participation in shared experience (Dohn, 2011). The goal of the psychological analysis is not to identify an individual's cognitive or affective mechanisms separate from the other individuals (Cobb et al., 2001).

In the social perspective of the analysis I viewed the teacher and students as members of a local community who jointly establish communal practices. Inspired by epistemic practice defined by Kelly (2008), I viewed epistemology as "the specific ways that members of a community propose, justify, evaluate, and legitimize knowledge claims within a disciplinary framework" (p. 99). Inter-subjective includes ways that knowledge claims are assessed, produced, communicated, or evaluated within a particular community.

To use the interpretive framework, the data corpus should be large and typically consist of recordings of students' conversations, copies of students' written work, and interviews after the lesson (Cobb et al., 2001). Cobb et al. (2001) suggested using grounded theory to analyze rich data set. Thus, I employed the constant-comparative method (Glaser & Strauss, 1967). I followed several steps to analyze audio-recordings. First, I transcribed all audio-recordings of class sessions. Then, I read all the transcriptions and parsed each transcript into an episode (Cobb et al., 2001). Next, I summarized each episode by writing notes about the nature of activity and topic. Then, I identified themes to characterize the topic. Also, all interviews were transcribed and merged with field notes and other documents. I employed open and axial coding followed by the selective coding (Strauss & Corbin, 1990) to analyze the transcribed verbatim, field notes, and other documents.

Findings

A qualitative case study was chosen to describe how ideas about scientific knowledge are mobilized in the school science practices. By choosing a case study design with qualitative research, I aimed to uncover students' personal epistemologies in practices of science by incorporating both social and psychological perspectives. Therefore, analysis, descriptions, and interpretations were used to generate thick description (Merriam, 2009). Thick description brings a rich description of students' personal epistemologies to the reader (Creswell, 2007). Below, I present the thick description of three themes that emerged from the analysis of students' school science practices. These are a) *can we study physics without experiment*, b) *accuracy and precision of scientific data*, and c) *practicing formula*.

Can We Study Physics without Doing Experiments.

Sandoval (2005) highlights that for a proper understanding of science and scientific inquiry; students should agree that there is no single method that applies to all scientific disciplines or inquiries. Students should know that scientific methods are diverse and there are methods other than controlled experimentation, for example, observation, theoretical model building, or mathematical explanation. Below I quote the conversation between Mr. Bryan and the students about theoretical physics versus experimental physics and gravity in physics.

Newton's Law unit: 20-Nov-13
Mr. Bryan: If you are going up and the acceleration is up, you will be heavier on the scale. What if you are going down?
Students: (silence)
Mr. Bryan: You will be lighter and then this is Einstein's question. What if you going down and the elevator are is at free fall?
Student 5: You weight nothing.
Mr. Bryan: Yes. You will be weightless in the elevator. What if Einstein says that you are in a big manned shuttle at free fall in the elevator? So, you'd think that you were in the space because you were weightless. In the contrast, if you were in the elevator in the space and swinging around but this time you'd not think you were in the space because you'd have artificial gravity that keeps you on the floor. That is where his thought experiment is turning around his relativity theory.
Student 5: Didn't he do any experiment like Aristotle?
Mr. Bryan: Did he just think like Aristotle or did experiment like Galileo? No. He did some experiments himself but he was more of a theoretical physicist; he had other people do his experiments during his life time and after his death.
Student 8: Can we just do physics without experiment?
Mr. Bryan: You can be a theoretical physicist. So actually, Aristotle's theoretical explanation and Galileo's experimental ball theory are still around today. You can be a theoretical physicist, or you can be an experimental physicist. They both work. Theoretical physicists understand the value of experimentation but it takes time for someone to figure out how to set up the experiment. For example, again Einstein's theory: he thought that light is affected by the gravity. His theory is that gravity should affect light. Well, so there is a solar eclipse coming from the sun. A bunch of guys experimented during the solar eclipse, so that they were able to have a good look at the stars that behind the sun. You usually cannot see these stars because there is dimmed light, like a flash light. But when the sun was blocked they can see those stars and they were able to see where they actually are versus where we thought they were. The results came out that "Yes the light was bent a little bit, making the star located at a wrong spot." This experiment proved that while stars' lights pass the sun, the sun's gravity bent the stars' light. That showed us that Einstein was right.

Mr. Bryan used Einstein's thought experiment to have students visualize the effect of gravity in an elevator. The discussion then turned to students' questions about theoretical versus experimental physics. Students seemed viewing experimentation as the only way to investigate phenomena in physics. Mr. Bryan used Einstein's theoretical explanation and the substantial experiments on the effect of gravity on the light to emphasize how theoretical physics can lead experimental research about gravity in physics and how these methods can work together. By emphasizing that there are other ways to investigate the phenomena in physics rather than experimentation, Mr. Bryan reinforced the idea that scientific methods are diverse.

I interviewed nine students after the class session. The purpose of interviews was to further understand (a) what they thought about theoretical and experimental physics, and (b) what methodology was convincing to them. This interview would also give an insight into the students' ideas on how they evaluated scientific theories and evidence that support scientific theories and the source of scientific knowledge for them. During the interview, I asked the students the question: "In your class, Mr. Bryan talked about some scientists and their theories about gravity. These are Aristotle's and Einstein's theoretical explanation about gravity, and Galileo's experimental explanation about gravity. What do you think about theoretical physicist versus experimental physics? Which theory is more convincing to you?" Then, I asked the reasoning behind their choice. I paid more attention to the students' reasoning since they convey the criteria students looked for to evaluate scientific claims.

The student’s choice of scientific methods about the gravity was analyzed at two levels. First, I looked at whether they chose the theoretical explanation or the experimental explanation. Next, I summarized the students’ explanations.

The first level of analysis revealed that overall students were more likely to choose the experimental methods. Whereas two of the nine students in the class chose Einstein’s theoretical explanation, seven students chose Galileo’s experimental explanation. Given the previous research on high school students (e.g. Driver et al., 1996), it is not surprising that students indicated experimentation as explaining the phenomenon of gravity. At the second level analysis, I looked at students’ explanation of their choice. Student 1 who chose Einstein’s theoretical explanation about the gravity explained his reasoning as the following:

> **Student 1:** I guess Einstein. Because I heard of Einstein’s equations through 8 grade years, and I have always heard of it. And I heard Galileo and Aristotle only at the 9^{th} grade. I heard Einstein more than others and that is why it makes more sense.

Student 1 indicated that Einstein’s theoretical explanation on gravity is more convincing to him because he has heard more about Einstein. Rather than whether the explanation is theoretical or experimental, interestingly his choice is based on who put the explanation forward. Another interesting point on his explanation is that he chose Einstein because Einstein’s theoretical explanation is widely accepted. His explanation indicates that he believed that a scientific explanation is more likely to be true if it is widely accepted by the others.

Student 7 who chose Einstein's theoretical explanation about gravity explained his reasoning as the following:

> **Student 7:** I guess Einstein because it is more recent that they can use technology than others. Technology makes more people interested in how stuffs work. People have more resources to help them figure out how things work. They have more reliable resources.

Student 7 indicated that Einstein's theoretical explanation on gravity is more convincing because it was more recent than others. Like Student 1, the reason of his choice was not whether the explanation is theoretical or experimental. Rather, he interestingly indicated that a recent theory is more convincing. His explanation for his reasoning can be interpreted in two ways. First, he believed that technology makes the scientific theories more reliable. The second is that he viewed the development of scientific theories as cumulative. His explanation indicates that scientists use a combination of first hand and second hand sources of information to develop theories. Overall, these two students' explanations suggest that the students did not realize that scientists use different methods to answer their research questions. Also, the results indicate that in terms of justification of knowledge, the students may not justify properly the scientific claim they encounter in science learning activities or other settings.

The other seven students in the class mentioned that Galileo's experimental explanation on gravity is more convincing to them. The following excerpts illustrate students' ideas that Galileo's experimental explanation were convincing to them. In all cases, these students indicated that the experimental explanation is more convincing. These students defined the theoretical explanation as an idea or thought, and mentioned that experimenting is a required way to explain phenomena in physics.

Student 2: I guess it is experimental one because if it is tested and then we can see if it is true or not. Like Aristotle, he thought that one heavier mass falls faster but that one was not true. And Galileo is the one who did the experiment to prove that Aristotle was wrong. Einstein was the theoretical guy. And he won't be always correct because he needs to test it. He hasn't been proven right to wrong because he did not try to do experiment, to find what is actually true.
Student 6: I'd say Galileo because all other ones were what they thought, but Galileo put it in an experiment.
Student 9: I think experimental because if you try experimenting how gravity works, it is more likely to be better than just thinking about. Actually doing it is better.

The results presented here indicate that a number of students in this class (seven students) mentioned that a scientific explanation should be derived from experimentation. Like the students mentioned in classroom conversation and the post interviews, they defined theoretical explanation as an idea that requires testing. Underlying factor for these students' explanation may be how they defined "scientific theory." Therefore, to get a better insight on their ideas about scientific explanation, I triangulated students' explanation of their choice with the initial interviews about the definition of theory. The following excerpts illustrate students' definition of scientific theories.

Interviewer: What is a scientific theory?
Student 6: Theory is something like what everyone believes. It has been said so many times like universal truth that everybody believes in. It is like if you have a theory, then this is going to happen. Like for me, my theory is you say something over and over again, it is going to happen. So, it is like something that you believe or multiple people believe it is true but not really.
Interviewer: What is a scientific theory?
Student 2: Theory is what they think is right. What they think happens. Stephen Hawking and his theory are about black hole. He cannot really test black holes but he thinks that this happens and this happens.

Triangulations revealed that students' ideas about theoretical explanation on gravity are coherent with how they defined scientific theory. According to Student 2, Einstein's theoretical explanation may not be correct because his idea was not tested. Student 2 also viewed scientific theories as ideas that we do not know if they were true or not until we actually test them. Like Student 2, Student 6 defined theoretical explanations on gravity as a belief scientists had, which is coherent with how she defined scientific theories. This is noteworthy because it indicates that the students may not justify properly theoretical scientific claim they encounter in science learning activities or other settings.

Accuracy and Precision of Scientific Data

Among the other steps outlined by NRC (2007), scientific inquiry includes observing, measuring, being concerned with accuracy, precision, and measurement error of scientific data. In scientific inquiry students are expected to collect sufficient data and state conclusions that are consistent with their data and the theory. From an epistemological perspective, these expectations underscore the importance of dealing with what count as scientific data and how students know if scientific data are accurate and/or precise in scientific inquiry.

Accuracy of scientific data refers to how close the data are to an accepted value. In other words, accuracy of data means how close data that collected from an experiment are to the expected result that is obtained from different scale or calculated from the theory. Precision of scientific data refers to how close data points are to each other. That is, precision of scientific data refers to reproducibility and repeatability of scientific data. Collecting both accurate and precise data are concerns of scientists.

A task, called *the gravitational acceleration experiment*, was introduced to students to observe the movement of a ball at free-fall. One of the objectives of the task was to make measurements with accuracy and precision and record data using scientific notation and International System (SI) units (PHYS. 2H). Although this objective was included in all scientific investigations in the class, during my visits only at this task students had a chance to directly investigate the accuracy and/or precision of data they collected.

The task consisted of five parts: (a) free-fall movement--students were asked to drop a ball from specific heights to free fall (50, 100 and 150 cm; 30, 50, and 70 inches), (b) recording the free fall of the ball--students were asked to observe the movement of the ball, and record the duration of the free fall, (c) calculating--students were asked to calculate the gravitational acceleration from data, (d) accuracy and /or precision of scientific data--students were asked to tell if they found accurate and/or precise data, and (e) inches vs meter--students were to asked compare their findings in inch and meter scales. Since my purpose was to investigate how the students know about the accuracy and the precision of the data they collected from the experiment, I paid attention to the fourth part of the task.

To illustrate how students evaluated the scientific data in terms of accuracy and/or precision, I present the following themes: *scientific data must be accurate but can be precise accuracy via following the right procedure,* and *accuracy via what the* *others find*. Additionally, I discuss how students' ideas about accuracy and/precision of scientific data relate to their ideas about the justification of scientific knowledge.

Scientific data must be accurate but can be precise

Except Group 3, all groups found that their results were accurate. For example, Group 1 members repeated the experiment three times for each height. They averaged their findings and reported the averaged gravitational acceleration as 11.2 m/s^2 for 50 cm, 10.8 m/s^2 for 100 cm, and 10.3 m/s^2 for 150 cm. They concluded that their findings were accurate. What students did here indicated that they did trials multiples times because they were aware of error factor in scientific experimentation. Group 1 members explained their reason for multiple trials as following:

> **Interviewer:** In this class you did an activity to see whether scientific data is accurate and/or precise. Could you tell me what you got?
> **Student 1:** After experiment, we pretty got accurate results.
> **Interviewer:** Why do you think your results were accurate?
> **Student 3:** Our results were close to the exact value of gravitational acceleration, 10. Of course, you cannot measure the exact time for free-fall with a stop watch. We made some mistakes. So, we repeated our experiment for three times.
> **Student 1:** You can see that when we dropped the ball from a higher point, we got a closer result to the right value.
> **Student 3:** Yes because for 50 cm, we had a short time to start and stop the watch. But for 150 cm, we had more time to do it. That is why we got more accurate results at 150 cm.

Students in Group 1 already knew that they might make mistakes during data collection. This led the students to do multiple trials for their experiments. They emphasized that doing multiple trials and averaging the results would create more accurate scientific data. This indicates that the students know that scientific experiments require being aware of measurement error factor and reporting the results of experiments with accuracy concerning. Group 4 members explained their views as follows:

> **Interviewer:** What do you think about the precision of scientific data?
> **Student 5**: I think it is important. If you get precise data, your results may be more convincing.
> **Student 8**: Yes but it is difficult to get precise data because we cannot have the same results for each trial. For example, we round our results.
> **Student 7**: I think scientific data should be accurate to get better answer because if scientific data are more accurate, the experiment is more right.
> Only Group 3 emphasized that scientific data should be accurate and precise.

They explained their reason as follows:

> **Interviewer:** In this class you did an activity to see whether scientific data is accurate and/or precise. Could you tell me what you got?
> **Student 6:** Precise. We did our experiment for the first level and we got a certain number and then we did some trials again and we got the same number. Or it was less than that number.
> **Interviewer**: What do you think about the precision and accuracy of scientific data?
> **Student 9:** I think both are important but I believe precise data are more convincing.
> **Interviewer:** Why do you think precise data are more convincing?
> **Student 9:** If you are doing a scientific experiment, you have to get the same results or close. If you don't, you are doing something wrong. That makes your results less convincing.

One noteworthy aspect of the excerpt presented above is that students are aware of the importance of the precision and the accuracy of scientific data. Students indicated that they might have concern if they did not get the same or close results while they did multiple trials. That can be interpreted in two ways: (a) students may believe that scientific experiments have one right answer, and (b) students may think that scientific knowledge should be replicable. To better understand what students thought about scientific experiments and scientific results, and how they justified scientific data that they collected from an experiment, I triangulated these findings with pre- and post-interviews and instances from other class. I present the following two themes, *accuracy via the right procedure* and *accuracy via what the others find*, about how students in this class know if their results are accurate.

Accuracy via following the right procedure

One of the themes that emerged from the students' school science practices is that they believed that their results were accurate if they followed the right procedure and established the right experiment design. To illustrate students' ideas about the accuracy of scientific data via the right experiment design, I present an excerpt from a conversation. In the excerpt below, the students articulate what they thought about collecting accurate scientific data. In the excerpt, Group 2 members were working on the pendulum bob experiment in which students calculated the amount of kinetic energy converted to potential energy by measuring the height that the block went up so that they could find the velocity of the block at the beginning.

> **Work-Energy Theorem unit: 12-December, 13**
> **Student 2:** This is not scientific
> **Interviewer:** Why do you think it is not scientific?
> **Student 2**: Because what I am measuring does not seem right. I measure the height but it does not seem I am measuring it correctly. (The student pointed out that while she was measuring the vertical distance that the block moved, she referenced the edge of block). The height is different for each point on the block.
> **Mr. Bryan:** What is your solution?
> **Student 2:** I don't know. Maybe we should get some point average.
> **Mr. Bryan:** No. Think
> **Student 4:** If we measure the distance from the center of the block, I think we will not make mistake.
> **Mr. Bryan:** Yes. Get your reference point from the center of the block.

In this excerpt, the students did not define what they were doing as scientific because they thought that they were doing a systematic error in which violated the accuracy of scientific experiment. After they talked with Mr. Bryan about the possible solution, they decided to measure the height that the block went up from the center of the block. This indicates that collecting data in a correct way was considered as collecting accurate scientific data. In another instance, Mr. Bryan reminded the students the importance of following the right direction for a scientific experiment.

> **Force and Laws of Motion unit, 21 Nov-13**
> **Mr. Bryan:** You should keep records of your trails if it is the same with other trials. If you start off wrong, you will continue wrong. You cannot change your conditions during the experiment. It renders all trials invalid.

Following the right procedure or correctly collecting data during the experiments, students believed, would help them have accurate scientific data and then made a right conclusion. Students in this class mentioned that they might have different numbers as scientific data but their interpretation would have to be the same. Students indicated that they might have different reference point or different materials that did not exactly match with another. Yet, eventually they would reach the same conclusion. The following excerpts illustrate students' idea about how they evaluate the conclusion of a scientific experiment.

> **Interviewer:** Do you think your friend should reach the same results that you have found in your experiment?
> **Student 8:** If the procedure tells you to do it in a certain way, then it is supposed to be the same results. If the experiment is to drop the pencil off the table, then the result should include the same results. But it is different if it is ending up floor or chair or something. It is important for them to have the same conclusion for you did right or wrong.

Interviewer: Do you think your friend should reach the same results that you have found in your experiment?
Student 1: They should not get the same numbers because we are testing different weight, they can test grams or they may test a hundred gram. There are difference but both are similar in what we are doing, they should follow the same rules that our experiment goes through. So they should reach the same interpretation. I think the conclusion should be the same. If we graph each variable, it should form a line; I forgot what kind of graph is that, I think other group members should get almost the same line.

Accuracy via what the others find

Another theme emerged from students' school science practices on the accuracy of scientific data is that students in this class believed that their friends in the class should reach the same results. Students indicated that finding the same results from an experiment depends on what they were doing in the experiment. Students indicated that if they did the experiment, the other groups should have gotten the same answer with them because the experiment they did mostly have a single answer, and they all followed the same exact procedure with their peers. If the experiment had multiple answers, they might not get the same results. The following excerpt illustrates how the students evaluated the accuracy of their data via their friends' findings.

Force and Laws of Motion unit, 22 Nov 13
Student 5: What you got *g* for 50 inches?
Student 4: 374.2 we got at the first.
Student 5: Yeah it is close. I think we are doing right.

In the excerpt presented above, Group 4 members were not sure about their finding of the gravitational acceleration in inches. Since they did not know the value of the gravitational acceleration in inches, to figure it out if they were on the right track, they asked Group 2 member what they had found. Group 2 members told them a value that was close to theirs (*g* as 374.2). Group 4 members compared these two values. One noteworthy aspect of the excerpt presented above is that students already knew that their friends would get results similar to their own since they were doing the same experiment and following the same procedure. To illustrate students' ideas on their friends' finding, I present the following excerpts from pre-interview and post interviews.

> **Interviewer:** Do you think your friend should reach the same results that you have found in your experiment?
> **Student 3:** When we do lab experiments, we all get the same results. Sometimes like project, we don't always get the same results. If we drop something, we get 10 second but other groups get 11 second or sometimes we round the number. It is not always we get the exact the same results. Sometimes they have experiments like equation something like that. Sometimes there is only one right answer problem or experiments.
> **Interviewer:** What do you do if you have had different results from your friends? (post-interview)
> **Student 1:** If I am doing an experiments, and I got different answer from everybody else, and everybody else has the same answer. As I am only the person who got the wrong answer, then that helps me see that I did something wrong.

Students in this class indicated that they used their friends' findings from the same experiment to see if their results were accurate. One interesting point Student 3 mentioned here is that when he worked on a project-based, open-ended experiment with multiple answers, he was less likely to use his friends' findings. The following excerpt illustrates how students viewed experiments that might have multiple answers.

> **Interviewer:** Do you think a scientist should reach the same results that the other scientists have found?
> **Student 8:** Probably experiments they do have multiple answers. So they will not get the same answers. It depends on the experiments they are doing.
> **Interviewer:** Do you think a scientist should reach the same results that the other scientists have found?
> **Student 7**: Possible. I don't know any scientist. It may be little bit different. They do experiment on some hard projects. They can get different results I guess.

> It just depends on how they are doing experiment. For example gravity thing, Galileo and others. They all believe different things, and it was actually the same thing but they had different ideas about it.

It should be noted that some students in this class indicated that the differentiation between themselves and scientists' experimentation depended on the problem that led to the experiment. Students indicated that if the experiment has a single answer, they should find the same result on the one hand. On the other hand, if the experiment is open-ended and has multiple answers, they may reach different results. They differentiated their experiments from the experiments scientists do. They defined the experiments scientists did as ones or "hard projects" that might have multiple answers. A noteworthy aspect of students' ideas on the accuracy via what the others find is that students are able to recognize and to react differently for structured single answer experiments and open-ended multiple answer experiments in terms of accuracy of scientific data.

Practicing Formula

One objective of the present study is to describe the ways in which students' personal epistemologies are mobilized (a) in teacher-directed lectures, and (b) in laboratory activities. Students' views on the nature of scientific knowledge develop through their interaction with school science. Therefore, it is important to investigate students' school science practices in these two learning activities, teacher-directed lectures and laboratory activities. Analyzing the ways students' ideas on the nature of scientific knowledge are mobilized and how scientific knowledge is portrayed in these two activities may help us better understand how students' practice of teacher-directed lectures influences their laboratory activities and vice versa, and what they see similar and/or different in two activities.

One theme emerged from the students' school science practice in the teacher-directed lectures and in the laboratory activities is *practicing formula*. Practicing formula is learning and/or teaching strategy that students and/or Mr. Bryan used in teacher-directed and laboratory activities in the following ways: students suggested practicing formula to learning physics in many teacher-directed and laboratory activities, and students reported using practicing formula when they reflected on their activities. Additionally, I discuss how students' practices on practicing formula in teacher-directed lecturing and laboratory activities relate to their ideas about the certainty of knowledge.

Practicing formula in teacher-directed lectures. The physics course was designed as the Pre- Advanced Placement (AP) Physics course where the students are prepared for the college level physics course. In such a higher level course than the regular physics course, students were expected to be independent learners and to study at home before the physics course. Therefore, teacher-directed lectures were generally implemented as problem solving activities. I referred teacher-directed lectures as "problem solving activity" in the rest of the present study and interviews with the students.

Typically, in problem solving activity in this class Mr. Bryan and the students worked together on the physics problems. The problems that would be covered in the problem solving activity were presented to the students on the blackboard via a computer projector. Mr. Bryan began reading the questions to the students. After the introduction of the question, Mr. Bryan explained the necessary steps to solve the problem. When necessary, he asked the students some questions to make them aware of how they should approach the questions to solve it. The conversation in problem solving activities occurred sometimes between Mr. Bryan and a student and/or Mr. Bryan and several students. Mr. Bryan's and students' talks in the following excerpts are typical conversations that occurred between him and students in problem solving activities.

Conversation of Energy- 15 Dec 2013

Mr. Bryan: If we actually knew the mass of the rock, we could compare the mass we got and the mass they say we got. Do you expect our mass will be higher or lower than the reported mass?

Student 2: Higher

Mr. Bryan: Do you expect to get a higher mass?

Student 2: What was wrong?

Mr. Bryan: Yeah. The answer we got is 18.99. Do you think the answer that came out would be bigger than the actual reported value?

Student 8: No

Mr. Bryan: If we ended up a mass too small, what would that be?

Student 6: Mass.... (Inaudible)

Mr. Bryan: We are assuming a perfect conversion from the work to kinetic energy, right?

Students: Right

Mr. Bryan: Which is assuming no friction loss. This one has to assume completely the friction on the surface. If we have friction, where should some work go?

Student 1: Toward friction

Mr. Bryan: Yes. It is towards friction, which actually means that there is less kinetic energy work from what we got. That gives us a smaller mass. So we expected the reported value different from what we calculated.

Force and Motion unit- 11 Nov 2013

Mr. Bryan: Let's start with good questions. What did we call the force the table exerting to the box?

Student 1: Normal.

Mr. Bryan: Right. It is the normal force. What is the normal force again?

Student 9: It is the counter force.

Mr. Bryan: Not exactly. It is the counter force of gravity, right. It is the counter weight of the box. This is saying that it equals to 40 N.

Student 9: It is 40 N because the bigger box is heavier than the smaller box.

Mr. Bryan: Does anyone agree with Student 9 that it is 40 N?

Student 7: Yes.
Mr. Bryan: Why?
Student 7: It looks like it is going to stay there.
Student 5: It is going to stay there.
Student 3: If it is 40, then it will need more weight to take it off from the table.
Mr. Bryan: Wrong. They are not asking how much force the table pushing up the box.
Student 6: Then it is 70.
Mr. Bryan: Right, it is 70 if it is resting there.
Mr. Bryan: Let's draw the force diagram together. I got the force of the gravity. It is going to pull down, right. What is going to try to hold it up?
Student 1: The rope.
Mr. Bryan: Yes. It is the rope. What do we call it?
Student 2: Tension
Mr. Bryan: Yes. Are these equal?
Students: Yes.
Mr. Bryan: How do you know? There is no movement, right? They are equal. The fact, there is no acceleration. So I am pulling this rope with 40 N. On this side, it will be 40 N, right. I got gravity down. And also I got normal force up, right. I know that the tension close to the normal has to equal the weight of the box.
Student 9: So, the force for the tension is 30 N.
Mr. Bryan: Yes. The force for the tension is 30 N.

In the first excerpt, Mr. Bryan introduced a problem on the conversation of energy topic. Mr. Bryan asked the students what they would expect if the mass of the rock they got was higher or smaller than the reported mass of the rock. After he replied that Student 2 gave the wrong answer, Mr. Bryan re-worded the question. Then, he explained what would be the reason of finding a smaller mass. Finally, the students understood that Mr. Bryan wanted to tell them in the question that some of the energy would be spent for the friction on the surface. In the second excerpt, Mr. Bryan and the students were working on a force and motion problem. In this problem Mr. Bryan wanted to show the students how to calculate the normal force and the tension force on the rope.

Practicing formula in laboratory activities. Another instance of practicing formula occurred in laboratory activities. In a typical laboratory activity, the students were asked to collect data as to calculate another variable in the formula. The following excerpt illustrates Mr. Bryan's direction that he gave the students before they started experimenting.

> **Force of Friction – 18 Dec 2013**
> **Mr. Bryan:** Today we will investigate the friction. Every station has one of these blocks. If you look at the bottom of your block, you see different materials that are glued on the bottom of the block. Some of you got felt, some of you got a smooth plastic, and some of you have a metal. And you have a force sensor. It has got a hook on it. Here is what you are going to do. I have masses in that box over there. What you are going to do is to put some mass, I don't care how much, but you should know how much you are using. So put some mass on the cart. There is a little hook there. You hook with the hook. And you are going to able to record how much force you are pulling on this with. Put it down on the table. I want you to pull gentle and slowly because what you are measuring is how much force does it take to get it to start moving. The more mass you put in it the more force you will need it for going. If you feel like if it is take off fast, put more mass on it. I do want to see some calculations because your goal is to figure out what is the μ on the surface is. We are practicing this formula again. The force of friction is how much force you will apply to get it moving. It is the data you are measuring, this is the mass you put in it, and then g as 10.

Mr. Bryan's strategy for using laboratory activities was to emphasize that students should be able to collect data to do the calculations for the formula that was being covered. One noteworthy aspect of the excerpt presented above is that Mr. Bryan had already informed the students what results they would get from the experiment. This may explain why students in the class believe that they would get accurate scientific data from an experiment if they followed the right procedure. The following excerpt illustrates what the students thought were similar and/or different in both activities.

Interviewer: In your class, you do a problem solving activity. Could you tell me how this activity is similar or different from the experiment that you do?
Student 4: The problem solving is like getting a deeper answer which we were doing in lab experiments. You are getting more and more answer to why this happens. They are similar because you are kind of doing the same thing. All you are doing is the same thing, the same procedure to figure things out.

Interviewer: In your class, you do a problem solving activity. Could you tell me how this activity is similar or different from the experiment that you do?
Student 8: Problem solving is like what you know and how you basically bring them in paper and show in a piece of paper. Experiment is hands-on, how you show what you know. Together they both were solving the same thing but you get a feeling of hands-on during the experiment. So I think they are the same but in different ways.

Interviewer: In your class, you do a problem solving activity. Could you tell me how this activity is similar or different from the experiment that you do?
Student 1: They are similar because they both help us use formula to solve physics problem. They are different because of the interactions. It is because in the experiment we are among other people; like we are able to help each other figure out. The other way is just individual.

Interviewer: In your class, you do a problem solving activity. Could you tell me how this activity is similar or different from the experiment that you do?
Student 2: They are different because in the experiment you actually get real data but at problem solving you are just making it up to solve formula. Similarity can be to do the math. To do the math in the experiment is with real data and in the problem solving it is maybe real or make up data.

The students in this class indicated that the two activities are similar and different in some ways. They viewed that both activities were similar because they followed the same procedure and did the same thing. Students reported that in the laboratory activities after they collected data, they followed the same math procedure in which they used to do in the problem solving activities. Some students also pointed out some differences between the problem solving activities and the laboratory activities. Student 1 mentioned that both activities created different learning environments, where he viewed the problem solving activities are more individual and the laboratory activities as more interactive. Student 2 also mentioned that to practice a formula in the laboratory activities they used real data whereas in the problem solving activities they used make-up data. One noteworthy point in the students' response is that they viewed both activities similar in terms of what they were doing and how they were approaching scientific problems in physics.

The excerpts presented above give insight into how the students mobilized their personal epistemology in problem solving activities. The first noticeable thing is that the questions that Mr. Bryan asked in the problem solving activity had only *one right answer*. For instance, in the conversations, Mr. Bryan confirms that the students' responses are either *right or wrong*. Second, the students in this class were expecting that their answer would be either *right or wrong.* That may be because of the nature of the questions that were covered in the activity and/or how Mr. Bryan implemented it. However, the students' expectation that their answer would be either right or wrong may indicate that the students in this class viewed that the problems in physics should have either a right or a wrong answer. That is evident, for instance, from how the students defined the purpose of the experiment. The students defined the experimentation as a requirement to test a scientific theory. The students also said that the results of the experiment could prove if the theory that led the experiment was *right or wrong*. In the following excerpt, I present a conversation from the initial interviews in which the students articulate what they think the purpose of the scientific experiment is.

> **Interviewer:** What is a scientific experiment?
> **Student 1:** It is to figure it out if something is true or false.

Interviewer: Why do scientists do them?
Student 1: So they can have concrete evidence or something like they are talking about so that people believe them more. When they are asked how they know this stuff, they can show them proof how they know and got conclusion.
Interviewer: What is a scientific experiment?
Student 9: Experiment is they do to prove something right or not.
Interviewer: Why do scientists do them?
Student 9: Because they obviously want to know if a reacts to b and then what causes the reaction. An example is, which one drops faster, two times heavier or lighter? All depends on the experiment to find it out, what the outcome is, so you can see what is happening.

Conclusion

There have been very few previous studies on students' personal epistemologies in school science practices. Therefore, the purpose of this study was to describe students' personal epistemologies in school science practices and how they mobilized their personal epistemologies in teachers' directed instruction and students' directed instruction. Although the focus of this study was not to classify students' views as naïve or sophisticated, the findings of this study show that the students in this study hold naïve beliefs about the nature of scientific knowledge and knowing. The students viewed a scientific theory as an idea or a thought that needed to be tested.

The findings of this study are consistent with the previous studies on students' ideas about the relationship between scientific theory and scientific experiment. Ibrahim et al. (2007) found that, typically, undergraduate physics students viewed the experimental results as more accurate than the theoretical results, and the scientific experiments were required to provide evidence about the phenomena in physics. Also, Driver et al. (1996) reported that students aged 16 were more likely to view experimentation as the only way to test ideas in science. Unsurprisingly, the students in this study mentioned theories must be tested to go beyond being an idea or a thought.

The present study's participants seemed to use the relation-based reasoning defined by Driver et al. (1996). In the relation-based reasoning, the purpose of a scientific experiment is to identify the relationship between the variables.

One interesting finding from this study is that although Student 1 and Student 7 defined scientific theories as an idea or a thought that needed to be tested, they chose Einstein's theoretical explanation as more convincing than Galileo's experimental explanation and Aristotle's theoretical explanation. Yet, it should be noted that the reason behind their choice is not whether the explanation is theoretical or experimental. This is notable because this result suggests that how students evaluated specific scientific theories is different from how they defined scientific theories in general at the interviews. This result supports my argument at the beginning of the study as to why interviews may be insufficient to map students' personal epistemologies (Leach, 2000). This result also supports the previous studies on students' epistemic judgments. The previous studies in students' epistemic judgment reported that students' judgments were inconsistent across contexts (Driver et al. 1996; Leach et al., 2000; Sandoval & Cam, 2011). Sandoval and Cam (2011) argued that the inconsistency among students' choices might be explained by epistemological resource framework defined by Hammer and Elby (2002). They asserted that, while the students in their study judged the scientific claims, they seemed to trigger epistemological resources such as *claims are more believable with evidence, causal mechanisms must be plausible* and *authorities are less persuasive than evidence*. By the same token, the students in this study may trigger different epistemological resources across scientific explanations. By adapting "claims are more believable with evidence" to this study, one epistemological resource can be *scientific explanations are more believable with experimenting*. Student 1 and Student 7 might use other epistemological resources like *scientific explanations are more believable with social acceptance* or *scientific explanation are more believable with technology*. Because the collected data are insufficient to support this claim and the main focus of this case study is not on students' epistemological resources, I am not able to make such claims. Yet, the future studies on personal epistemology and/or students' epistemic judgments should consider epistemological resources framework to explain inconsistency at students' choices.

Analysis revealed that students in this study accepted human error in the nature of their scientific experimentation. Yet, the sort of errors they might make in scientific experiments would not change the conclusion from the experimentation. The students viewed the school science experiment they did as a simple experiment whether it had right or wrong answer. Therefore, they reported that the number in the lab report would be different, but the conclusion would be the same. One interesting finding from this study is that students defined project-based investigations as having multiple answers. They mentioned that if an investigation had multiple answers, they did not think that they would get the same answer. This result suggests that students are able to differentiate the experiments they do in terms of whether the experiment is simple or complex. It means that students in this study do not view every single experiment as the same. This result can be explained by what the previous studies found. The previous studies that investigated students' personal epistemologies on school science practice have reported that students' personal epistemologies are localized and fragmented (Sandoval & Reiser, 2004; Hammer et al., 2005; Rosenberg et al., 2006). Because all activities the students did were simple experiments during the data collection, I am not able to compare students' performance in simple experiment and project-based investigation.

This study suggests that traditional formula-based instruction leads students to develop an idea that a problem in physics had either a right or a wrong answer. Muis (2004) argues that teaching strategies that focus on accuracy, and memorization of rules and procedures is associated with the beliefs that there is only one right answer, knowledge is unchanging, and knowledge consists of isolated pieces of facts and in this sort of classroom the teacher is the source by which to justify knowledge. This study provides evidence of how experiments that were used for refuting scientific theories in physics conceal the epistemological aspects of scientific practice reported by studies on sociology of science (Lave & Wenger, 1991). Furthermore, Sin (2014) argues that in physics classes traditional teaching strategies that were centered on acquisition of certain and absolute knowledge ignore the process of knowledge production. Furthermore, these strategies fail to have students aware of key sociological aspects of the discipline and the ensuing epistemological implications related to how knowledge claims have come into being and achieved validation (Sin, 2014).

The results of this study support the previous studies' results that discuss the problems associated with traditional laboratory activities in high school classroom (Brown et al. 1989; Samaranpungavan et al., 2006; Tobin & Gallagher, 1987). The previous studies documented that typically students described their laboratory activities as simple and highly structured. Students reported that "exactly what needed to be done in the activities was given" to them. Students already knew the outcome of the experiments before they begin conducting it. In addition, the teacher observed in this study provided hints to his students that the teacher thought would help them "correctly" do the calculations.

In response to this problem, many scholars recommended that school science laboratory work should reflect epistemological aspects of authentic inquiry experiences (Chinn & Malholta, 2002; Sin, 2014). To foster epistemological understanding, it is important to integrate epistemological views with science content (Kittleson, 2011). One implication relates to Koponen and Mantyla's (2006) idea of generative justification of knowledge. Generative justification of knowledge, drawing insight from history and philosophy of physics, is based on inductive generalizations. Rather than copying historical experiments at school, considering epistemology of experiment, experiments should be source of new knowledge. When students begin to understand the epistemological aspects of the experiments, they will be a better judge of the ways to approach experiments in physics (Chinn & Malhotra, 2002; Koponen & Mantyla, 2006).

CHAPTER V

CONCLUSION

In Greek, *episteme* means “knowledge.” *Logos* means “study of.” Epistemology, therefore, is “the study of knowledge” in simple terms. It is assumed that one’s personal epistemology plays a role in her learning, thinking, and reasoning. Research in personal epistemology examines how individuals come to know, the theories and beliefs they hold about knowing, and how these beliefs and theories relate to individuals’ thinking and reasoning. Personal epistemology studies have explored how individuals’ explanations vary in their strategies for learning science, decision-making process, source choices, and the acquisition of scientific knowledge. For the efforts to design sound learning environments in science education, understanding the complex nature of personal epistemology and its relations with self-regulated learning is of importance. In this dissertation, I investigated students’ personal epistemologies and self-regulated learning in the context of school science practice in physics. Below, I provide a summary of the empirical research detailed in Chapters II, III, and IV.

The purpose of the Chapter II was to examine the relations between the students’ personal epistemologies and self-regulated learning, and how this relationship is differentiated by mediator variables including culture, age, subject area, and sex. The findings of this meta-analytic study indicate that personal epistemology is positively related to self-regulated learning strategies with a weighted average effect size of .24 under fixed effects model and .22 under random effects model. The analysis indicates that the relationship between personal epistemology and self-regulated learning strategies was not statistically significant in fixed- and random-effects model in terms of students' grades. The findings support the previous studies that culture, subject area, and students' sex influence the strength of the relations.

Using Muis's (2007) theoretical model, in Chapter III, I examined the relations among the Turkish students' physics-related personal epistemologies, self-regulated learning strategies, and physics achievement. Study findings show that students' personal epistemologies predict their self-regulated learning strategies and physics achievement. More specifically, students' ideas about the nature of knowledge and knowing in physics relate to their achievement goals towards learning physics. Also, personal epistemologies predict cognitive and meta-cognitive strategies that students use to learn physics by relating to the goals for the task.

With respect to physics-related self-regulated strategies and achievement in physics, the findings suggest that students' self-regulated strategies explain the variation in their achievement in physics. The previous studies reported that students view learning physics as effectively memorizing how to use formulas (Ehrlich, 2002; Sin, 2014). Consistent with the previous studies, students reported rehearsal strategies as the most frequently used strategies to learn physics.

In Chapter IV, I discussed students' physics related personal epistemologies in school science practices. The findings show that the students viewed scientific theories as ideas needed to be tested in order to figure them out whether they are right or wrong. The students reported that scientific data should be accurate; yet, while they collect data, they can make mistakes that do not change the conclusion of experiments. Traditional, formulation-based, physics instruction might have led students to view physics knowledge as unchanging and isolated pieces of facts, and physics problems as having one single answers.

Implications and Future directions

A sophisticated personal epistemology towards scientific knowledge is viewed as a vital component of scientific literacy and crucial for thinking, reasoning, and learning in science (Deng et al., 2011). Chapter II suggests that personal epistemologies relate to students' self-regulated learning strategies in general. Furthermore, students' personal epistemologies predict their motivational, cognitive and meta-cognitive strategies towards learning physics, and their achievement in physics. Therefore, science education researchers should investigate the ways to implement learning activities that enhance students' ideas about the nature of knowledge and knowing in physics.

What students think about their school science practice can be a starting point to design learning environments. As Chapter III suggests, students use surface-processing strategies, for instance rehearsal without conceptual understanding of concepts in physics since they believe that learning physics involves memorization of formulas. Furthermore, as discussed in Chapter IV, classroom physics instruction is mostly based on teaching how to solve physics problems using the formulas, instead of trying to teach a deep conceptual understanding. Chapters III and IV and the previous studies (e.g., Elby, 1999) note that how achievement is measured in physics might be the reason for the strong belief that physics is mostly solving problems. Many students believe that tests are designed to measure how students are able to use equations and formulas in physics. Therefore, science educators should investigate the ways to encourage the use of more constructivist assessments to focus on deep conceptual understanding in evaluating students' success in physics.

Students' personal epistemologies depend on the context in which physics knowledge is generated. In order to have a more comprehensive picture of students' physics-related personal epistemologies in school science practices, a further investigation is necessary to describe the contextualized nature of students' personal epistemologies. In future research, students' personal epistemologies may be investigated in different school science practices and/or curricular context.

A recent discussion on personal epistemology suggests that students' ideas about the nature of knowledge and knowing may be domain general or domain specific (Kittleson, 2011; Muis et al., 2006). Kittleson (2011) suggests that investigating the domain generality or domain specificity is important for understanding whether personal epistemology associated with a discipline (e.g., physics) supports students' personal epistemologies in another discipline (e.g., history). The findings of Chapter II suggest that the relations between personal epistemology and self-regulated learning may vary across hard versus soft sciences. Recent studies reported that students may have different ideas about the nature of knowledge and knowing in two different scientific disciplines, for example, in physics vs. biology. Another future direction can be examining the relation between personal epistemology and self-regulated learning in different scientific domains, for example, physics vs chemistry.

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APPENDIX A

SAMPLED STUDIES USED IN META-ANALYSIS

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APPENDIX B

EPISTEMIC BELIEFS QUESTIONNAIRE*

		Strongly Disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
1	Everybody has to believe what physicists say.	1	2	3	4	5
2	All questions in physics have one right answer.	1	2	3	4	5
3	Ideas about physics experiments come from being curious and thinking about how things work.	1	2	3	4	5
4	Some ideas in physics today are different than what physicists used to think.	1	2	3	4	5
5	It is good to have an idea before you start an experiment.	1	2	3	4	5
6	In physics, you have to believe what the physics books say about stuff.	1	2	3	4	5
7	The most important part of doing physics is coming up with the right answer.	1	2	3	4	5
8	The ideas in physics books sometimes change.	1	2	3	4	5
9	In physics, there can be more than one way for physicists to test their ideas.	1	2	3	4	5
10	Whatever the teacher says in physics class is true.	1	2	3	4	5
11	Ideas in physics can come from your own questions and experiments.	1	2	3	4	5
12	Physicists pretty much know everything about physics; there is not much more to know.	1	2	3	4	5
13	There are some questions that even physicists cannot answer.	1	2	3	4	5
14	One important part of physics is doing experiments to come up with new ideas about how things work.	1	2	3	4	5
15	If you read something in a physics book, you can be sure it is true.	1	2	3	4	5
16	Physics knowledge is always true.	1	2	3	4	5

17	Ideas in physics sometimes change.	1	2	3	4	5
18	It is good to try experiments more than once to make sure of your findings.	1	2	3	4	5
19	Only physicists know for sure what is true in science.	1	2	3	4	5
20	Once physicists have a result from an experiment, that is the only answer.	1	2	3	4	5
21	New discoveries can change what physicists think is true.	1	2	3	4	5
22	Good ideas in physics can come from anybody, not just from physicists.	1	2	3	4	5
23	Physicists always agree about what is true in physics.	1	2	3	4	5
24	Good answers are based on evidence from many different experiments.	1	2	3	4	5
25	Some times physicists change their minds about what is true in physics.	1	2	3	4	5
26	A good way to know if something is true is to do an experiment.	1	2	3	4	5

[1]

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APPENDIX C

MOTIVATED STRATEGIES FOR LEARNING QUESTIONNAIRE

		Not at all true of me						Very true of me
27	In this physics class, I prefer course material that really challenges me so I can learn new things.	1	2	3	4	5	6	7
28	Getting a good grade in this physics class is the most satisfying thing for me right now.	1	2	3	4	5	6	7
29	The most important thing for me right now is improving my overall grade point average, so my main concern in this physics class is getting a good grade.	1	2	3	4	5	6	7
30	If I can, I want to get better grades in this physics class than most of the other students.	1	2	3	4	5	6	7
31	In this physics class, I prefer course material that arouses my curiosity, even if it is difficult to learn.	1	2	3	4	5	6	7
32	The most satisfying thing for me in this physics course is trying to understand the content as thoroughly as possible.	1	2	3	4	5	6	7
33	When I have the opportunity in this physics class, I choose course assignments that I can learn from even if they don't guarantee a good grade.	1	2	3	4	5	6	7
34	I want to do well in this physics class because it is important to show my ability to my family, friends, employer, or others.	1	2	3	4	5	6	7
35	When I study the readings for this physics course, I outline the material to help me organize my thoughts.	1	2	3	4	5	6	7
36	During this physics class time I often miss important points because I'm thinking of other things.	1	2	3	4	5	6	7
37	When reading for this physics course, I make up questions to help focus my reading.	1	2	3	4	5	6	7
38	I often find myself questioning things I hear or read in this physics course to decide if I find them convincing.	1	2	3	4	5	6	7
39	When I study for this physics class, I practice saying the material to myself over and over.	1	2	3	4	5	6	7
40	When I become confused about something I'm reading	1	2	3	4	5	6	7

	for this physics class, I go back and try to figure it out.							
41	When I study for this physics course, I go through the readings and my class notes and try to find the most important ideas.	1	2	3	4	5	6	7
42	If the course materials are difficult to understand, I change the way I read the material.	1	2	3	4	5	6	7
43	When studying for this physics class, I read my class notes and the course readings over and over again.	1	2	3	4	5	6	7
44	When a theory, interpretation, or conclusion is presented in this physics class or in the readings, I try to decide if there is good supporting evidence.	1	2	3	4	5	6	7
45	I make simple charts, diagrams, or tables to help me organize course material.	1	2	3	4	5	6	7
46	I treat the course material in this physics course as a starting point and very to develop my own ideas about it.	1	2	3	4	5	6	7
47	When I study for this physics class, I pull together information from different sources, such as lectures, readings, and discussions.	1	2	3	4	5	6	7
48	Before I study new course material thoroughly, I often skim it to see how it is organized.	1	2	3	4	5	6	7
49	I ask myself questions to make sure I understand the material I have been studying in this physics class.	1	2	3	4	5	6	7
50	I try to change the way I study in order to fit the course requirements and instructor's teaching style.	1	2	3	4	5	6	7
51	I often find that I have been reading for class but don't know what it was all about.	1	2	3	4	5	6	7
52	I memorize key words to remind me of important concepts in this physics class.	1	2	3	4	5	6	7
53	I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.	1	2	3	4	5	6	7
54	I try to relate ideas in this subject to those in other courses whenever possible.	1	2	3	4	5	6	7
55	When I study for this physics course, I go over my class notes and make an outline of important concepts.	1	2	3	4	5	6	7
56	When reading for this physics class, I try to relate the material to what I already know.	1	2	3	4	5	6	7
57	I try to play around with ideas of my own related to what I am learning in this course.	1	2	3	4	5	6	7
58	When I study for this physics course, I write brief summaries of the main ideas from the readings and the concepts from the lectures.	1	2	3	4	5	6	7

59	I try to understand the material in this physics class by making connections between the readings and the concepts from the lectures.	1	2	3	4	5	6	7
60	Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.	1	2	3	4	5	6	7
61	I make lists of important terms for this course and memorize the lists.	1	2	3	4	5	6	7
62	When studying for this physics course I try to determine which concepts I don't understand well.	1	2	3	4	5	6	7
63	When I study for this physics class, I set goals for myself in order to direct my activities in each study period.	1	2	3	4	5	6	7
64	If I get confused taking notes in this physics class, I make sure I sort it out afterwards.	1	2	3	4	5	6	7
65	I try to apply ideas from course readings in other class activities such as lecture and discussion.	1	2	3	4	5	6	7

APPENDIX D

TURKISH VERSION OF MOTIVATED STRATEGIES FOR LEARNING QUESTIONNAIRE*

		beni hiç yansıtmıyor						beni tam olarak yansıtıyor
27	Fizik dersinde yeni bilgiler öğrenebilmek için, büyük bir çaba gerektiren sınıf çalışmalarını tercih ederim.	1	2	3	4	5	6	7
28	Benim için şuan fizik dersi ile ilgili en tatmin edici sey, iyi bir not getirmektir.	1	2	3	4	5	6	7
29	Genel not ortalamamı yükseltmek şuan benim için en önemli seydir, bu nedenle fizik dersindeki temel amacım; iyi bir not getirmektir.	1	2	3	4	5	6	7
30	Eger başarabilirsem, fizik dersinde sınıftaki pek çok ögrenciden daha iyi bir not getirmek isterim.	1	2	3	4	5	6	7
31	Fizik derslerinde öğrenmesi zor olsa bile, bende merak uyandıran sınıf çalısmalarını tercih ederim.	1	2	3	4	5	6	7
32	Fizik dersinde beni en çok tatmin eden sey, konuları mümkün oldugunca iyi öğrenmeye çalısmaktır..	1	2	3	4	5	6	7
33	Fizik dersinde, iyi bir not getireceğimden emin olmasam bile, öğrenmeme olanak saglayacak ödevleri seçerim.	1	2	3	4	5	6	7
34	Fizik dersinde basarılı olmak istiyorum çünkü yeteneğimi aileme, arkadaşlarıma göstermek benim için önemlidir.	1	2	3	4	5	6	7
35	Fizik dersi ile ilgili birşeyler okurken, düşüncelerimi organize etmek için konuların ana başlıklarını çıkarırım.	1	2	3	4	5	6	7
36	Fizik dersi sırasında baska şeyler düşündüğüm için önemli kısımları sıklıkla kaçırırım.	1	2	3	4	5	6	7
37	Fizik dersi ile ilgili birşeyler okurken, okuduklarıma odaklanabilmek için sorular olustururum.	1	2	3	4	5	6	7
38	Fizik dersiyle ilgili duyduklarımı ya da okuduklarımı ne kadar gerçekçi olduklarına karar vermek için sıklıkla sorgularım.	1	2	3	4	5	6	7

39	Fizik dersine çalısırken, önemli bilgileri içimden defalarca tekrar ederim.	1	2	3	4	5	6	7
40	Fizik dersi ile ilgili birşeyler okurken bir konuda kafam karısırsa, başa döner ve anlamak için çaba gösteririm.	1	2	3	4	5	6	7
41	Fizik dersine çalısırken, daha önce okuduklarımı ve aldığım notları gözden geçirir ve en önemli noktaları belirlemeye çalışırım.	1	2	3	4	5	6	7
42	Eğer fizik dersi ile ilgili okumam gereken konuları anlamakta zorlanıyorsam, okuma stratejimi değiştiririm.	1	2	3	4	5	6	7
43	Fizik dersine çalışırken, dersle ilgili okumaları ve ders sırasında aldığım notları defalarca okurum.	1	2	3	4	5	6	7
44	Ders sırasında veya ders için okudugum bir kaynakta bir teori, yorum ya da sonuç ifade edilmiş ise, bunları destekleyen bir bulgunun var olup olmadığını sorgulamaya çalışırım.	1	2	3	4	5	6	7
45	Dersle ilgili konuları organize etmek için basit grafik, sema ya da tablolar hazırlarım.	1	2	3	4	5	6	7
46	Fizik dersinde islenen konuları bir baslangıç noktası olarak görür ve ilgili konular üzerinde kendi fikirlerimi oluşturmaya çalışırım.	1	2	3	4	5	6	7
47	Fizik dersine çalışırken, dersten, okuduklarımdan, sınıf içi tartışmalardan ve diğer kaynaklardan edindigim bilgileri bir araya getiririm.	1	2	3	4	5	6	7
48	Yeni bir konuyu detaylı bir şekilde çalışmaya baslamadan önce çoğu kez konunun nasıl organize edildigini anlamak için ilk olarak konuyu hızlıca gözden geçiririm.	1	2	3	4	5	6	7
49	Fizik dersinde işlenen konuları anladığımdan emin olabilmek için kendi kendime sorular sorarım.	1	2	3	4	5	6	7
50	Çalışma tarzımı, dersin gereklilikleri ve öğretmenin öğretme stiline uygun olacak tarzda degiştirmeye çalışırım.	1	2	3	4	5	6	7
51	Genelde derse gelmeden önce konuyla ilgili birşeyler okurum fakat okuduklarımı çoğunlukla **anlamam.**	1	2	3	4	5	6	7
52	Fizik dersindeki önemli kavramları hatırlamak için anahtar kelimeleri ezberlerim.	1	2	3	4	5	6	7
53	Fizik dersine çalışırken, konuları sadece okuyup geçmek yerine ne öğrenmem gerektiği konusunda düşünmeye çalışırım.	1	2	3	4	5	6	7
54	Mümkün olduğunca fizik dersinde öğrendiklerimle diğer derslerde öğrendiklerim arasında bağlantı kurmaya çalışırım.	1	2	3	4	5	6	7
55	Fizik dersine çalışırken notlarımı gözden geçirir ve	1	2	3	4	5	6	7

	önemli kavramların bir listesini çıkarırım.							
56	Fizik dersi için birşeyler okurken, o anda okuduklarımla daha önceki bilgilerim arasında bağlantı kurmaya çalışırım.	1	2	3	4	5	6	7
57	Fizik dersinde öğrendiklerimle ilgili ortaya çıkan fikirlerimi sürekli olarak gözden geçiremeye çalışırım.	1	2	3	4	5	6	7
58	Fizik dersine çalışırken, dersle ilgili okuduklarımı ve derste aldıgım notları inceleyerek önemli noktaların özetini çıkarırım.	1	2	3	4	5	6	7
59	Fizik dersiyle ilgili konuları, ders sırasında öğrendiklerim ve okuduklarım arasında bağlantılar kurarak anlamaya çalısırım.	1	2	3	4	5	6	7
60	Fizik dersindeki konularla ilgili bir iddia ya da varılan bir sonucu her okuduğumda veya duyduğumda olası alternatifler üzerinde düşünürüm.	1	2	3	4	5	6	7
61	Fizik dersinde önemli kavramların listesini çıkarır ve bu listeyi ezberlerim.	1	2	3	4	5	6	7
62	Fizik dersine çalışırken iyi anlamadığım kavramları belirlemeye çalışırım.	1	2	3	4	5	6	7
63	Fizik dersine çalışırken, çalışmalarımı yönlendirebilmek için kendime hedefler belirlerim.	1	2	3	4	5	6	7
64	Ders sırasında not alırken kafam karışırsa, notlarımı dersten sonra düzenlerim.	1	2	3	4	5	6	7
65	Fizik dersinde, okuduklarımdan edindiğim fikirleri sınıf içi tartışma gibi çeşitli faaliyetlerde kullanmaya çalışırım.	1	2	3	4	5	6	7

[2]

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APPENDIX E

INTERVIEW PROTOCOL

Time and data of interview:
Place:
Interviewer:
Interviewee:
Research Questions: What are the epistemic views that students hold?
Questions (The questions below will guide the conversation, as needed emerging questions will be asked):

Probe- Certainty of scientific knowledge:
To what degree students believe that scientific knowledge is certain versus fluid and tentative?

1. Do you think that scientific knowledge about …. (physics subject that being covered) in textbooks (teachers and scientists) always true?
2. How do scientists know if they are right about something?

Probe- Simplicity (Development) of scientific knowledge:
To what degree do students believe that scientific knowledge consists of an accumulation of facts or a system of related constructions? What do students think about how scientific knowledge and theories have been developed?

1. What is experiment? Why do scientists do them?
2. What is a theory? After scientists have (had) developed a theory, does the theory ever change? What kind of change may occur in the development of science? How and why?

Probe- Justification of knowledge:
To what degree do students think the role of evidence to evaluate scientific knowledge claim?

1. What is evidence? What is the role of evidence on scientists' claim?
2. What is your understanding of the word "data"?
3. Do you think your friend should reach the same results that you have found in your experiment? (scientists, too)
4. Is it possible that the same results are interpreted differently by different scientists?

Probe- Source of knowledge:
To what degree do students see scientific knowledge as transmitted from external sources or internally constructed?

1. Do you think we have to believe what textbooks say about …. (physics subject that being covered)?
2. How do you know this equation or etc.? (showing a formula from the textbook) If you had to teach this … to someone, how would you do that?

3. Where do you go when you have questions about a scientific issue? What do you do if you find a disagreement among sources?

Post-activity Interview Questions:

1. How do you prepare for the lab?

2. How do you define the purpose of the activity?

3. Do you think that there is anything that you find it for sure in your activity?

4. What do you do when your results do not match the expected results from the theory?

5. How do you draw conclusions from the experiment?