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Exploring High School Students' Topic Specific Epistemologies And Their Impacts On Conceptual Understanding In The Topic Of Force And Motion: A Structural Equation Study

Lise Öğrencilerinin Konu Odaklı Epistemolojik İnançlarının Kuvvet Ve Hareket Konusunda Kavramsal Anlamaya Yönelik Etkisinin İncelenmesi: Bir Yapısal Eşitlik Çalışması

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Abstract

The purpose of this study is to examine the structural relations between Turkish high school students' 'force and motion' specific epistemologies and their conceptual understanding of this topic. An instrument measuring connotative aspects of epistemological beliefs by adjectives have been adapted and distributed together with Force Concept Inventory. 284 students have participated. Exploratory factor analysis has revealed that the instrument has four dimensions in topic specific epistemologies: certainty, simplicity, source and justification. Structural equation modeling analysis has showed that sophistication in certainty and justification dimensions have positively related to conceptual understanding whereas sophistication in source dimension has negatively related. Additionally, simplistic beliefs have not significantly related to students' conceptual understanding of 'force and motion'.

Keywords: *Personal epistemology, domain specific epistemological beliefs, topic specific epistemological beliefs, force and motion, conceptual understanding*

Özet

Bu çalışmanın amacı lise öğrencilerinin 'kuvvet ve hareket' odaklı epistemolojik inançları ile bu konunun kavramsal olarak anlaşılabilmesi arasındaki yapısal ilişkilerin ortaya çıkarılmasıdır. Epistemolojik inançları sıfatlar yarıdımı ile çağrımsal açıdan ölçen bir ölçüm aracı dilimize uyarlanarak kuvvet konuları kavram testi ile birlikte 284 lise öğrencisine dağıtılmıştır. Açıklayıcı faktör analizi sonuçlarına göre ilgili konuya yönelik alan odaklı epistemolojik inançlar bilginin kesinliği, basitliği, kaynağı ve gerekçelendirilmesi olmak üzere dört farklı boyuta sahiptir. Yapısal eşitlik modellemesi sonuçlarına göre bilginin kesinliği ve gerekçelendirilmesi boyutlarında üst düzey inançlara sahip olma kavramsal anlama ile pozitif olarak ilişkilendirilebilirken bilginin kaynağı boyutunda negatif bir ilişkilendirme gözlemlenmiştir. Bununla birlikte bilginin basitliği boyutundaki inançlar öğrencilerin 'kuvvet ve hareket' konusunu kavramsal olarak anlamasına herhangi bir etkide bulunmamıştır.

Anahtar Kelimeler: *Kişisel epistemoloji, alan odaklı epistemolojik inançlar, konu odaklı epistemolojik inançlar, kuvvet ve hareket, kavramsal anlama*

1. Introduction

Personal epistemology is a research area corresponding individuals' beliefs about knowledge and how they come to know (Hofer & Pintrich, 1997). Since Perry's introduction of the construct, educators have attempted to relate it to other educational variables (Buehl & Alexander, 2005). Text comprehension (Schommer, Crouse & Rhodes, 1992), academic achievement (Hofer, 2000), conceptual learning (Hammer, 1994), motivation (Buehl & Alexander, 2005), learning approach (Cano, 2005) are examples among these variables. Trend in research of personal epistemology has followed developmental structure, belief system approach and domain specific character. This study is an attempt to examine structural relations between Turkish high school students' topic specific epistemologies and conceptual understanding.

Background

Research Trends in Personal Epistemology

Research in personal epistemology has been divided into three different trends. First, beginning from Perry (1970) certain researchers (e.g. Baxter Magolda, 1992; King & Kitchener, 1994) have claimed the developmental structure. That is individuals' personal epistemology develops stage by stage from dualistic to relativistic stance and epistemological doubt (Bendixen, 2002) has made the shift to onward. In the second tradition, Schommer (1994) has argued that personal epistemology is a set of beliefs more or less independent. In other words, an individual can trust to authority (as source) while s/he believes that knowledge is not certain. Schommer's inclusion of speed and control of knowledge acquisition into the epistemological belief system have been criticized by many researchers since these dimensions have been related to learning instead of knowledge (Hofer & Pintrich, 1997).

The last tradition has been about the domain specific characteristic of personal epistemology, that is to say an individual's beliefs of knowledge may depend on the domain and context (Hammer & Elby, 2002; Palmer & Marra, 2008; Schommer-Aikins & Duell, 2013). Some researchers following this trend believe that domain general and domain specific personal epistemologies have a reciprocal relationship by providing feedback for each other. That is domain general epistemology is an umbrella for domain specific epistemologies and inconsistencies among domain specific epistemologies are also possible (Buehl & Alexander, 2006; Buehl, Alexander & Murphy, 2002; Hofer, 2006; Muis, Bendixen & Haerle, 2006). In other words, individuals may hold generalized (domain general) epistemological beliefs affecting their approaches to multiple domains. At the same time, individuals may hold some particularized beliefs that can be activated when they are encountered to certain domains (Buehl & Alexander, 2005). These exciting comments open the door slightly to the idea that personal epistemological beliefs may have a dual character.

Domain Specific Epistemological Beliefs

Hammer and Elby (2002) have argued that epistemological beliefs should have not been admitted as individuals' constitutional attributes like their learning styles. Domain general epistemological approaches have an assumption: How an individual sees knowledge directly affects his/her views of knowledge in physics. This is similar to "asking golfers about their techniques in other activities and using their responses to infer how they play golf" (Hammer and Elby, 2002, pp. 172). This approach directs researchers to examine relationships considering domain specific character of the epistemological beliefs to better predict students' behaviours and finds itself support from the belief literature (Pajares, 1996).

Buehl and Alexander (2006) have stated that domain specific beliefs develop from more general beliefs; but arise if assessments are realized on particular levels or specific tasks. Additionally the same researchers have argued difficulty in investigation of individuals' epistemological beliefs in comparison to knowledge. Individuals can articulate their knowledge (about a concept) rather easily than their epistemological beliefs (e.g. source, authority, certainty and justification). Because, many factors such as exposure time to knowledge, cultural background, and experience are affecting development of beliefs. These factors also make differentiation between domain general and domain specific epistemologies.

Palmer and Marra (2008) have conducted qualitative studies including university students from departments of Sciences, Social Sciences and Liberal Arts. In-depth interview results have proved that almost 80% of students have different orientations towards the nature of knowledge in science and humanities. The researchers have also indicated that instructional contexts, teacher implementations, teachers' epistemological views, and a long exposure to a domain are effective on students' own construction of domain specific epistemologies and on stepping to further stages in epistemological stance. For example, ill-structured problem solving implementations can support development of domain specific epistemologies.

Certain researchers (e.g Buehl et al. 2002; Muis et al. 2006) have claimed that the nature of the domain is a potential determinant in separation of domain based epistemologies. For example, while students may admit science as a hard domain, they may admit humanities as a soft domain. If so, this admission results with that students have simple beliefs towards science and higher order beliefs related to humanities. Palmer and Marra (2008) argued that this predicted pattern has not been observed on 40% of their participants.

Hofer (2006) has pointed out that disciplinary focused epistemological beliefs have been driven by initial studies on general epistemic (domain general) beliefs. She has divided these studies into two distinct parts in accordance to their approaches: disciplinary perspectives on beliefs and discipline-specific beliefs. The former converts the domain general items (e.g. "You can believe almost everything you read") into disciplinary baseline (e.g. “You can believe almost everything you read in this subject”). The latter, however, subsumes beliefs particular to a discipline (e.g. “In science, there can be more than one way for scientists to test their ideas”). Considering these approaches this study will utilize the former, disciplinary perspectives on beliefs, but I will focus on a particular topic (force and motion) instead of whole discipline (physics).

Assessment of Domain Specific Epistemologies

In assessment of personal epistemology, interviews and open-ended questions have been utilized by many researchers (e.g. Baxter Magolda, 1992; King & Kitchner, 1994) to realize in-depth analyses. However, these methods are time consuming and including small number of participants. This is the main reason of why Schommer’s Epistemological Questionnaire has been widely utilized by researchers (Buehl et al., 2002). The underlying common assumption approved by the mentioned assessment tools has been their domain general character.

Hofer (2000) has sought the dimensional structure of college students’ epistemological beliefs attained to psychology and science. She has developed the Discipline-Focused Epistemological Beliefs Questionnaire (DFEBQ), including 27 (5 point) Likert items, by adaptations from previous domain general tools and questionnaires. In answering the questionnaire students have been asked to keep in mind a domain. She has found the similar four dimensions: certainty/simplicity of knowledge, justification for knowing, source of knowledge, and attainability of truth for both psychology and science. However, students’ epistemological belief scores have varied differently. Results has showed that to the students, knowledge in science is more certain, unchanging, authoritarian and attainable by experts than knowledge in psychology. Topcu (2013) has investigated Turkish preservice teachers’ domain specific epistemological beliefs by utilizing DFEBQ. He has stated that preservices believe that knowledge in chemistry is more certain and less complex in comparison to biology. Also, preservices believe that knowledge in physics is more authority-dependent than in biology.

Buehl et al. (2002) have also developed the Domain-Specific Beliefs Questionnaire (DSBQ) with a sample of university students. While the previous measurement tools have asked the participants to keep in mind a domain in answering, the DSBQ items have been prepared by considering the structures of domains. The researchers have constructed mathematics (as well-structured domain) and history (as ill-structured domain) related items. Analyses have showed that mathematics and history items have loaded on two different factors. That is different domains force individuals to form an epistemological stance considering structural properties of those domains.

Stahl and Bromme (2007) have developed an instrument to measure university students’ connotative aspects of epistemological beliefs. The researchers have argued that assessment of connotative (rather than denotative) aspects of epistemological beliefs provide individuals to mark their affective and associative judgments and evaluations that are more personal, emotional and context-dependent. The instrument has included certainty, source and simplicity dimensions. Analyses have confirmed that two factor (decided as texture and variability) solution produces more reliable results than three factor solution. Results also showed that participants' epistemological beliefs have been domain dependent. For example, physics is more precise than genetics, and genetics has a more dynamic nature.

Effects on Academic Achievement and Conceptual Understanding

Certain research studies have provided empirical evidence or argued that individuals' epistemological beliefs relate to their academic achievement. For example, Hofer (2000) has found that college students' discipline-specific epistemologies have negatively related to their end-of-term grade in psychology and GPA. More specifically, if a student has believed that knowledge in psychology is simple and certain, s/he has had a lower academic achievement.

Certain physics educators also have contributed to epistemology related studies. In general, physics educators have mostly attempted to relate students' conceptual understanding (instead of academic achievement) to their domain specific epistemologies. For example, Hammer (1994) has found that when introductory physics students have a better epistemological stance their conceptual understanding seems to present more coherence. In other words, even the cases (utilized for assessment of students' conceptual understanding) have changed; students (better in epistemological stance) will be successful. Moreover, Lising and Elby (2005) have argued that an introductory physics student's epistemology has been a potential barrier between his/her formal and informal reasoning and can have prevent s/he from making successful connections between them. In this way, a student's epistemological status can have directly affected conceptual understanding. Furthermore, Stathopoulou and Vosniadou (2007) have specifically studied on the relationship between high school students' domain (physics) specific epistemological beliefs and their understanding of force and motion. Results have evidenced that when students hold more sophisticated epistemological beliefs of physics, they have been better in understanding of force and motion. Finally, certain scholars (Duit & Treagust, 2003; Qian & Alvermann, 1995) have taken attention to the role of students' epistemological status on their readiness to conceptual change. In other words, if students have sophisticated epistemological beliefs, conceptual change can be realized more readily.

Schommer-Aikins and Duell (2013) have studied with 701 college students to explore their general epistemological beliefs and domain specific mathematical problem-solving beliefs and their effects on students' academic performance. The analyses have evidenced that if students' mathematical background has been limited, their mathematical beliefs have presented a wide variation which let general epistemological beliefs to support higher order thinking. These results clearly stress necessity of measurement of individuals' background knowledge when examining their domain-specific epistemologies. In this study, I will explore participants' conceptual understanding about force concept.

The question of why the epistemological beliefs of individuals affect their academic achievement has not had a clear answer. Certain empirical results shed light on this issue. Cano (2005) has provided evidence that secondary school students' epistemological beliefs affect their academic achievement directly. This effect is mediated with students' learning approaches. Kizilgunes, Tekkaya and Sungur (2009) have modeled the relations among students' epistemological beliefs of scientific knowledge, motivation, learning approach and achievement with a Turkish sample including 1041 sixth-grade students. As a result of their analyses these scholars have evidenced that, for example, students' certainty beliefs have negatively related to their performance goal and learning goal. Certainty and justification beliefs have positively associated with students' learning approaches. Additionally, students' source beliefs have negatively predicted their self-efficacy beliefs and learning approaches. Schommer et al. (1992) also have found that students' epistemological beliefs affect their strategy use and text comprehension. In addition, Buehl and Alexander (2005) have evidenced that students who view knowledge as a collection of isolated bits, certain and comes from authority have also lower levels of motivation and task performance.

More specifically, individuals' epistemological beliefs affect their academic achievement and conceptual understanding. This effect seems to be mediated by other psychological or cognitive variables such as learning approach and motivation. Whether or not effects of (domain specific) epistemological beliefs on academic achievement and conceptual understanding are mediated by some other variables a plethora of attempts have proved its direct effect. However, this does not mean that epistemological beliefs are the unique set of variables directly affecting students' academic achievement and conceptual understanding. Considering the purpose of this study, I have just focused on direct effect of high school students' topic specific epistemological beliefs (among a number of variables) on their conceptual understanding.

A Rationale Model

Based on the aforementioned research attempts, I propose the model in Figure 1. Domain specific approach of the study is topic specific that is I have attempted to measure high school students' force and motion specific epistemological beliefs. The first assumption of the study is that students have a multidimensional topic specific epistemological belief system. These dimensions are certainty, simplicity, source and justification of force and motion related knowledge.

The underlying assumption of the proposed model is that high school students' force and motion specific epistemological stance predict their conceptual understanding. In other words, if students believe that knowledge in topic of force and motion is tentative, complex, subjective, and justified, they have a better conceptual understanding.

Research trends shift to domain specificity. The proposed model supports domain specific nature of students' epistemological beliefs. I believe that if beliefs are particularized and activated depending on tasks, domain specific epistemological studies should also particularized on concepts or topics. If not, domain specific epistemological studies produce their own counter arguments involuntarily. What we should achieve is to recalibrate our focus and to direct studies related to context dependency of individuals' beliefs and epistemological stances into a topic specific approach. When empirical evidences of such studies arise and show the differences particularized to topics or concepts then domain specific studies more readily support their baseline assumption that epistemological beliefs are context driven.

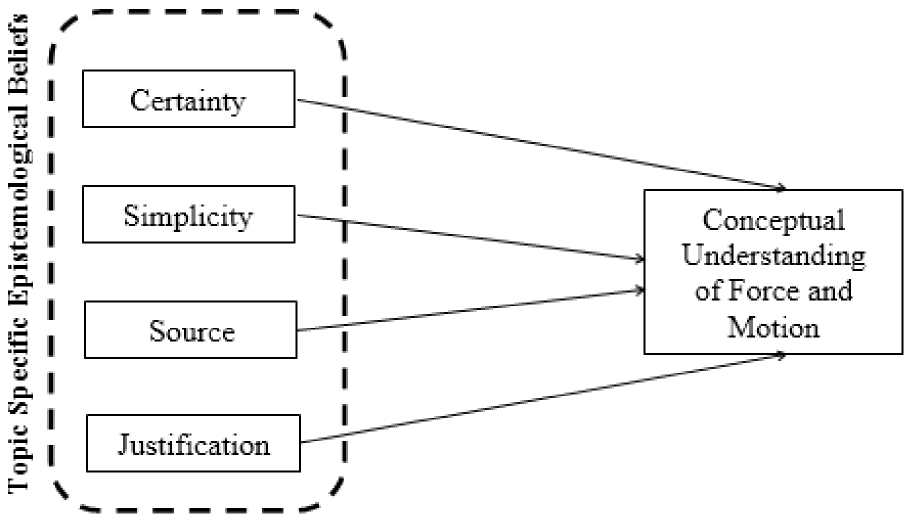

Figure 1. Proposed Model of the Study

The bridge between students' epistemological beliefs and conceptual understanding of physics concepts needs empirical evidence. There are a few studies mostly adapted qualitative studies. I have conducted structural equation modeling (SEM) analysis to test the assumptions. I believe such attempts produce more powerful empirical evidences and contributions.

I hope this study produces curricular and pedagogical implications. Depending on confirmation of the assumptions, I can offer justified advises to empower students' conceptual understanding of force and motion. Such attempts uncovering other concepts or topics in physics inform and provide directions for curriculum designers, teacher educators and physics teachers.

For assessment of students' topic specific epistemological beliefs, I have adapted the questionnaire originally developed by Stahl and Bromme (2007). In adaptation, I have enlarged the scope of the questionnaire, originally includes three dimensions of domain specific epistemological beliefs: certainty, simplicity and source. I have added justification as a new dimension.

The last but not the least, as far as I browse through the national and international research studies, this study is the first attempt (focusing on topic specific epistemological beliefs) realized in Turkey. Considering the context dependency of epistemological beliefs, I shed light on Turkey context.

Purpose and Research Question

Based on the aforementioned literature, I believe that topic specificity of epistemological beliefs have merits to study in international research arena. In exploring possible effects of topic specific epistemologies on conceptual understanding, research studies from Turkey (as a country between east and west) have potential to provide feedback for other parts of the world. In this regard, the purpose of present research is to investigate relationship between Turkish high school students' force and motion specific epistemologies and conceptual understanding. Considering the purpose, the research question of the study is:

What is the relationship between Turkish high school students' force and motion specific epistemological beliefs and their conceptual understanding about this topic?

2. Method

Sample

The sample has included 284 (110 male and 156 female) high school students. 18 participants have not marked gender. Participants' age has had a range of 15-18 with a mean of 16.6. Convenience sampling procedures have been utilized (Creswell, 2008). Participants have been purposefully selected among four different high schools in Bolu, a mid-western city in Turkey. There are 171 11th class and 113 12th class students. These students have already been introduced with force and motion concepts uncovered by Force Concept Inventory (FCI). The reason why I have selected 11th and 12th class students to study is that these students' epistemological beliefs and conceptual understanding of force and motion has better constructed and more coherent than prior year students.

Instruments

I have used two instruments: Force Concept Inventory (FCI) (Hestenes, Wells & Swackhamer, 1992) and Connotative Aspects of Epistemological Beliefs (CAEB) (Stahl & Bromme, 2007).

Force Concept Inventory (FCI): Originally FCI includes 30 multiple choice items. Despite critics about the factorial structure (Huffman & Heller, 1995), FCI is still one of the widely used measurement tools to investigate students' conceptual understanding concerning Newtonian physics around the world (Ateş, 2008). Each FCI item has a unique right answer. I have coded correct answers as 1, whereas unmarked or false responses have been coded as 0. The instrument was adapted into Turkish by Cataloğlu (1996). The researcher indicated a .89 Cronbach alpha reliability. In this study, I have examined item-total correlation scores both to increase the reliability of measurement results and to decide which FCI items to be included in SEM. Items having a correlation score smaller than 0.20 are extracted from the dataset.

Connotative aspects of Epistemological Beliefs (CAEB): This instrument originally consists of 24 adjective pairs distributed to 3 dimensions of domain specific epistemological beliefs: simplicity, certainty and source. Each dimension includes 8 adjective pairs; while one side of the pairs has a negative meaning other side has a positive meaning in terms of epistemological status. Participants are requested to mark the closest choice of their affective representation on a two sided 7-point scale. The adjective pairs have been placed in a form that right side of each pair coincides a sophisticated belief, so that higher CAEB scores point out a better epistemological stance. On the top of the adjective pairs I have put a remarkable sentence: To me, the knowledge related to force and motion in physics is….

In adaptation, a pool of 3 science educators has translated the adjective pairs together. 6 pairs for certainty, 4 pairs for source and 6 pairs for simplicity dimension have been translated. Remaining 8 adjective pairs could have not been translated due to homonymy. That is we could have not found different adjective pairs in Turkish language to match meaning of remained items, because the meanings have been already covered by other translated items in related dimension. A Turkish language educator has also confirmed translation. In addition, 3 science educators have added 5 adjective pairs for justification dimension. Table 1 presents all the adjective pairs together with their epistemic dimensions.

Table 1. Adjective pairs represented in Turkish version of CAEB

Dimensions	Adjective Pairs
Certainty	Certain-Uncertain
	Absolute-Relative
	Inflexible-Flexible
	Everlasting-Temporary
	Stable-Unstable
	Static-Dynamic

Dimensions	Adjective Pairs
Simplicity	Simple-Complex
	Superficial-Profound
	Sorted-Unsorted
	Integrated-Separated
	Structured-Unstructured
	Divided-Connected
Source	Irrefutable-Refutable
	Confirmable-Unconfirmable
	Accepted-Disputed
	Objective-Subjective
Justification	Not evidenced-Evidenced
	Unjustified-Justified
	Ungrounded-Grounded
	Not based on personal beliefs-Based on personal beliefs
	Truth-Presumptive

Data collection

I have combined aforementioned two instruments in a unique questionnaire form which is preceded by a cover sheet probing certain personal information such as gender, age and class. The physics teachers have been informed about the study and requested to distribute the questionnaires to students in a regular classroom hour. 487 questionnaires have been distributed. The data has been entered into SPSS. 203 responded questionnaires have been extracted from data because of highly missing responding. That is the actual dataset of the study has included 284 participants. Participants are allowed enough time to response. Completion of the questionnaires took approximately 25 minutes.

Data analyses

I have used both descriptive and inferential analyses in the present study. As descriptive analyses, mean and standard deviation scores have been used. Exploratory factor analysis (EFA) and structural equation modeling (SEM) have constituted inferential analyses. EFA has been conducted for validation of Turkish version of CAEB. In addition, I have used SEM in examining fit of the proposed model in Figure 1.

3. Results

Validation of Connotative Aspects of Epistemological Beliefs

I have examined KMO measure of sampling and the Bartlett's test of sphericity to determine the appropriateness of sample for EFA. The KMO measure of sampling adequacy index has been observed to be 0.82, and Bartlett's test of sphericity has been significant, chi-square (210, n=284) = 1864.952, $p < 0.0001$. Results have pointed out that the sample has been appropriate for such an analysis. I have performed a Maximum Likelihood analysis with a varimax rotation. I have used various methods (e.g., eigenvalue > 1, communality value > 0.5, scree plots and maximizing cumulative variance accounted for) in determination of item distribution which have presented that five factors were retained. The fifth factor has included two adjective pairs of source dimension and one more from justification dimension. I have extracted these three items from dataset due to meaningless interpretation of this factor. Analysis has been re-executed. In determination of item-factor matching, the pattern coefficient (factor loading) of items should preferably get values greater than 0.40 on the relevance factor and less than 0.40 on all other factors (Stevens, 1996). Five adjective pairs due to factor loadings less than 0.40 and one another due to loading on two factors with a factor loading greater than 0.40 have been extracted. I have examined a final attempt. As a result, 12 items have been retained uncovered by 4 factors: Certainty (5 adjective pairs), source (2 adjective pairs), simplicity (2 adjective pairs), and justification (3 adjective pairs). The variance explained by the CAEB has got lowered from 20% to 16% because of extraction 9 adjective pairs. The factor pattern and factor structural coefficients are presented in Table 2.

Table 2. Rotated factor patterns of CAEB

	Factors			
Adjective Pairs	**Certainty**	**Simplicity**	**Source**	**Justification**
Certain-Uncertain	**.62**	.14	.16	-.24
Absolute-Relative	**.64**	.12	.03	-.19
Inflexible-Flexible	**.46**	.06	.12	.02
Everlasting-Temporary	**.66**	-.13	.19	-.13
Stable-Unstable	**.73**	-.06	.19	.04
Simple-Complex	.09	**.54**	.09	.11
Superficial-Profound	-.02	**.83**	.08	.20
Irrefutable-Refutable	.27	.07	**.96**	-.02
Confirmable-Unconfirmable	.33	.21	**.54**	.01
Not evidenced-Evidenced	-.18	.20	.05	**.69**
Unjustified-Justified	-.01	.05	-.05	**.75**
Ungrounded-Grounded	-.12	.14	-.01	**.74**

Moreover, the reliability (Cronbach's alpha) coefficients of finalized factors have been found as 0.77, 0.65, 0.77, and 0.78, respectively for the dimensions of certainty, simplicity, source and justification. Results indicate that high school students' scores on the instrument present sufficient reliability in assessment of their topic specific epistemological beliefs.

Descriptive Results

Connotative Aspects of Epistemological Beliefs: Adjective pairs have been presented to students in a form that right side of each pair indicates a higher status in terms of force and motion specific epistemological beliefs. Figure 2 shows the mean scores of participants in each dimension of topic specific epistemological beliefs.

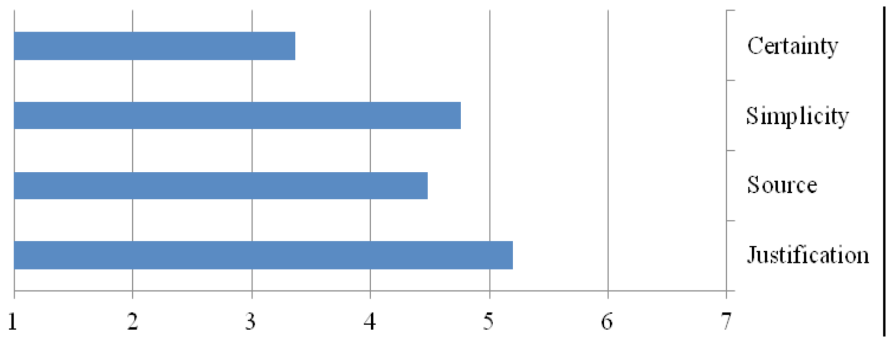

Figure 2. Means diagram showing participants' topic specific epistemological beliefs

According to Figure 2, I can argue that high school students have presented higher scores than midpoint score except for certainty dimension. In other words, participants have seemed to possess more sophisticated beliefs in simplicity, source and justification than certainty.

Force Concept Inventory: At the beginning of the analysis FCI has a .68 of Alpha reliability. I have examined item-total correlation scores to decide which FCI items should be retained in SEM. I have eliminated four items (5, 16, 17 and 29) since their item-total correlation scores are smaller than 0.20. Then Alpha reliability has reached to .71. Table 3 presents the number of correct responses, means (M), and standard deviations (SD) of remained items.

Table 3. Descriptive results of FCI items

Item Number	Correct responses	M	SD
1	110	.39	.49
2	90	.32	.47
3	63	.22	.42
4	75	.26	.44
6	115	.40	.49
7	103	.36	.48
8	103	.36	.48
9	93	.33	.47
10	109	.38	.49
11	38	.13	.34
12	133	.47	.50
13	45	.16	.37
14	83	.29	.46
15	64	.23	.42
18	47	.17	.37
19	68	.24	.43
20	37	.13	.34
21	44	.15	.36
22	53	.19	.39
23	56	.20	.40
24	97	.34	.48
25	61	.21	.41
26	34	.12	.33
27	75	.26	.44
28	51	.18	.39
30	55	.19	.40

Table 3 shows that participants get the highest mean score on item 12. The lowest scores are observed on items 26 and 11. Accordingly, linear motion on a frictional surface and Newton's third law seems to force high school students, while trajectory prediction of a horizontally fired object is comprehended better than other problems. However, trajectory prediction of students deviates when relativistic motion is adapted to items. Additionally, students mostly think that action and reaction forces depend on mass of objects (such as the one more massive exerts more impetus on the other). This misunderstanding or misconception is also observed on free fall in a similar form. Students think that massive objects fall on the ground before than others when they are released on the same reference point.

The Relationships between Topic Specific Epistemologies and Conceptual Understanding

I have conducted SEM analysis on the proposed model in Figure 1 to elicit the relationships between high school students' topic specific epistemological beliefs and their conceptual understanding of force and motion. Figure 3 displays the structural model with path coefficients. The model presented a reasonable model fit (A chi-square for per degree of freedom=1.19, CFI=0.93, GFI=0.89, TLI=0.92, RMSEA=0.02).

Apart from simplicity, all of the force and motion specific epistemological dimensions have significantly predicted conceptual understanding of force and motion. In my estimations, I have assumed that sophisticated beliefs will predict conceptual understanding by positive coefficients. However, a few results in Figure 3 are opposite to my estimations. For instance, negative prediction of 'source' on conceptual understanding is an opposite result. Additionally, I have expected 'simplicity' to present a positive and significant prediction; however, the observed pattern in the model is not significant.

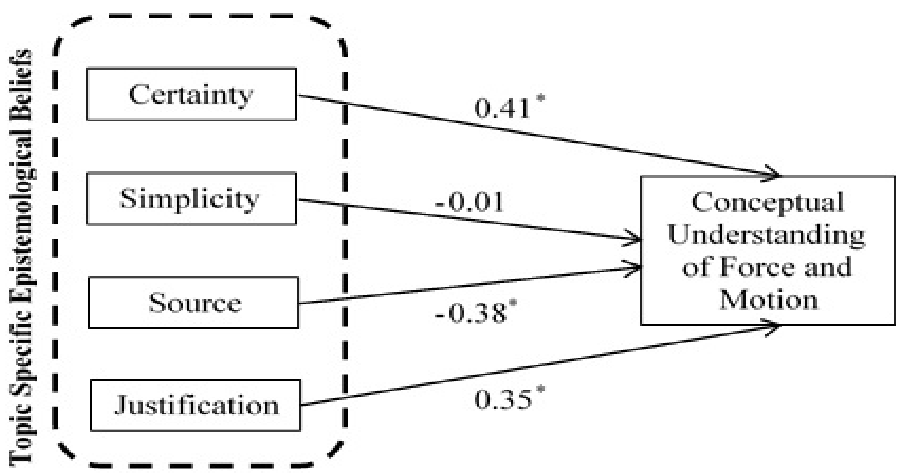

Figure 3. The path coefficients of the structured model ($^{*}p$<0.05)

4. Discussion

In adaptation study, exploratory factor analysis has been examined in validation of the CAEB. Results has presented that the instrument has produced a four factor solution. Factors have been labeled as certainty (5 items), simplicity (2 items), source (2 items) and justification (3 items). Aforementioned factors have reliability scores 0.77, 0.65, 0.77, and 0.78, respectively. Despite of small number of items in each dimension, CAEB has produced reliable scores.

By validating results of such an instrument, I can argue that Turkish high school students have particularized epistemological beliefs of knowledge in 'force and motion'. A plethora of research attempts have already proved that individuals (from different education levels) have domain or discipline specific epistemological beliefs (e.g. Buehl et al., 2002; Hofer, 2000; Topcu, 2013). In other words, individuals hold epistemological beliefs particularized to each domain or discipline. In this study, based on this literature I have assumed that if individuals have domain specific epistemologies, it may also possible to expect they have topic specific epistemologies. From this standpoint, this study has yielded understandable results. In a further step, two different topics or concepts in a discipline may be investigated. Possible differences among topic/concept specific epistemologies validate the claims presented.

Results of the study have revealed that Turkish high school students have not sophisticated epistemological beliefs in dimension of certainty. Considering the structure of remained adjective pairs, I can firstly argue that high school students believe that force and motion related knowledge is certain, absolute, inflexible, everlasting and stable rather than uncertain, relative, flexible, temporary and unstable. Similar results, in Turkey context, by different samples has already been observed at domain-specific level. For example, with a sample of Turkish preservice teachers Topcu (2013) has claimed that preservices believe that knowledge in physics is more certain than knowledge in chemistry and biology. Kizilgunes et al. (2009) has also evidenced that Turkish elementary school students hold more sophisticated beliefs in scientific epistemic dimensions of source, development and justification than in certainty dimension. To the developmental viewpoint of personal epistemology, considering trajectory of Turkish people's scores in certainty dimension of different scales, one may believe that almost up to the end of undergraduate education Turkish people do not present developmental shifts in their epistemological status of certainty. However, when I compare sample scores with aforementioned results, I have detected development in dimensions of personal epistemology except for certainty as parallel to education level. This result of comparison actually seems to confirm what Schommer (1994) has asserted.

Turkey has adapted constructivist teaching programs since 2005 in all educational levels. Nature of physics has a specific chapter in adapted programs. However, teachers query requirement of such a chapter. Additionally, students are still taught by traditional approaches. Educational medium does not create chances for students to argue certainty of physics knowledge. In current mediums, every question has a unique answer (Topcu, 2013; Yilmaz-Tuzun & Topcu, 2008). This may be the main reason of why Turkish high school students do not hold sophisticated epistemological beliefs concerning certainty of 'force and motion' related knowledge.

When it comes to structural relationships between high school students' topic specific epistemological beliefs and conceptual understanding, this study has produced intriguing results. Students' topic specific epistemological beliefs (in certainty and justification dimensions) has positively related to their conceptual understanding as assumed at the beginning of the study. Considering the remained adjective pairs, it can be said that when Turkish high school students believe that force and motion related knowledge is uncertain, relative, flexible, temporary and unstable (adjectives of certainty dimension), and evidenced, justified and grounded (adjectives of justification dimension) they have better in conceptual understanding of this topic. Hammer (1994) has stated that when introductory physics students have more sophisticated epistemological beliefs their conceptual understanding of physics present coherence that is even the cases are changed students apply the physical laws appropriately to problems. More specifically, Stathopoulou and Vosniadou (2007) have evidenced that when high school students hold sophisticated physics specific epistemological beliefs they have qualified understanding of force and motion. Results of this study in dimensions of certainty and justification are compatible with Hammer (1994), and Stathopoulou and Vosniadou (2007).

On the other hand, simplistic beliefs of Turkish high school students have not related to their conceptual understanding, and beliefs of source has negatively related to conceptual understanding. In other words, regarding the source dimension, when Turkish high school students believe that knowledge in force and motion is irrefutable and confirmable they comprehend this topic better. Kizilgunes and her colleagues (2009) found that Turkish middle school students' domain (science) specific epistemological beliefs (in certainty and justification dimensions) have positively related to their learning approach whereas students' beliefs of source have negatively related to their learning approach. In the same study, researchers have also found that students' learning approach has positively related to their achievement. Comparing results of this study with Kizilgunes et al. (2009), I can claim that when Turkish students have more sophisticated beliefs in source dimension of epistemology they tend to learn by rote memorization and such a reverse relationship damages their conceptual understanding. This reverse relationship may appear because of cultural background of Turkish students. However, such a speculation needs emprical evidence because of two reasons. Firstly, when I compare high and middle school students' epistemological beliefs, I should have an underlying assumption that is there is not any developmental difference between Turkish high and middle school students' epistemological status. Secondly, this study does not present any evidence concerning how Turkish cultural context affects high school students' epistemological status.

At this point, another discussion should be realized concerning reasons of differences between observations of this study and the previous ones. For example, Stathopoulou and Vosniadou (2007) have stated that physics specific epistemological sophistication positively affected high school students' conceptual understanding of force and motion. The researchers have conducted stepwise regression analysis whereas SEM analysis has been realized in this study. Differences between analyses may cause statistical differences between results. Another difference relates to focus of the researchers' epistemological stance. In this study, I have attempted to measure high school students' epistemological beliefs at a topic (force and motion) specific level, whereas Stathopoulou and Vosniadou (2007) have realized their measurement at discipline (physics) level. I believe that such a differentiation may point out that domain specific epistemologies is an umbrella of topic/concept specific epistemologies which is similar to dualistic relationship between domain general and domain specific epistemological beliefs (Buehl & Alexander, 2006). That is students may think that knowledge in 'force and motion' is more certain than knowledge in 'electricity' whereas knowledge in physics is not certain.

5. Implications and Limitations

Based on the results of this study I can offer three main implications. Firstly, when Turkish high school students hold more sophisticated 'force and motion' specific epistemological beliefs in certainty, these beliefs have positively predicted their conceptual understanding. However, descriptive statistics have indicated that students in the sample of this study hold not sophisticated beliefs in certainty dimension. As science educators our aim is to reinforce students' epistemological sophistication which should also contribute positively to conceptual understating of physics topics/concepts. In context of Turkey, history of science should be actively utilized in learning environments. I believe that history of science gives students a powerful opportunity to investigate previous argumentations of scientists and such examples in 'force and motion' topic may get Turkish students closer to questioning certainty of current physical knowledge in this topic. In the current high school physics teaching programs of Turkey, history of science is involved among objectives, but we should query readiness of inservice physics teachers. If required professional development of inservice teachers should be supported by training programs. Additionally, preservice physics teacher training programs should also have a specific course to pursue such a development.

Secondly, this study contributes to literature of domain specific epistemological beliefs, but requires empirical supports. This study has simply evidenced that domain specific epistemology has a macro approach of individuals epistemological beliefs which actually can be observed at topic/concept specific level (micro approach). If following researchers replicate this study on different physics topics/concepts, then it may be possible to claim macro level interpretations safely. Comparative studies to compare students' topic specific epistemologies related to knowledge in different topic also empower my claims. The basic assumption of domain specific epistemology literature is that there may be possible differences among an individual's epistemological beliefs related to knowledge in different domains. There is no reason to doubt the same assumption may be offered for different topics/concepts in the same domain or discipline. We need more empirical evidence in this way.

Thirdly, in this study CAEB has been adapted to measure Turkish high school students' 'force and motion' specific epistemological beliefs. In adaptation EFA has been conducted. Based on the EFA results I have eliminated several items. Because of inadequate number of items, reliability of scores is not found as much as expected. This is also a limitation of this study. At this point, I can suggest following researchers to increase the number of adjective pairs in the instrument to get more reliable results.

Another limitation of the study is about the generalizability of findings. Self-reported data of the study comes from a mid-western city of Turkey. Finally, result of this study should be supported by qualitative data to explore the reasons of relationships among high school students' epistemological beliefs and conceptual understanding. In generalizing the findings these limitations should be considered.

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