How Students' Epistemological Beliefs in the Domain Of Physics and Their Conceptual Change are Related?

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Abstract
The purposes of this study were to determine high school students' epistemological beliefs in the domain of physics and to explore and explain the possible relationship between their beliefs and their conceptual change in physics by taking the students' learning strategies into account. A multi-case study design was used for the research in order to focus on the epistemological beliefs-conceptual change relationship within several examples. The research was conducted with 17 tenth-grade students studying in an urban high school. Various instruments were used for the study. The following conclusions can be drawn from the study. First, high school students' level of epistemological beliefs in the domain of physics is very close to sophistication. Second, there is a positive association between students' physics epistemological beliefs and their learning gains. Third, sophisticated domain-specific epistemological beliefs especially in the dimensions of simplicity of knowledge and quick learning are prerequisite but not adequate for conceptual change. When these beliefs are existed together with advanced learning strategies, knowledge revision is accomplished and scientific knowledge is acquired.
Keywords*:* Epistemological beliefs, physics, conceptual change, learning strategies, high school students

Introduction

Research indicates that students' epistemological beliefs may either enhance or constrain the scope and nature of the motivational beliefs, learning strategies, and knowledge that are accessible to the learner as well as the nature and quality of various learning outcomes (Paulsen & Wells, 1998). Therefore, students' epistemological beliefs have come into prominence. Although there is valuable research on epistemological beliefs, there are still some issues that need to be explored. One issue that is under discussion is how epistemological beliefs are related to learning. The purposes of this study were to determine high school students' epistemological beliefs in the domain of physics and to explore and explain the possible relationship between their beliefs and their conceptual change in physics.

Theoretical Framework

Theoretical framework of this study is based on the conceptual change model (or CCM) developed by Posner et al. (1982). According to this model, learning involves an interaction between new and existing conceptions with the outcome being dependent on the nature of the interaction. There are two major components to the CCM (Hewson, 1992). The first of these components is the conditions that need to be met (or no longer met) with the status of a person's conception in order for a person to experience conceptual change. The second component is the person's conceptual ecology

(Toulmin, 1972) described as the existing interrelated networks of concepts that influence the selection of a new concept playing a central and organizing role in thought. Several elements of conceptual ecology are identified as anomalies, analogies, metaphors, epistemological beliefs, metaphysical beliefs, knowledge from other areas of inquiry, and knowledge of competing conceptions. Therefore, personal epistemological beliefs, namely, beliefs about the nature of knowledge and acquisition of knowledge were considered as playing an important role in learning.

Other researchers support the link between epistemological beliefs and learning. For example, Pintrich, Marx, and Boyle (1993) state that beliefs play a crucial role in how students approach and process information. In other words, epistemological beliefs may act as resources facilitating conceptual change and guide students to intentionally pursue the goal of knowledge revision (Mason, 2002). They can influence both the kinds of new information that is picked up from the physical and sociocultural context and the way in which this information is interpreted (Stathopoulou & Vosniadou, 2007a). Students with more constructivist epistemological beliefs are more likely to accept scientific explanations of events (Sinatra et. al., 2003).

Empirical research about students' epistemological beliefs and their relation to learning will be examined in the next section.

Literature Review on Epistemological Beliefs and their Relation to Learning

Some researchers focused on beliefs and their relation to knowledge construction and found positive relationship between these two phenomena (Braten & Stromso, 2004; May & Etkina, 2002; Qian & Alvermann, 1995; Schommer, 1990; Songer & Linn, 1991; Stathopoulou & Vosniadou, 2007a; Tsai, 1998; Youn, Yang, & Choi, 2001; Windschitl & Andre, 1998). Their research and findings are explained below.

Schommer (1990) proposed four dimensions to measure epistemological beliefs. These dimensions were simple knowledge and certain knowledge- naive beliefs about the nature of knowledge- and innate ability and quick learning- naive beliefs about the acquisition of knowledge. Schommer suggested that epistemological beliefs were reconceived as a system of more or less independent beliefs. By system it was meant that there were multiple beliefs to be considered. By more or less independent it was meant that within an individual student's belief system, epistemological dimensions were not necessarily consistently sophisticated. Therefore, a student might have more sophisticated beliefs in one dimension, and less sophisticated in another. Schommer conducted her research in a Midwestern city with 117 junior college students and 149 university students to find an answer for the following question: "How do beliefs about the nature of knowledge affect comprehension?" She suggested that epistemological beliefs seemed to affect students' processing of information and monitoring formation. Additionally, belief in quick learning appeared to influence the degree to which students integrate knowledge (Schommer, 1990).

In their study, Songer and Linn (1991) characterized 153 middle school students' views of science as falling into three groups: static, mixed, and dynamic. Those who viewed science as static asserted that science consisted of a group of facts that were best memorized. Those who viewed science as dynamic believed that scientific ideas developed and changed and that the best way to learn these ideas was to understand what they meant and how they were related. They examined the relationship between views of science and acquisition of integrated understanding of thermodynamics and presented that students with dynamic views acquired more integrated understanding than those with static views.

Qian and Alvermann (1995) carried out canonical correlation analyses to explore the relationship between epistemological beliefs and conceptual change learning (CCL) by using Schommer's questionnaire. Their participants were 212 students in Grades 9-12 at a high school in Georgia. They showed that beliefs about Simple-Certain Knowledge contributed the most to CCL whereas beliefs about Innate Ability contributed the least. The authors found that epistemological beliefs predicted conceptual change and beliefs about simple-certain knowledge and quick learning were important factors in CCL.

Windschitl and Andre (1998) investigated the effects of a constructivist versus objectivist learning environment on college students' conceptual change by taking the students' epistemological beliefs into account. They used Schommer's questionnaire. Their results indicated that students with less advanced beliefs about nature and acquisition of knowledge reached higher results in the traditional setting while students with more sophisticated beliefs performed better in the innovative setting.

Braten and Stromso (2004) examined the relative contribution of epistemological beliefs to the adoption of mastery, performance-approach, and performance-avoidance goals by working with 80 Norwegian student teachers with the help of quantitative research methods. They found that epistemological beliefs about the speed of knowledge acquisition predicted achievement goals. That is, students who believed that learning occurs quickly or not at all were less likely to adopt mastery goals and more likely to adopt performance-approach and performance-avoidance goals. In addition, students who believed in stable and given knowledge were less likely to adopt mastery goals (Braten & Stromso, 2004).

Tsai (1998) interviewed with 20 Taiwanese eighth graders. His qualitative analysis revealed that students holding constructivist epistemological beliefs about science tended to employ a more active manner as well as more meaningful strategies when learning science, whereas students having epistemological beliefs more aligned with empiricism tended to use more rote-like strategies to enhance their understanding.

Youn, Yang, and Choi (2001) surveyed 455 South Korean high school students. Multiple regression analysis of their study showed that students' academic achievement (GPA) and the independent self-construal were positively related with their beliefs about knowledge.

May and Etkina (2002) explored the roles of self-reflection skills and appropriate views about knowledge and learning in conceptual understanding. In order to do that, they studied 12 students' weekly reports, in which they reflected on how they learned specific physics content, during 20 weeks of college physics instruction. They measured students' conceptual learning gains with standard survey instruments. They proposed a possible correlation between conceptual gains and epistemological views. May and Etkina further explained that students with high conceptual gains were more likely to show reflection on learning that was more articulate and epistemologically sophisticated than students with lower conceptual gains.

Stathopoulou and Vosniadou (2007a) selected 38 students with the highest scores in the GEBEP (Greek Epistemological Beliefs Evaluation Instrument for Physics) and 38 students with the lowest GEBEP scores and measured their understanding of Newton's three laws using the Force and Motion Conceptual Evaluation instrument (FMCE). The results showed that the high epistemological sophistication group had significantly higher scores in the FMCE than the low epistemological sophistication group. Regression analysis illustrated that beliefs regarding the Construction and Stability of physics knowledge and the Structure of physics knowledge were good predictors of physics understanding. They suggested that sophisticated physics-related epistemological beliefs were necessary but not sufficient for physics understanding.

Reviewing the literature indicates the link between general epistemological beliefs and learning. However, little has been done to address possible relationship between students' epistemological beliefs in the domain of physics and their conceptual change in the same domain by taking their learning strategies into account.

Purposes of the Study

Epistemic conceptual change or change in students' views of knowledge in general probably promotes domain-specific conceptual change (Alexander & Sinatra, 2007). The majority of studies have focused on the relations between general epistemological beliefs and learning outcomes. Thus, there is a need to examine the relations between domain-specific epistemological beliefs and learning within specific academic domains (Buehl & Alexander, 2005). The adopted approach to learning and the consequent selection of study strategies may intervene in the relationship between epistemological beliefs and conceptual change (Stathopoulou & Vosniadou, 2007b). Consequently, the following research questions were addressed in this study:

1. What are the high school students' epistemological beliefs in the domain of physics?
2. How are the students' epistemological beliefs in the domain of physics related to their conceptual change in physics?
3. How are the students' learning strategies playing role in explanation of the relationship between their epistemological beliefs and learning?

Methodology

A multi-case study design with qualitative and quantitative methods was used for the research in order to focus on the epistemological beliefs-conceptual change relationship within several examples. "A case study is a detailed examination of one setting, or a single subject, a single depository of documents, or one particular event" (Bogdan & Biklen, 1998, p. 54). When two or more subjects, settings, or depositories of data are studied, it is called multi-case studies (Bogdan & Biklen, 1998).

Participants and Setting

The research was conducted with 17 tenth-grade students from the same class, who were studying in an urban high school. Their average age was 16. There were nine females. Data were collected in their physics class.

Instruments

Research supports the idea that epistemological beliefs are domain-specific. In other words, students' general epistemological beliefs may be different from their epistemological beliefs in the domain of physics (Ogan-Bekiroglu & Sengul-Turgut, 2011). Hence, the participants' epistemological beliefs in the domain of physics, not their general epistemological beliefs, were assessed to make a comparison between their beliefs and their conceptual change in physics.

Various instruments were used for the study. The first instrument was Physics Related Epistemological Beliefs Instrument (PEBI) developed by the authors to determine the students' epistemological beliefs in the domain of physics. Schommer (1990)'s dimensions were used for this research because two of her dimensions were directly related to learning. Eight open-ended questions based on the dimensions of simple knowledge, certain knowledge, innate ability, and quick learning was created for the PEBI. Driver, Leach, Millar and Scott (1996) stated that through the decontextualized approach, it was impossible to know what students had in mind when answering a general question. Using decontextualized questions, researchers can obtain information about students' exposed views and not those those they express implicitly when in action (Mason, 2002). Considering these critics, the questions in the PEBI were prepared as contextualized. The questions asked students their opinions about some scientific claims related to physics and whom they agree with in controversial dialogues between two people.

The development procedure of the PEBI was as follows: First, the authors created some questions for each dimension after reviewing the instruments in the literature. Second, appropriate questions were selected among them by considering the students' grade level and backgrounds. Third, the authors worked together with two physics educators, who had research on epistemological beliefs, to ensure content validity of the instrument and face validity of the questions. Some revisions in the questions were made during this process. Fourth, the inventory was pilot tested with tenth-grade students in another high school to make sure that the questions were understood correctly and the epistemological beliefs distributed under four dimensions could be measured with these questions. Last, final revisions were made after the pilot study. Examples of questions from the PEBI are given in Table 1.

Dimension	Question
Certainty of knowledge	During Aristotle's time, it was known that objects fell at speeds proportional to their weights; hence the heavier the object, the faster it fell. However, today it is known that objects of various weights, when they are released at the same time, fall together and hit the ground at the same time. How can such a change be possible?
Simplicity of knowledge	Do you agree with the idea that physics is an accumulation of separate and independent facts about the nature? Why?
Innate ability	John: I read an article about Einstein. To me, he was a very intelligent person and had an innate ability in physics. William: We cannot know that he had had ability to learn physics when he was born. He might have developed his ability by studying hard. John: I do not believe that ability to learn can be changed, it is fixed. Who do you agree with, John or William? Please explain your reasons.
Quick learning	Mary: If we do not understand a physics subject at the moment of the first introduction, we will never understand it no matter how much work we spend on it. Denis: We may need some time to understand a physics subject. The subject may not be understood immediately. But, if we revise the subject and solve problems about it, it is possible to understand the subject later. Who do you agree with, Mary or Denis? Please explain your reasons.

Table 1. *Examples of questions from the PEBI*

The second instrument was Assessment Instrument for the Concepts of Work, Power, and Energy (AIWPE) developed by the authors to assess students' conceptual change. The concepts of work, energy and power exist in the elementary science curriculum. Therefore, the students had prior knowledge of these concepts. The development procedure of the AIWPE was as follows: After common misconceptions of the concepts of work, power, and energy were discovered by reviewing the literature, interviews about students' difficulties on these concepts were done by the first author with four physics teachers. Then, the authors created open-ended questions of the instrument based on the data gathered from the literature review and interviews. The authors ensured content validity of the instrument and face validity of the questions by working together with the experts i.e. two physics educators and one physics teacher. At last, the inventory was pilot tested with a group of tenth graders and the final document was got ready.

The AIWPE consisted of 13 open-ended questions measuring conceptual and procedural knowledge (Kaymak, 2010). Each question was worth five points; thus, the highest score that someone could get from the instrument was 65. The measured concepts and Bloom's Taxonomy level for each question are given in Table 2. According to Table 2, one question was in knowledge level, four questions were in comprehension level, three questions were in application level and five questions were in analysis level.

Question	Measured Concepts	Bloom's Taxonomy Level
1	Work	Comprehension
2	Power and force	Comprehension
3	Work	Comprehension
4	Potential energy, conservation of energy	Application
5	Potential and kinetic energy	Application
6	Transformation of energy	Comprehension
7	Transformation of energy	Application
8	Work	Analysis
9	Work-energy relation	Analysis
10	Power	Analysis
11	Potential energy, reference point	Knowledge
12	Transformation of energy	Analysis
13	Variables of potential and kinetic energy, conservation of energy	Analysis

***Table 2**. Measured concepts and Bloom's Taxonomy level for each question in the AIWPE.*

The third instrument was rating scales. The students were asked to fill in the rating scales describing their learning and study strategies and to answer three open-ended questions. The questions were about description of the way(s) that they studied and the technique they used to learn best. In addition, the first author observed the participants throughout the research and completed the observer rating scales to determine their learning strategies. Examples from the student and observer rating scales are as follows (Kaymak, 2010):

Student Rating Scale (1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always)
I repeat what I have learned in the school when I get home 1 2 3 4 5
I learn best when I solve problems about new subject 1 2 3 4 5
I study only when I have an exam 1 2 3 4 5
I ask to my teacher or peers if I have difficulties in learning a subject 1 2 3 4 5
Observer Rating Scale ((1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always)
S/He prefers to be silent 1 2 3 4 5
S/He takes notes 1 2 3 4 5
S/He does not listen to the teacher 1 2 3 4 5
S/He asks relevant questions 1 2 3 4 5

Data Collection

Although interviewing is a time consuming and costly process, it may provide a better window on individual beliefs and allow the researcher better access to the meaning-making process (Hofer, 2000). Thus, the PEBI was used in the semi-structured interview protocol.

The first author, who was a silent observer in the classroom throughout the research, conducted the interviews; therefore, the participants had recognition of him. The interviews lasted 20 to 25 minutes. The purpose of the interviews was told to the participants before starting to the interview. Furthermore, the participants were ensured that their answers would not affect their grades. The interviews were video-recorded. Video records were examined to make sure that the interviewer did not orient students without being aware of.

The students' knowledge of work, power and energy concepts was assessed in the pre-test before the instruction started. The instruction lasted six weeks. They gave their responses to the questions in the AIWPE one more time in the post-test. Each application lasted one lesson hour. Meantime, data about the students' learning strategies were collected.

Data Analysis

The students' epistemological beliefs were categorized as low, medium, high, and very high for each dimension because beliefs are held in clusters. The explanations of the levels within the dimensions are as follows:

Simplicity of knowledge
Low (L): Individuals believe that physics knowledge is simple and composed of isolated and unambiguous facts.
Medium (M): There is beginning of the recognition among individuals that physics knowledge is not simple.
High (H): There is growing realization among individuals that physics knowledge is not isolated.
Very High (VH): Individuals believe that physics knowledge is composed of highly interrelated physics concepts.
Certainty of knowledge
Low: Individuals have dualistic, absolutist, right and wrong view of the world. They believe that physics knowledge is certain and absolute.
Medium: There is beginning of the recognition of diversity and uncertainty of physics knowledge among individuals.
High: There is growing realization among individuals that one cannot know with certainty. They claim that physics knowledge can be change over time.
Very High: Individuals believe that physics knowledge evolves continually reconstructed on the basis of new evidence and new contexts; therefore, physics knowledge is uncertain and contextual.
Innate Ability
Low: Individuals believe that ability to learn physics is fixed and cannot be changed.
Medium: There is beginning of the recognition among individuals that ability to learn physics is not fixed.
High: There is growing realization among individuals that ability to learn physics is not fixed and may be developed.
Very High: Individuals believe that ability to learn physics is incremental and can be changed with education and experience.
Quick Learning
Low: Individuals believe that learning occurs quickly or not at all.
Medium: There is beginning of the recognition among individuals that learning is not quick. There is a small chance that someone learns physics in time.
High: There is growing realization among individuals that one cannot learn physics quickly and learning may be a developmental process. There is a possibility that someone learn physics in time.
Very High: Individuals believe that learning is a gradual enterprise.

The answer of one student to the PEBI question about the different perceptions of falling objects in Aristotle's time and now was as follows:

> *"Aristotle did not have enough technology to do various experiments on falling objects. I believe that as technology continuous to develop and scientists do more experiments, we will learn more new information. There might be more changes in what we already know. We may hear very soon that gravity is not the only factor causing objects to fall."*

The student declined that physics knowledge was not certain. However, this was already implied in the question. What expected from the participants was their realization that the change mentioned in the question was not the final point. He seemed to have this realization. Therefore, his physics epistemological belief in the dimension of certainty of knowledge was categorized very high.

The students' knowledge for each question was categorized as compatible elaborate, compatible sketchy, compatible-incompatible, incompatible sketchy, incompatible elaborate, and no response based on the two dimensional coding offered by Hogan and Fisherkeller (1996). Based on this scale, participants' response concurring with the scientific proposition and having sufficient detail to show the thinking behind them was coded as "compatible elaborate". However, if the essential details were missing, it was coded as "compatible sketchy". Participants' response disagreeing with the scientific proposition and having details or coherent logic was coded as "incompatible elaborate". Nevertheless, if very little detail or logic was given in the response, it was coded as "incompatible sketchy". If the participant made sketchy statements concurring with the scientific proposition and s/he also made sketchy statements disagreeing with the scientific proposition, his/her knowledge was coded as "compatible/incompatible". If there was no response, it was coded as "no response".

For example, the third question in the AIWPE was as follows: Does the Earth do work on its satellite? The following response was coded as compatible elaborate: "The gravitational force on the satellite acts toward the Earth as a centripetal force, inward along the radius of the satellite's orbit. The satellite's displacement at any moment is along the circle, in the direction of its velocity, perpendicular to the radius and perpendicular to the force of gravity. Hence, the angle between the force and the instantaneous displacement of the satellite is 90^0. Therefore, the work done by gravity is zero".

Since some of the questions required doing calculations and application of formulas, the students' knowledge levels were coded based on the percentage of the correct solution. Consequently, if the participant could solve up to 20% of the question scientifically, his/her response was coded as incompatible elaborate. On the other hand, if the participant could find 81% to 100% scientific solution for the question, his/her knowledge for that question was coded as compatible elaborate. Table 3 shows this coding scheme in detail.

The first author categorized the participants' physics related epistemological beliefs. The second author randomly selected 20% of the students' beliefs and categorized them. Then, both authors compared their categorizations and reached 87% of agreement. The reliability measured by Cohen's κ was 0.67. There seems to be general agreement that Cohen's κ value should be at least 0.60 or 0.70 (Wood, 2007). Consequently, the categorization done for the participants' beliefs had adequate reliability. The authors re-categorized the beliefs that they could not have agreement on and final categorization was constructed by reaching consensus. Finally, the first author revised all the students' belief categories. The same procedure was followed to do reliable coding for the students' knowledge. Two authors compared their codes and reached 91% of agreement. Cohen's κ was 0.85.

Percentage of the correct solution	Code
0-20	Incompatible elaborate
21-40	Incompatible sketchy
41-60	Compatible/Incompatible
61-80	Compatible sketchy
81-100	Compatible elaborate

Table 3. *Coding scheme for the questions requiring calculations*

In order to determine if the change between pre-test and post-test was significant, paired samples t-tests were performed.

After coding process was completed, the researchers looked for patterns (Miles & Huberman, 1994) among the students' epistemological beliefs, conceptual change and learning strategies to find a relationship and to make explanations for this relationship.

Results and Discussion

Results are presented according to the research questions.

What are the high school students' epistemological beliefs in the domain of physics?

The students' epistemological beliefs in the domain of physics are shown as percentage values in Table 4.

Dimensions	Epistemological Beliefs in the Domain of Physics (%)			
	Low	Medium	High	Very High
Simplicity of Knowledge	12	29	59	0
Certainty of Knowledge	0	35	59	6
Innate Ability	6	18	70	6
Quick Learning	0	6	88	6

Table 4. *Percentage values of the students' epistemological beliefs in the domain of physics (N=17)*

Regarding the simplicity of knowledge dimension, more than a half (59%) of the students were able to reach high level, 29% of the students had medium level beliefs, and 12% of them held low-level beliefs. In the certainty of knowledge dimension, on the other hand, 6% of the students had very high-level beliefs, 59% of them had high-level beliefs, and 35% of them held medium-level beliefs. In the innate ability dimension, 6% of the students had very-high level beliefs, 70% of them had high-level beliefs, 18% of them held medium-level beliefs, and 6% of them held low-level beliefs. In terms of the quick learning dimension, while high population of the students (88%) had high-level beliefs, 6% of the students achieved very high levels, and only 6% of them held medium-level beliefs. Findings show that majority of the students' epistemological belief level in the domain of physics was high. This result is compatible with Yang's (2005) finding that most students were multiplist i.e. the second highest belief level. Multiplists deny the possibility of expert certainty and are skeptical about expertise generally. On the other hand, the result of the current study is not in line with result by May and Etkina (2002). They demonstrated that many high school students considered science as a collection of facts and did not differentiate between observational evidence and explanations of this evidence.

Findings of the current study also reveal that the dimension in which the majority of the students developed nearly sophisticated physics epistemological beliefs was quick learning. That is, the students believed that learning was a gradual enterprise and did not occur quickly. However, it was hard for almost a half of the students to believe that knowledge was composed of highly interrelated concepts.

How are the students' epistemological beliefs in the domain of physics related to their conceptual change in physics?

Results of the paired samples t-tests illustrated that the students showed significantly higher performance in the post-test than they showed in the pre-test ($M_{Pre-Post}$ = -1.08), t (16) = -7.69, $p <$ 0.001. There was no correlation between two tests (r = 0.12, p = 0.648). That is, it is not possible to say that the students whose scores were high in the pre-test had high scores in the post-test. Average scores and knowledge levels for each question in the pre-test and post-test are presented in Table 5. Since each question is worth five points and there were 17 students, the highest average score for each question was 85.

According to Table 5, the students increased their scores and developed their knowledge levels in all of the questions after the instruction. The highest improvement in the students' knowledge occurred in the questions of 1, 3, 10, and 12. The first and the third questions were related to the definition of work in everyday usage and in physics. Although the students had confused the meaning of work in physics with its meaning in day-to-day affairs, they corrected their misconceptions and learned that the work was defined as the product of the component of the force in the direction of the displacement and the magnitude of the displacement after the instruction. The tenth question was about the concept of power in the analysis level and Question 12 required students to do analysis about transformation of energy on a rough incline surface. The students' mistakes decreased and they reached the compatible sketch level in the post-test in these questions. On the other hand, the lowest improvement happened in the ninth question. The students could not understand exactly that objects lifted up do work against the force of gravity and this work equals to potential energy. Put differently, they could not relate two phenomena, i.e. work and energy. They had scored lowest in Question 4 in both pre-test and post-test. This means that, they could not accurately use the law of conservation of energy in problem solving in both tests. In addition, the students could accomplish compatible elaborate level for the questions of 1, 3, 6, 11, and 13. Three of these questions were in the comprehension level and Question 13 was in the analysis level.

	Pre-Test		Post-Test		
Question	**Average Score**	**Average Knowledge Level**	**Average Score**	**Average Knowledge Level**	**Score Difference Between Pre-Test and Post-Test**
1	48	Compatible / Incompatible	73	Compatible Elaborate	25
2	47	Compatible / Incompatible	64	Compatible Sketchy	17
3	44	Compatible / Incompatible	70	Compatible Elaborate	26
4	21	Incompatible Sketchy	37	Compatible / Incompatible	16
5	43	Compatible / Incompatible	57	Compatible Sketchy	14
6	52	Compatible Sketchy	69	Compatible Elaborate	17
7	43	Compatible / Incompatible	60	Compatible Sketchy	17
8	24	Incompatible Sketchy	45	Compatible / Incompatible	21
9	32	Incompatible Sketchy	40	Compatible / Incompatible	8
10	30	Incompatible Sketchy	54	Compatible Sketchy	24
11	56	Compatible Sketchy	71	Compatible Elaborate	15
12	30	Incompatible Sketchy	55	Compatible Sketchy	25
13	57	Compatible Sketchy	71	Compatible Elaborate	14

***Table 5**. Average scores and knowledge levels for each question in the pre-test and post-test.*

Each student's physics epistemological beliefs in four dimensions and their knowledge level before and after the instruction are shown in Table 6. While, 65% of the students raised their learning to the compatible sketchy level after the instruction, 18% of them were able to reach the compatible elaborate level. Although 12% of the students (Student 10 and Student 14) kept their compatible / incompatible knowledge level in the post-test, there was an increase in their scores. On the other hand, Student 11 (5%) did not change his knowledge level and decreased his post-test score by two points. However, his knowledge level had already been high and concurred with the compatible sketchy level. These findings illustrate that conceptual change process occurred and almost all of the students repaired some of their misconceptions.

Findings with regards to the students' high level epistemological beliefs in the domain of physics and their knowledge gain direct us to the positive relationship between domain-specific epistemological beliefs and learning within the same domain. Mason (2002) explains this relationship as follows: Students having sophisticated beliefs about the nature and acquisition of knowledge can develop and refine thinking dispositions crucial to fostering learning through knowledge revision. Results of this study are consistent with the results of other studies (May & Etkina, 2002; Songer & Linn, 1991; Stathopoulou & Vosniadou, 2007a).

Most of the students' physics epistemological beliefs in the dimension of quick learning were close to the advanced level. Likewise, most of the students increased their learning after the instruction. Nevertheless, none of the students' physics epistemological beliefs in the dimension of simplicity of knowledge were in advanced level. Besides, two of the students had unsophisticated beliefs in this dimension. Correspondingly, most of the students could not improve their knowledge to the highest level (compatible elaborate level) in the questions required them to do analysis and relate two concepts. Consequently, students' physics related epistemological beliefs in the dimensions of quick learning and simplicity of knowledge may be good predictors in their conceptual change process in physics. Students with beliefs in gradual learning may study more to reach their learning goals. Students who view physics knowledge as a complex system of organized and re-organized theoretical concepts may think critically and consider alternative views (Kruglanski, 1989; Pintrich, 1999; Stathopoulou & Vosniadou, 2007a). Thus, students having sophisticated beliefs in the dimensions of quick learning and simplicity of knowledge are likely to be successful in knowledge acquisition. Schommer (1990) and Qian and Alvermann (1995) found the parallel result regarding general epistemological beliefs.

S.	Simplicity of Knowledge	Certainty of Knowledge	Innate Ability	Quick Learning	K. L. in the Pre-Test	Score in the Pre-Test	K. L. in the Post-Test	Score in the Post-Test	Conceptual Change
1	M	H	H	H	IS	22	CS	45	+
2	M	M	M	H	CI	33	CS	44	+
3	H	H	VH	H	CI	32	CS	49	+
4	H	VH	H	H	CI	37	CS	48	+
5	M	H	H	H	CI	32	CS	51	+
6	M	M	H	H	CI	33	CE	53	+
7	H	H	H	M	CI	35	CS	50	+
8	H	M	H	H	CI	38	CS	41	+
9	H	H	M	VH	CI	32	CE	53	+
10	L	M	H	H	CI	32	CI	39	+
11	H	H	H	H	CS	46	CS	44	-
12	M	M	L	H	CI	30	CS	43	+
13	H	M	H	H	IS	24	CS	41	+
14	H	H	H	H	CI	31	CI	35	+
15	H	H	H	H	CI	27	CS	50	+
16	H	H	M	H	CI	27	CS	41	+
17	L	H	H	H	CI	34	CE	56	+

Note: L = Low, M = Medium, H = High, VH = Very high, IS = Incompatible sketchy, CI = Compatible / incompatible CS = Compatible sketchy, CE = Compatible elaborate

Table 6. *Epistemological beliefs in the domain of physics and knowledge levels before and after the instruction*

How are the students' learning strategies playing role in explanation of the relationship between their epistemological beliefs and learning?

In order to answer the third research question, physics epistemological beliefs, knowledge and learning strategies of each student are compared and discussed.

Student 1: This student learned by listening, participating, taking notes, asking questions, and solving problems. She repeated what she had learned at the class when she got home and solved problems about the subject. She was aware of her misconceptions and asked questions to her teacher to get rid of those misconceptions. She had medium-level epistemological belief in the dimension of simplicity of knowledge whereas she held high-level beliefs in other dimensions. Although her knowledge level was in the incompatible sketchy level before the instruction, she repaired most of her misconceptions and reached the level of compatible sketchy after the instruction. She showed effort to learn. However, she could not reach the highest knowledge level. Because she believed that physics knowledge was quite simple, she might not think critically enough to complete her learning progress.

Student 2: Although this student actively participated to the lessons and took notes, she did not prefer to study at home apart from exam times. Because she had high-level belief in the quick learning dimension, she used her class notes to learn the content better while studying for the exams. She held medium-level belief in the dimension of innate ability. That might be the reason for why she neither showed much effort to learn nor did her performance tasks. The reason that she rarely asked questions might be her medium-level belief in the simplicity of knowledge dimension. As a result, she could increase her score from the pre-test to post-test only by 11 points.

Student 3: This student always paid attention and took notes during the class times. He studied daily and showed high effort to learn. If he did not understand something, he asked it to someone who knew it. His sophisticated belief in the dimension of innate ability might cause that he studied more by himself if he still had some struggle. There is a possibility that since he did not have advanced level beliefs in other dimensions, complete conceptual change did not occur in his mind although he increased his score by 17 points.

Student 4: In spite of her effort, she lost her attention easily and preferred to be passive in the class. She though that physics knowledge was tentative; as a result, she tried to understand the rationale instead of memorization while studying. She had high-level epistemological beliefs in other three dimensions. She solved problems about the content that she tried to learn. Nonetheless, she studied only if she had an exam. Tough she was aware of her misunderstandings during the class times, she did not do anything about them. At the end, she could only raise her pre-test score from 37 to 48 in the post-test.

Student 5: This student listened to the lessons carefully, did her performance tasks, asked questions if she did not understand the subject and solved problems from various textbooks about the content she had learned. She held high-level beliefs in the dimensions of certainty of knowledge, innate ability and quick learning. She improved her knowledge level after the instruction and increased her score by 19 points. Probably, she would have gained more scientific knowledge if she had not had medium-level belief in the dimension of simplicity of knowledge.

Student 6: This student held medium-level beliefs in the simplicity and certainty of knowledge dimensions. Therefore, he preferred to be silent and did not ask questions in the class. However, he always listened to the lessons and took notes. He was aware of his misconceptions and chose to solve them own his own by studying alone. He stated that he listened to his teacher, compared the new knowledge with his prior knowledge and solved problems about the new knowledge in order to learn. His high-level beliefs in the dimensions of innate ability and quick learning might orient these learning strategies. He achieved the compatible elaborate level in the post-test and increased his score by 20 points.

Student 7: This student tried too much to learn the content during the class times. She was always ambitious to solve the teacher's questions on the board. She expressed her ideas all the time. Because she held medium-level belief in the quick learning dimension, she might think that she would not be able to understand the content later. Therefore, she spent too much effort during the class times. Her belief level in other three dimensions was high and she improved her compatible / incompatible knowledge level to the compatible sketchy level.

Student 8: This student missed some classes during the instruction. He could not keep his attention long and got bored easily. His belief in the dimension of certainty of knowledge was medium. On the other hand, he had high-level beliefs in other dimensions. He neither showed much effort to learn nor stressed his misunderstandings. As a result, he could not gain much new knowledge.

Student 9: She believed in gradual learning and studied hard to learn. However, she though that ability to learn was quite fixed and she had that ability. She reviewed the notes that she took in the class and solved problems about the subject when she got home. Her belief level in the dimensions of simplicity and certainty of knowledge was high. She achieved the compatible elaborate level and earned 21 more points in the post-test.

Student 10: This student preferred to talk to Student 11 instead of participating in the class activities. Although he had high-level belief in the dimensions of innate ability and quick learning, he did not show much effort to learn physics. He believed that physics knowledge was simple and did not change much. He neither completed his performance tasks nor studied hard for his exams. He kept his compatible / incompatible level in the post-test.

Student 11: Even though this student had high-level belief in all dimensions and compatible sketchy knowledge level in the pre-test, he decreased his score by two points in the post-test. He generally did not involve with the lesson. He had high self-confident and taught that he did not have to attend the class to learn. From his points of view, he could learn by studying himself. Apparently, he did not study.

Student 12: This student believed that ability to learn was fixed. However, his belief in the dimension of quick learning was high. Consequently, he overviewed the content that he learned after the class. He was aware of his misconceptions and tried to correct them. He showed effort to learn. He held medium-level belief in the dimensions of simplicity and certainty of knowledge. That might be the reason for why he did not think critically about the knowledge he was introduced. He increased his score from 30 to 43 after the instruction.

Student 13: This student stayed passive and lost her interest easily during the class times. She was aware of her misunderstandings. Due to the fact that she had medium-level belief in the dimension of certainty of knowledge, she might not accept new knowledge as valid. Her belief in other dimensions was high. She could be able to improve her knowledge level from the incompatible sketchy level to the compatible sketchy level but not to the compatible elaborate level.

Student 14: This student held high-level epistemological beliefs in all dimensions. On the other hand, she kept her compatible / incompatible knowledge level throughout the instruction. This contrast might be explained by her little involvement with the lessons. She did not show any effort to learn.

Student 15: This student had high-level beliefs in all dimensions, too. He participated in the activities, took notes and asked questions. He stated that he tried to make connections between his prior knowledge and new knowledge to learn. He showed effort and increased his score by 23 points in the post-test.

Student 16: This student kept her silence during the class times and did not answer to the teachers' questions by willing. She did not prepare for the lessons. The reason that she neither participated to the class nor showed much effort to learn might be her medium-level epistemological belief in the dimension of innate ability. Nonetheless, she kept notes during the class times and solved problems about the subject when she was studying. As a result, she increased her score by 14 points in the post-test despite of her high belief levels in other dimensions.

Student 17: This student always asked questions and expressed his ideas during the class times. He compared the new knowledge with his prior knowledge. He was aware of his knowledge level and studied to improve it. He solved problems from various textbooks to learn the new knowledge. He got the highest score in the post-test and reached the compatible elaborate level. He would have learned more if he had not held low belief in the simplicity of knowledge dimension and had consider alternative views.

Findings illustrate that when the students had high-level epistemological beliefs in the certainty of knowledge dimension, they tended to solve problems from various textbooks to learn the content better. Moreover, when the students had high-level beliefs in the dimension of quick ability, they likely took notes during the class times and solved problems after the class. That is to say, the students' epistemological beliefs affected their learning strategies.

In some cases, for example the situations of Student 1, Student 9, and Student 15, (almost) sophisticated epistemological beliefs interfered with advanced learning strategies (such as taking notes, solving problems, awareness of misunderstandings, and comparing new knowledge with pre-existing knowledge) and high knowledge gain occurred. On the other hand, in some cases, for instance the situations of Student 8, Student 11, and Student 14, (almost) sophisticated epistemological beliefs did not involve with any effort to learn and little knowledge gain occurred. These findings highlight that there was a reciprocal relationship among the students' epistemological beliefs in the domain of physics, their knowledge gain and their learning strategies. When the student either had unsophisticated physics epistemological beliefs or insufficient learning strategies, his/her knowledge gain in physics was low.

Conclusions and Implication

The following conclusions can be drawn from the study. First, high school students' level of epistemological beliefs in the domain of physics is very close to sophistication. Second, there is a positive association between students' physics epistemological beliefs and their learning gains. Third, sophisticated domain-specific epistemological beliefs especially in the dimensions of simplicity of knowledge and quick learning are prerequisite but not adequate for conceptual change. When these beliefs are existed together with advanced learning strategies, knowledge revision is accomplished and scientific knowledge is acquired.

Overall results suggest that in order to facilitate conceptual change, students' domain-specific epistemological beliefs should be developed and their learning strategies should be improved.

The limitation of this research is the small number of participants. However, this current study would contribute to the science education literature toward a better understanding of the relationship between domain-specific epistemological beliefs and learning by taking learning strategies into consideration. This study suggests that predictions can be made about students' conceptual change and epistemological beliefs; hence, pedagogical changes can be made in the classroom.

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