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Examining relations between physics-related personal epistemology and motivation in terms of gender

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ABSTRACT

The gender gap continues to exist in physics education. The author examines the gender-related differences in the relations and strengths among personal epistemologies, motivation, and achievement in physics among Turkish high school students. Established questionnaires were used to identify students' personal epistemologies, motivations and achievement in physics. A total of 567 ninth-grade students from three high schools in Mugla Province in Turkey participated in the study. Multigroup structural equation modeling was used to determine the gender differences in the relations and strengths among personal epistemology, motivation, and achievement in physics. Results from the structural equation modeling showed that students' personal epistemologies directly predicted their motivation and indirectly their achievement in physics. Multigroup structural equation modeling analysis showed that the strength of the relations between personal epistemology and motivation varied for female and male students. Implications for future directions are discussed.

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Introduction

Gender-related issues in science education have been well documented and are still persistent today. Recent reviews and studies have highlighted that gender differences are to exist in science achievements, motivation, self-efficacy, and interest for science, technology, engineering and mathematics (STEM)–related careers in favor of male students (National Research Council, 2007; National Science Board, 2008; Watt, 2016). Because of these differences, projects that promote the gender equality in STEM-related careers have been launched in many countries. One example of such projects is the Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers in the United States. Another example is Honey Bees are Becoming Engineers Project, launched to increase the rate of female students in STEM-related careers with the cooperation of the Ministry of National Education and private companies in Turkey.

Personal epistemology and motivation in physics—a core discipline for science, engineering, and technology—have potential promoting students in STEM-related careers. While personal epistemology expresses students' views on the nature of knowledge and knowing (Hofer, 2008), motivation states a learner's goals and value beliefs related to a course and beliefs about skills to be successful in the course (Zimmerman, 2008). Research on personal epistemology and motivation has documented that both are important in general and particularly in physics education. Studies have reported that students' ideas about knowledge and knowing are related to their course preferences (Dai & Cromley, 2014), college major choice (Trautwein & Lüdtke, 2007), science-text reading comprehension (Yang, Huang, & Tsai, 2016), and attitudes toward science (Kapucu & Bahçivan, 2015). Similarly, research has reported the relations of motivation to career decision (Taskinen, Schütte, & Prenzel, 2013) and interest (Bøe & Henriksen, 2013). Therefore, it is important to foster personal epistemology and motivation among students, especially girls, and promote science and science-related careers.

Relations between personal epistemology and motivations have been well documented in literature. Studies have reported students' views on the nature of knowledge and knowing predict their motivation in physics and their academic achievement (Alpaslan, Yalvac, Loving, & Willson, 2016; Kapucu & Bahçivan, 2015). In addition to this, studies have reported gender-related differences in students' self-efficacy, goal orientation, and personal epistemology (e.g., D'Lima, Winsler, & Kitsantas, 2014; Tsai & Liu, 2006). Gender-related differences in students' motivation may be accounted by the variation of personal epistemology between female and male students because the influence of personal epistemology is indirect rather than direct (Schommer-Aikins, Duell, & Hutter, 2005). No study that examines the gender difference in the relations between personal epistemology and motivation has been located in the literature. Thus, a need emerges to examine the gender difference in

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the relations between personal epistemology and motivation Furthermore, physics is the discipline that suffers most from declining female students' interest and motivation (Hagay et al., 2013; Sadler, Sonnert, Hazari, & Tai, 2012). Therefore, investigating the gender difference in the relations between personal epistemology and motivation in physics would be beneficial to explain gender-related variations in self-efficacy, interest, and career choice, and to promote the efforts to bring female students into STEM-related careers. Thus, I aim to investigate the gender difference in the relations between personal epistemology and motivation in physics by utilizing multigroup analysis of structural equation modeling among ninth-grade students.

Personal epistemology, motivation, and learning in physics

Personal epistemology expresses a learner's beliefs on the nature of knowledge and knowing and how knowledge is constructed (Hofer, 2008). In the literature various theoretical models regarding personal epistemology have been proposed by researchers. Early theories of personal epistemology (e.g., Perry's scheme, dualism, multiplicity) view personal epistemology as a cognitive construct that develops through different stages from naïve to sophisticated. After Schommer's (1990) work, theories that defined personal epistemology as multidimensional constructs (Hofer and Pintrich's [2002] personal epistemology as source of knowledge, justification of knowledge) emerged. Recent theories of personal epistemology define personal epistemology as a more-fined grained and context-depended construct. For instance, in their model of epistemic cognition, Chinn, Buckland, and Samarapungavan (2011) argued that the scope of personal epistemology should focus on epistemological aspects of knowledge and consider sociocontextual aspects of knowledge.

Hofer and Pintrich's (2002) model of personal epistemology guided this study because it has been used as the guiding model in the previous studies and models addressing the relations between personal epistemology and motivation (e.g., Muis, 2007). Hofer and Pintrich defined personal epistemology in two categories, as the nature of (a) knowledge and (b) knowing. The nature of knowledge is about what the learner believes counts as knowledge. The nature of knowledge consists of two subdimensions: (a) the certainty of knowledge-referring ideas about tentativeness of knowledge and (b) the development of knowledge-referring ideas about connectedness of knowledge. The nature of knowing is about how the learner comes to know. The nature of knowing consists of two subdimensions as (a) the justification of knowledge-referring ideas about the role of knowledge in justifying claims, and (b) the source of knowledge-referring ideas about knowledge comes from authority or the learner. Hofer and Pintrich also stated that these four dimensions are related to each other.

The role of personal epistemology on students' learning is well documented in literature. Research has reported that students who hold sophisticated beliefs on knowledge and knowing are better learners (Sandoval, 2005), obtain higher scores in achievement tests (Stathopoulou & Vosniadou, 2007), and interpret the controversial evidence (Kardash & Scholes, 1996). Franco et al. (2012) investigated the influence of personal epistemology and knowledge representations on cognitive and metacognitive learning strategies in physics. The instruments used in the study ($N = 76$) are (a) the Force Concept Inventory to assess prior physics knowledge, (b) Psycho-Epistemological Profile questionnaire, and (c) four texts to engage students in learning about Newtonian concepts. Results showed that when the participants' personal epistemologies were similar with the knowledge representations of the to-be-learned physics materials, they achieved a higher score on three different measures of learning than they did when their beliefs were mismatching with the knowledge representations. Franco et al. concluded that research in personal epistemology should take into account aspects of the context that may influence personal epistemology, and be carried out in different contexts in educational settings.

Motivation is a complex and multidimensional construct that is related to cognition and learning. A learner's motivation includes her personal goals, beliefs and values about a particular course or task. According to Koballa and Glynn (2007), motivation seems to influence students' science learning in the short term and over longer periods of time. A variety of models of motivation has been theorized to explore students' motivation in educational settings. Expectancy value theory (EVT), for instance, focuses on how individuals' values, expectancies, and beliefs about their ability affect their choices and performance (Wentzel, 2016). Another theory regarding motivation, achievement goal theory, is interested in why individuals participate in particular tasks. Although these theories help us understand different aspects of motivation in educational settings, in this study a particular focus was given to EVT because it was initially developed by Eccles et al. (1983) to understand the gender-related issues in mathematics (Watt, 2016).

EVT discusses that learners' expectancies for success, and the subjective value on achievement tasks influence their performance and choice of achievement task (Wigfield & Eccles, 2002). Expectancies for success refer to the learners' beliefs that how well they will accomplish in the task (Wigfield, Tonks, & Klauda, 2016). As a task-specific construct, value is related to how important and useful the learners view the task (Watt, 2016). According to Eccles et al. (1983), the learners' expectancies for success and values were directly influenced by their goals, beliefs on their ability and previous achievement-related experience. Cultural and social factors including experiences and expectations of other people for the learners would also influence the developments of the learners' expectancies and values (Wigfield et al., 2016).

Research has documented the importance of students' motivation on learning in physics. Taasoobshirazi and Sinatra (2011) found that students' motivation in physics influenced their conceptual changes in physics both directly and indirectly. Furthermore, Koul, Lerdpornkulrat, and Chantara (2011) reported that motivational orientation predicted students' career aspirations in physics. Values for increasing and mastering skills and for curiosity were found to be positively related to Turkish high school students' deep approaches to learning science (Yerdelen-Damar & Aydın, 2015). Additionally, students who valued physics for rewards, grades, and performance reported to use more often critical thinking strategies in physics (Alpaslan et al. 2016). How important and interesting the learner viewed the task positively predicted Turkish high school students' metacognitive strategy use (Sungur, 2007). Lynch (2006) reported that students' views on their ability were positively correlated to their physics grade point average. Results from the aforementioned studies indicate that it is important to examine factors related to students' values and expectancies to promote scientific attitudes (Koballa & Glynn, 2007), STEM-related careers (Koul et al., 2011; Sadler et al., 2012), and achievement in physics (Gungor, Eryılmaz, & Fakıoglu, 2007).

Recently, researchers have proposed that students' personal epistemology may have an indirect relation to students' achievement through motivation. As such, in the recent handbook of personal epistemology, titled *Handbook of Epistemic Cognition* (Chen & Barger, 2016), a chapter was devoted to explore the connections between motivation and personal epistemology. In this chapter, Chen and Barger discussed how cognition regarding knowledge and knowing was related to the motivational aspects of cognition. According to Hofer and Pintrich (2002), students' ideas about knowledge and knowing serve as a guide in their learning. Moreover, Muis (2007) claimed that students' personal epistemology tends to shape their perception in learning and thus how the task is approached.

Studies addressing personal epistemology and motivation have provided evidence that sophisticated ideas on knowledge and knowing (more constructivist views) were positively related to students' values and expectancies. For instance, the more students viewed themselves as the source of knowledge, the more likely they were reported to study physics for curiosity and mastering the skills in physics ($\beta = .19$; Alpaslan et al., 2016). Similarly, Kapucu and Bahcivan (2015) showed that beliefs regarding scientific experimenting as a way to justify knowledge claims in science were positively related to judgements of their ability ($\beta = .16$). In another study, Chen and Pajares (2010) revealed that the more students viewed scientific knowledge as developing the more they viewed themselves competent in science. Furthermore, students who reported to view scientific knowledge as changing were more likely to value physics for reward and grades (Muis & Franco, 2009). Evidence from these studies indicates that students' views on knowledge and knowing were related to values that they had for learning physics and their expectancies of learning physics.

Gender in personal epistemology and motivation in physics learning

There has been limited research on the role of gender on personal epistemology in physics. The influence of gender on personal epistemology is controversial (Chen & Pajares, 2010; Mason, Boldrin, & Zurlo, 2006). On the one hand, Belenky, Clinchy, Goldberger, and Tarule (1986) in their model of women's ways of knowing proposed that girls were more likely to use a connected approach—paying more attention to understand the object of attention—to knowing, while boys were more like to use a separate approach—an approach that views "knowing" different from "the known" by putting their own feelings and values aside, and adopting a neutral perspective. On the other hand, Pintrich (2002) claimed that there is no important gender influence on epistemological thinking and development of personal epistemologies. He argued that when personal epistemology is taken as domain-specific and multidimensional (e.g., Hofer and Pintrich's model), opposite to more holistic models of personal epistemology (e.g., women's ways of knowing and Perry's model), boys' and girls' personal epistemology should develop in the same rate, and no gender difference exists. However, there is evidence that gender influences students' sophistication in personal epistemology. For example, girls had more sophisticated beliefs in quick learning than boys did (Neber & Schommer-Aikins, 2002). Additional to this, Topcu and Yilmaz-Tuzun (2009) reported that female Turkish middle school students tended to have ideas of more omniscient authority in science knowledge than boys did. Therefore, a gender difference may exist in the relations between personal epistemology and motivation and a need emerges to test it.

Gender is the single most important variable that influences students' attitudes and motivation in science (Baram-Tsabari & Yarden, 2010; Gardner, 1975). Studies guided by different theoretical frameworks have reported small but consistent gender difference in motivation. For example, in their recent synthesis of expectancy value model of motivation, Meece, Glienke, and Askew (2009) concluded that female and male students start school with different views on their abilities and values. Regarding the perceptions of their abilities, whereas the gender difference in mathematics ability closes over the course of schooling, in art and language ability it increases over time. In the *Handbook of Motivation at School*, Watt (2016) reviewed gender-related issues in motivation and discussed that gender difference seemed to influence students' academic performance and career decisions.

Studies addressing gender-related issues have provided evidence that gender difference exists in boys' and girls' values and expectancies, especially in mathematics and science at secondary and university levels. For instance, in a recent meta-analysis of self-efficacy over 187 studies, Huang (2013) reported boys tended to indicate higher self-efficacy in general ($g = 0.08$, $p < .05$) and in mathematics ($g = 0.08$, $p < .001$) than girls did. Girls reported putting more value on mastering the skills and curiosity than boys did, whereas boys did more value on rewards and grades oriented and self-efficacious in physics (Cavallo, Rozman, & Potter, 2004). In another study, which examined high school students' motivation profile in physics, Bøe and Henriksen (2013) reported that female students were underrepresented in the intrinsic-extrinsic profiles, whereas they were

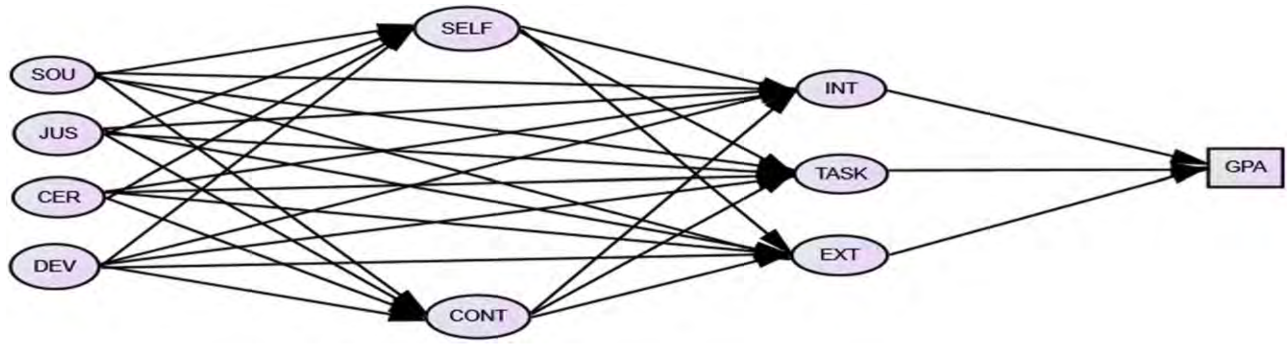

Figure 1. Hypothesized model. CER = certainty of knowledge; CONT = control of learning belief; DEV = development of knowledge; EXT = extrinsic goal orientation; INT = intrinsic goal orientation; JUS = justification of knowledge; SELF = self-efficacy; SOU = source of knowledge; TASK = task value.

overrepresented in the extrinsic profile. Evidence from these studies indicates that a gender-related difference (in favor of boys) exists in students' ability-related beliefs and values that they had for learning tasks, especially in mathematics and science (Watt, 2016). Therefore, it is worthwhile to examine factors that contribute to gender-related differences on students' expectancies and values.

The present study

The overarching purpose of this study is to examine gender difference on the relations among personal epistemology, motivation, and academic achievement by utilizing multi-group analysis of structural equation modeling. Relations between personal epistemology and motivation have been examined by previous research studies (e.g., Franco et al., 2012; Kapucu & Bahcivan, 2015). What is missing in the literature is that gender may influence the relations between these two constructs in physics. Although the rate of female students who choose science-related fields is increasing, this is not valid for all science majors. Recent studies and reports have indicated that girls favor biology over physics. For instance, according to the enrollment rate of undergraduate students to Turkish universities in the 2016–2017 academic year, the number of female students who chose to study physics (473) was almost half of the number of male students (833; Council of Turkish Higher Education, 2017). Therefore, there is a need to examine the gender differences in variables including personal epistemology, motivation and academic achievement, which contribute to students' career decision and interest.

In this study, the focus of participant selection was given on ninth-grade students. Examining the relations between personal epistemology and motivation in physics among ninth-grade students is important for three reasons. First, according to Muis, Bendixen, and Haerle (2006), when students enter into high schools, due to the branching of disciplines into more specific ones, they then start developing personal epistemology regarding the discipline (e.g., science as physics and chemistry). Second, similar to what happens in personal epistemology, shifts in the domain content are reflected in students' motivation (Buehl & Alexander, 2009). Last, to understand why female students are reluctant to choose STEM-related careers, it is important to examine determining factors of career-related choice at precollege level (Sadler et al., 2012). Addition to this, even though students' interest and motivation in physics were declined over the course of schooling, those who had had interest in the beginning of high school had the highest retention in STEM field (Sadler et al., 2012).

To examine gender differences on the relations between personal epistemology and motivation, a baseline model was constructed based on the literature and the previous studies (see Figure 1). It was hypothesized that students' ideas about knowledge and knowing including justification, development, source, and certainty of knowledge would be related to their motivation including expectancies beliefs (self-efficacy beliefs, control of learning beliefs) and value beliefs (task value, extrinsic goal orientation, intrinsic goal orientations) in physics. Because expectancies for success influence value beliefs, they are an antecedent of value beliefs (Elliot & Church, 1997; Wigfield et al., 2016). Therefore, it was hypothesized that students' ability beliefs, including self-efficacy and control of learning in physics, would predict value components of their motivation including intrinsic goal orientation, extrinsic goal orientation, and task value, and their achievement in physics. Finally, it was hypothesized that the dimensions of value components of their motivation would be related to students' achievement in physics.

Method

A quantitative survey design was employed to address the study purposes. Therefore, self-report questionnaires were used to collect data. A structural equation modeling approach was utilized to determine the relationships among the variables.

Sample

K–12 education in Turkey is managed by a national system that all schools must follow the national curriculum governed by the Ministry of National Education. Starting from the 2012–2013 academic year, compulsory education in Turkey increased from K–8 to K–12. Thus, after graduating from middle schools, students must enroll in a high school based on their scores on the Transition from Primary to Secondary Education test. In Turkey, students at Grades 9 and 10 take common courses including hard (e.g., physics, mathematics) and soft (e.g., language and art) sciences. At Grade 11, students must choose a specialized area—science, foreign language, or social science—take courses accordingly. At Grade 9, students take three science courses including biology, physics, and chemistry. Physics subjects covered at Grade 9 include the nature of physics, matter, force and motion, energy, and heat and temperature.

A convenience sampling strategy was employed (Creswell, 2007). Because of convenience to the researcher, Mugla Province was chosen to save time and money. There were three public high schools in the city center of Mugla, excluding vocational and science high schools. These school students are middle achiever from the Transition from Primary to Secondary Education test. The Office of the Turkish Ministry of Education in the city granted the permission for data collection in these three high schools. Students were informed about the study. Five hundred sixty-seven (300 girls) ninth-grade students voluntarily participated in the study in January 2015. Students completed the instruments in one class hour under the presence of their classroom teachers.

Instruments

The following questionnaires were chosen, which met three criteria: (a) being adaptable to physics, (b) capturing the facets of two constructs, and (c) being already validated in Turkey. In accord with the study purposes, the questionnaires were adapted to physics domain.

Epistemological Beliefs Questionnaire

The Epistemological Beliefs Questionnaire (EBQ; Conley, Pintrich, Wekiri, & Harrison, 2004) is a self-report questionnaire developed to map students' views about scientific knowledge, and is rated 5-point Likert-type scale. The EBQ was previously used and validated with elementary and secondary students in Turkey (e.g., Alpaslan, 2017; Kapucu & Bahcivan, 2015). The EBQ consists of 26 items in four dimensions defined by Hofer and Pintrich (2002) as the following: (a) certainty of knowledge (6 items), (b) source of knowledge (5 items), (c) justification of knowledge (9 items), and (d) development of knowledge (6 items). The higher value in source and certainty of knowledge dimensions stands for the more naive beliefs, and thus the scores were reversed. The questionnaire items were adapted from English into Turkish by Ozkan (2008). In a recent study, Kapucu and Bahcivan (2015) reported the EBQ's reliability with 498 Turkish high school students as the following Cronbach's alphas: .70 for development of knowledge, .58 for source of knowledge, .56 for certainty of knowledge, and .85 for justification of knowledge. As the questionnaire was originally developed to assess students' personal epistemologies in science, it was adapted to physics. In accord, words *science* and *scientists* were replaced with words *physics* and *physicists* in the questionnaire. Therefore, a sample item on the source of knowledge, for example, was "Everybody has to believe what physicists say." Cronbach's alphas for reliability were .72 for certainty of knowledge, .74 for source of knowledge, .73 for justification of knowledge, and .77 for development of knowledge. Confirmatory factor analysis (CFA) was conducted as they have been previously validated in Turkey. Considering Hu and Bentler's (1999) criteria (comparative fit index [CFI] > 0.95 or root mean square error of approximation [RMSEA] < 0.06 for good fit, and CFI >0.90 or RMSEA <0.08 for moderate fit), the results of CFA for the EBQ were in a moderate model fit, $\chi^2(293, N = 567) = 683.91$, $p < .001$, standardized root mean square residual [SRMR] = 0.056, RMSEA = 0.049, CFI = 0.92. After examining modification indices, to obtain the best model fit, the correlation between the Item 7 and Item 12, which were

Table 1. Factor loadings of the instruments.

	Dimension	Item	Girls	Boys	All
MSLQ	Intrinsic goal orientation	PHY_MC_1	.907	.843	.875
		PHY_MC_16	.905	.858	.880
		PHY_MC_22	.836	.881	.861
		PHY_MC_24	.814	.876	.844
	Extrinsic goal orientation	PHY_MC_7	.777	.873	.827
		PHY_MC_11	.863	.843	.859
		PHY_MC_13	.832	.819	.825
		PHY_MC_30	.800	.829	.807
	Task value	PHY_MC_4	.880	.886	.878
		PHY_MC_10	.864	.815	.839
		PHY_MC_17	.889	.854	.874
		PHY_MC_23	.858	.823	.840
		PHY_MC_26	.799	.849	.818
		PHY_MC_27	.826	.797	.813
	Control of learning	PHY_MC_2	.772	.833	.803
		PHY_MC_9	.885	.892	.887
		PHY_MC_18	.771	.862	.823
		PHY_MC_25	.857	.891	.875
	Self-efficacy	PHY_MC_5	.731	.684	.706
		PHY_MC_6	.808	.815	.810
		PHY_MC_12	.838	.824	.831
		PHY_MC_15	.832	.834	.830
		PHY_MC_20	.835	.825	.828
		PHY_MC_21	.852	.857	.853
		PHY_MC_29	.779	.800	.790
		PHY_MC_31	.814	.871	.843
EBQ	Source	PHY_PE_1	.694	.787	.742
		PHY_PE_6	.715	.636	.674
		PHY_PE_10	.776	.798	.790
		PHY_PE_15	.721	.753	.738
		PHY_PE_19	.712	.791	.755
	Justification	PHY_PE_3	.674	.629	.659
		PHY_PE_5	.669	.620	.647
		PHY_PE_9	.615	.627	.637
		PHY_PE_11	.722	.690	.716
		PHY_PE_14	.704	.810	.764
		PHY_PE_18	.629	.613	.605
		PHY_PE_22	.656	.736	.696
		PHY_PE_24	.649	.683	.667
		PHY_PE_26	.631	.686	.670
	Certainty	PHY_PE_2	.659	.723	.698
		PHY_PE_7	.680	.728	.713
		PHY_PE_12	.588	.619	.597
		PHY_PE_16	.657	.645	.647
		PHY_PE_20	.521	.544	.529
		PHY_PE_23	.527	.573	.548
	Development	PHY_PE_4	.537	.505	.525
		PHY_PE_8	.573	.555	.562
		PHY_PE_13	.642	.584	.617
		PHY_PE_17	.612	.695	.650
		PHY_PE_21	.545	.671	.603
		PHY_PE_25	.619	.608	.568

Note. CFI = comparative fit index; EBQ = Epistemological Beliefs Questionnaire; MSLQ = Motivated Strategies for Learning Questionnaire.

under the same factor, was put and the new CFA results for the EBQ were in a good model fit, $\chi^2(292, N=567)=620.51$, $p < .001$, SRMR = 0.046, RMSEA = 0.043, CFI = 0.95. For the female group, the results of CFA for the EBQ, $\chi^2(293, N=300)=383.41$, $p < .001$, SRMR = 0.032, RMSEA = 0.036, CFI = 0.96, resulted in good fit. For boys, the initial results of CFA for the EBQ, $\chi^2(292, N=300)=404.73$, $p < .001$, SRMR = 0.042, RMSEA = 0.051, CFI = 0.91, were in moderate fit. To obtain the best fit, a correlation between Item 18 and Item 22, which were under the same factor, was placed. The new CFA results were in good fit, $\chi^2(291, N=300)=523.79$, $p < .001$, SRMR = 0.055, RMSEA = 0.056, CFI = 0.94. The factor loadings of the items in the EBQ are given in Table 1.

Motivated Strategies for Learning Questionnaire

The Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, & McKeachie, 1991) is self-report questionnaire developed to measure students' motivation in any domain, and is rated on a 7-point Likert-type scale. The MSLQ has been previously validated and used by researchers in Turkey (e.g., Alpaslan et al., 2016). The MSLQ originally consists of 81 items in 15 dimensions to assess students' motivation and self-regulated learning strategies. For the study purposes, dimensions addressing expectancies including control of learning belief (4 items) and self-efficacy (8 items) and value beliefs including intrinsic goal orientation (4 items), extrinsic goal orientation (4 items), and task value (6 items) were used. Intrinsic goal orientation is related to goals that increase and to master skills for curiosity. Extrinsic goal orientation refers to reasons for rewards, grades, and performance. Task value is about how important and interesting a learner sees the task. Self-efficacy refers to students' views on their ability and competency about an academic task. Control of learning beliefs refers to students' views about their personal effort with learning would yield in positive outcomes.

Items in the MSLQ were adapted from English into Turkish by Sungur (2007). Yumusak, Sungur, and Cakiroglu (2007) explored the MSLQ's reliability with 519 Turkish high school students and found Cronbach's alphas of .64 for intrinsic goal orientation, .54 for extrinsic goal orientation, .79 for task value, .61 for control of leaning belief, and .85 for self-efficacy. Because the questionnaire was originally developed to assess students' motivation in any course, it was adapted to physics by adding word *physics*. Therefore, a sample item in extrinsic goal orientation, for example, was, "Getting a good grade in this physics class is the most satisfying thing for me right now." Cronbach's alphas for reliability were .75 for intrinsic goal orientations, .76 for extrinsic goal orientation, .74 for task value, .77 for control of leaning belief, and .79 for self-efficacy.

The initial results of the CFA for the MSLQ were in moderate model fit, $\chi^2(389, N=567)=808.01$, $p < .001$, SRMR = 0.040, RMSEA = 0.056, CFI = 0.93. After examining modification indices of the initial results, a correlation was established between Item 6 and Item 15 on the self-efficacy scale. The new results of CFA for the MSLQ were in good model fit, $\chi^2(288, N=567)=767.70$, $p < .001$, SRMR = 0.039, RMSEA = 0.050, CFI = 0.96. For the female group, the results of CFA for the MSLQ, $\chi^2(286, N=300)=532.91$, $p < .001$, SRMR = 0.051, RMSEA = 0.052, CFI = 0.96, were in good fit. For boys, the CFA for the MSLQ, $\chi^2(286, N=300)=605.51$, $p < .001$, SRMR = 0.045, RMSEA = 0.052, CFI = 0.95, resulted in good fit.

Table 2. Fit indices of models tested in the measurement variances.

	EBQ				MSLQ			
	χ^2	*df*	CFI	ΔCFI	χ^2	*df*	CFI	ΔCFI
Configural model	907.19	583	0.933	–	1283.24	578	0.941	–
Weak measurement variance	932.45	605	0.928	0.005	1311.08	599	0.938	0.003
Strong measurement variance	970.04	631	0.925	0.008	1342.11	622	0.935	0.006
Strict measurement variance	985.22	643	0.924	0.009	1353.70	634	0.934	0.007

Note. CFI = comparative fit index; EBQ = Epistemological Beliefs Questionnaire; MSLQ = Motivated Strategies for Learning Questionnaire.

Achievement

Some studies used students' grade as their achievement score (Muis & Franco, 2009); others were utilized additional achievement tests (Stathopoulou & Vosniadou, 2007). In this study, students' physics grade in the fall semester was taken as their achievement score (1–100) because an additional achievement test would take extra time for the participants. Because the researcher did not take any role in the development and evaluation of achievement score, the reliability of using achievement score can be questionable. However, students' end term grade consisted of two tests. These tests were developed and evaluated by all physics teachers at the high schools. Thus, every student at the high school took the same test. Although using the end-of-term grade is a limitation of this study, because the tests were evaluated by a total of eight teachers at three high schools and all students took the same test, it can be assumed that the end-of-term grade is valid.

Data analysis

To address the purpose of the study, structural equation modeling was utilized. Structural equation modeling enables the researcher to test the combination of indirect and direct effects among variable in the model (Kline, 2011). Moreover, structural equation modeling provides estimations for all specific paths in the model (Kline, 2011). With structural equation modeling, the researcher also is able to apply the model's test of the fit to observed data. Therefore, using structural equation modeling was an appropriate way to address the study purposes. All analyses were done on Mplus 6.12 software with maximum likelihood estimation (Muthén & Muthén, 2011). Kline recommended at least 200 participants to run structural equation modeling. Each variable in the model was considered as a latent variable, which excludes measurement errors in the model.

To test the gender difference, multigroup structural equation modeling analysis was utilized. Multigroup structural equation modeling analysis consists of two phases as testing

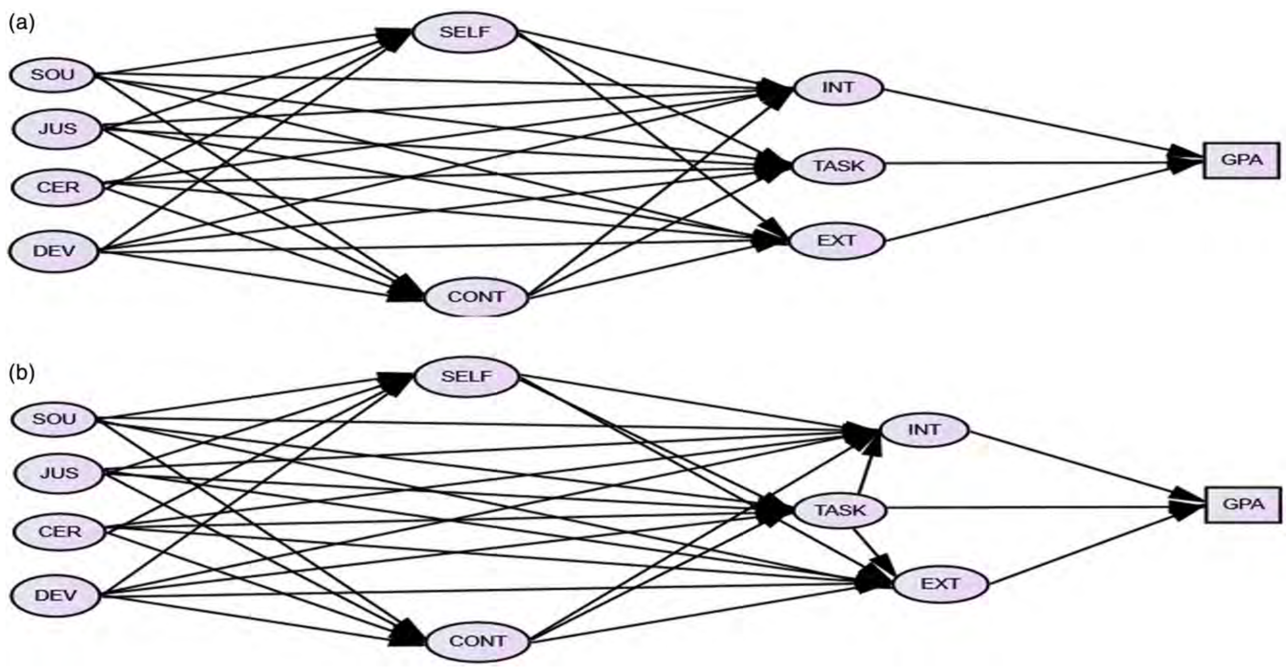

Figure 2. (A) The hypothesized model. (B) The competing model.

Table 3. Fit indices of the hypothesized and competing models.

Model	χ^2	*df*	CFI	AIC	BIC	RMSEA
Original	2573.88	1293	0.94	89459.95	89678.49	0.04
Competing	2565.92	1291	0.94	88626.60	88824.37	0.04

Note. $\chi^2_d(2) = 7.96$, $p < .001$. AIC = Akaike information criterion; BIC = Bayesian information criterion; CFI = comparative fit index; RMSEA = root mean square error of approximation.

measurement invariance and structural invariance. Measurement invariance is a prerequisite to test structural invariance. Because two independent questionnaires were used in this study, the first measurement invariance for each questionnaire was done to ensure items in the questionnaire measure the same theoretical construct for girls and boys (Wang & Wang, 2012). Four steps described by Wang and Wang were followed. First, pattern invariance tests were done. The fit indices of the configural models of the EBQ and MSLQ were in good fit (see Table 2). Then, weak measurement invariance tests (testing that the factor loading are invariant across groups) were run and the results of test weak measurement invariance were not statistically significant, $\chi^2_d(22) = 25.26$, $p = .25$ for the EBQ; $\chi^2_d(21) = 27.84$, $p = .21$ for the MSLQ. Next, the strong measurement invariance test was done and the result was not statistically significant, $\chi^2_d(15) = 21.54$, $p = .12$ for the EBQ;, $\chi^2_d(48) = 62.85$, $p = .13$ for the MSLQ. Last, a strict measurement variance test was run and the result was not statistically significant, $\chi^2_d(60) = 78.03$, $p = .14$ for the EBQ; $\chi^2_d(56) = 70.48$, $p = .09$ for the MSLQ. Statistically nonsignificant results and CFI differences that were less than .01 indicate that measurement invariance were established (Wang & Wang, 2012). After ensuring measurement invariance, path coefficients of the constructed model in each group were tested by utilizing the Wald test to examine whether it differs for the groups (Wang and Wang, 2012).

Results

Students' personal epistemology on source, certainty, justification, and development of knowledge were assessed by the EBQ. Motivational factors including intrinsic goal orientation, extrinsic goal orientation, task value, self-efficacy, and control of learning belief were measured by the MSLQ. Before running structural equation modeling, the normality of the dataset including skewness and kurtosis values were examined. The range were for skewness from −1.02 to 1.25 and for kurtosis from −1.40 to 0.93.

Baseline model

The results of structural equation modeling depend on the dataset. It is suggested that rather than testing a single hypothesized model, it is more appropriate to test competing models, which may explain the observed relations better and fit better (Kline, 2011). Therefore, addition to the hypothesized model in Figure 1, a competing model that assumes that task value directly predicts students' goal orientations. Logic for this pathway is that task value is a determinant on an individual's goal and desire to accomplish a task (Wigfield et al., 2009). Furthermore, previous studies reported that high school students' task value predicts their intrinsic goal orientation in science (e.g., Sungur, 2007). The hypothesized and competing models are displayed in Figure 2.

After examining the modification indices, the same paths were identified for both models. The results of structural equation modeling for both models were in good fit (see Table 3). To see which model should be chosen, a chi-square difference test was utilized. The results of the chi-square test showed a statistically significant difference between the two models, $\chi^2_d(2) = 7.96$, $p < .001$. The values of the Akaike information criterion (AIC) and Bayesian

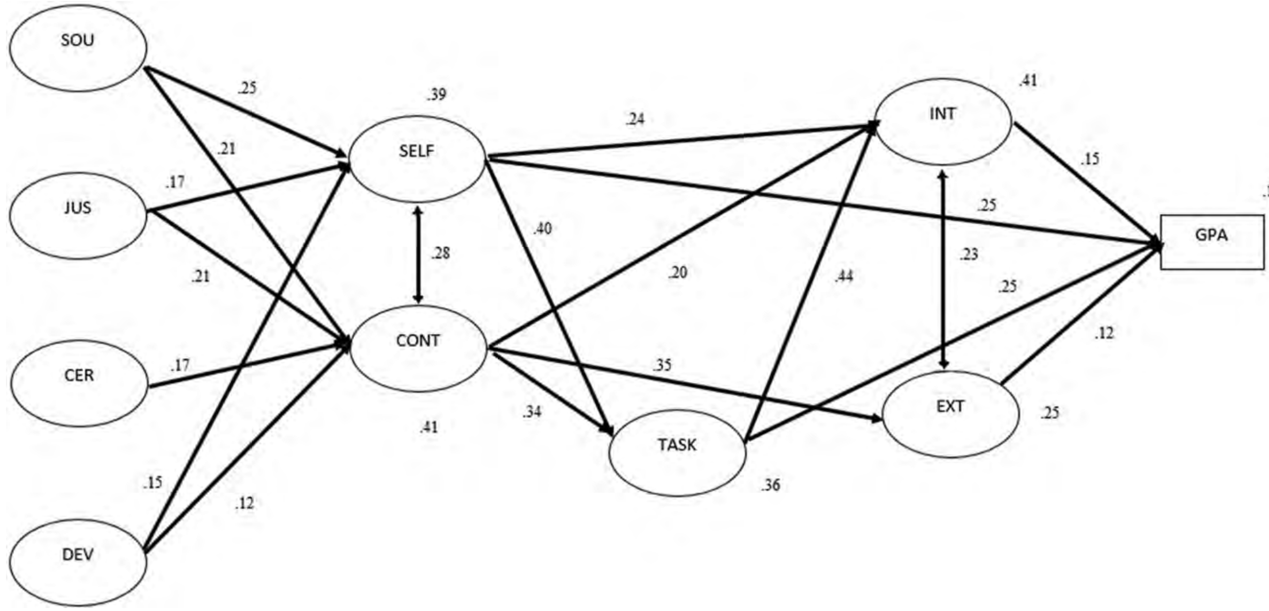

Figure 3. The path coefficients for the tested model. The number that associated with the factor displays the variation explained by the model. The path coefficients between personal epistemology and task value, extrinsic and intrinsic goal orientation, and grade point average were not displayed in the figure for its simplicity; instead, they are shown Table 2.

Table 4. Path coefficients in the model.

Variable	SELF	CONT	TASK	INT	EXT	GPA
SOU	.25**	.21**	.12*	.11*	.09*	**.09****
JUS	.17**	.21**	.17**	.28**	.27**	**.11****
CER	.07	.17**	.04	.04	.07**	**.04**
DEV	.15**	.12*	.15**	.09*	.10*	**.05**
SELF	–	.28**	.40**	.24**	.08	.25**
CONT	–	–	.34**	.20**	.35**	.08
TASK	–	–	–	.44**	.07	.25**
INT	–	–	–	–	.23**	.15**
EXT	–	–	–	–	–	.12**
R^2	.39	.41	.36	.41	.25	.16

Note. Bolded represents the indirect effect coefficients.
$^*p < .05$. $^{**}p < .01$.

information criterion (BIC) were lower for the competing model than for the hypothesized model. Because of the result of chi-square difference test and lower values of AIC and BIC, the competing model was chosen (Kline, 2011).

Once the competing model was run, the result showed good fit of the data, $\chi^2(1293, N = 567) = 2717.11$, $p < .001$, SRMR = 0.06, RMSEA = 0.044, CFI = 0.916. After the modification indices were examined, an intercorrelation was established between (a) self-efficacy and control of learning and (b) intrinsic goal orientation and extrinsic goal orientation to obtain a better fit with the data. These correlations were also theoretically reasonable because students' learning beliefs may be correlated to their self-efficacy. The fit indices of the second run for the competing model were in better fit; $\chi^2(1291, N = 567) = 2565.92$, $p < .001$, SRMR = 0.049, RMSEA = 0.04, CFI = 0.94. The model explained the 16% of variance in the students' achievement in physics (see Figure 3).

Examination of path coefficients revealed that some dimensions of personal epistemology significantly predicted students' self-efficacy and control of learning beliefs in physics. Except the path coefficient between the certainty of knowledge and self-efficacy, all significant path coefficients were positive (see Table 4). This implies that the more students hold sophisticated ideas about knowledge and knowing in physics, the higher beliefs on their ability to learn physics.

Students' judgment on their ability to learn physics was related to source of knowledge ($\beta = 0.25$), justification of knowledge ($\beta = 0.17$), and development of knowledge ($\beta = 0.15$). Belief on the nature of knowledge and knowing explained 39% of variation in self-efficacy in physics. Control of learning beliefs was related to all dimensions of personal epistemology as source of knowledge ($\beta = 0.21$), justification of knowledge ($\beta = 0.21$), development of knowledge ($\beta = 0.12$), and certainty of knowledge ($\beta = 0.17$). Addition to this, students' ideas on the nature of knowledge and knowing explained 41% of variation in control of learning beliefs. Students' self-efficacy and control of learning beliefs were correlated ($\beta = 0.28$).

Additionally, task value was related to self-efficacy ($\beta = 0.40$) and control of learning belief ($\beta = 0.34$). Task value also predicted intrinsic goal orientation ($\beta = 0.44$) and academic achievement ($\beta = 0.25$). The path coefficient between task value and extrinsic goal orientation was not statistically significant ($\beta = 0.07$). The model explained 36% of variation in task value. Intrinsic goal orientation was related to extrinsic goal orientation ($\beta = 0.23$) and academic achievement ($\beta = 0.15$). Extrinsic goal orientation also predicted academic achievement ($\beta = 0.12$). The model explained 41% of variation in intrinsic goal orientation, 25% of variation in extrinsic goal, and 16% of variation in academic achievement.

Testing the gender difference on baseline model

To examine the difference in the research model in terms of gender, multigroup analysis method in Mplus 6.12 was

Table 5. Path coefficients in the constructed model for girls and boys.

Variable	SELF		CONT		TASK		INT		EXT		GPA	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
SOU	**.28****	**.15****	**.24****	**.09**	**.20****	**.06**	.16**	.09	.10	.08	.14**	.05
JUS	**.25****	**.12****	**.35****	**.15****	**.25****	**.12***	**.22****	**.35****	**.14**	**.35****	.15**	.08
CER	.02	.12	**.06**	**.35****	**.12**	**-.10**	**-.10**	**.20****	.02	.10	.10	.16**
DEV	**.07**	**.22****	.13**	.20**	.16**	.12	**.16****	**.01**	.16**	.05	.11	.10**
SELF	–	–	**.45****	**.22****	**.42****	**.25****	**.18****	**.43****	.12	.06	.29**	.19**
CONT	–	–	–	–	**.30****	**.55****	.16**	.26**	**.28****	**.41****	.12*	.07
TASK	–	–	–	–	–	–	**.56****	**.25****	.05	.12**	.25**	.16**
INT	–	–	–	–	–	–	–	–	**.18****	**.30****	.15**	.12**
EXT	–	–	–	–	–	–	–	–	–	–	.09	.15**
R^2	.40	.39	.35	.45	.38	.30	.44	.35	.20	.30	.21	.14

Note. Bolded coefficients represent the statistically significant difference in Wald tests.
$^{*}p < .05$. $^{**}p < .01$.

utilized, as described by Wang and Wang (2012). After measurement invariance established, structural invariance was tested by using Wald test (Wang and Wang, 2012).

For girls, the fit indices of the constructed model were in good fit, χ^2 (1290, $N = 300$) = 1973.74, $p < .01$, SRMR = 0.042, RMSEA = 0.042, CFI = 0.93. The model successfully explained 21% of variance in girls' academic achievement in physics (see Table 5). Beliefs in source and justification of knowledge were positively associated with self-efficacy ($\beta = 0.28$ and $\beta = 0.25$, respectively). Additionally, development of knowledge predicted significantly control of learning beliefs ($\beta = 0.24$, $\beta = 0.35$, and $\beta = 0.13$, respectively) and task value ($\beta = 0.16$, $\beta = 0.22$, and $\beta = 0.16$, respectively). Only development of knowledge was significantly related to extrinsic goal orientation ($\beta = 0.16$). Beliefs in source and justification of knowledge were positively and indirectly associated with academic achievement ($\beta = 0.14$ and $\beta = 0.15$, respectively).

For girls, the path coefficient between self-efficacy and control of learning indicated a strong relation between the two ($\beta = 0.45$). While students' learning ability beliefs were significantly related how much they valued learning physics ($\beta = 0.42$ and $\beta = 0.30$, respectively) and intended to mastery physics for sake of learning ($\beta = 0.18$ and $\beta = 0.16$, respectively), self-efficacy were more strongly related to task value and intrinsic goal orientation than to control of learning belief. Only the relation between control of learning and extrinsic goal orientation was statistically significant ($\beta = 0.28$). Task value ($\beta = 0.25$) and self-efficacy ($\beta = 0.29$) were strong predictors of academic achievement in physics among motivational variables, while source ($\beta = 0.14$) and justification of knowledge ($\beta = 0.15$) were the variables that were significantly related to achievement among dimensions of personal epistemology.

For boys, the fit indices of the constructed model were in good fit, χ^2(1293, $N = 267$) = 2135.69, $p < .01$, SRMR = 0.055, RMSEA = 0.055, CFI = 0.91. The model successfully explained 14% of variance in boys' academic achievement in physics (see Table 3). Source, justification, and development of knowledge were positively associated with self-efficacy ($\beta = 0.15$, $\beta = 0.12$, and $\beta = 0.22$, respectively). Beliefs on justification, certainty, and development of knowledge were significantly related to control of learning beliefs ($\beta = 0.15$, $\beta = 0.35$, and $\beta = 0.20$, respectively). Among other dimensions of personal epistemology, only justification of knowledge significantly predicted task value ($\beta = 0.12$). Beliefs on justification and certainty of knowledge were significantly related to intrinsic goal orientation ($\beta = 0.35$ and $\beta = 0.20$, respectively), whereas only justification of knowledge were significantly associated with extrinsic goal orientation ($\beta = 0.35$). Certainty and development of knowledge significantly predicted boys' achievement in physics ($\beta = 0.16$ and $\beta = 0.10$, respectively). As it was for girls, for boys the correlation between self-efficacy and control of learning beliefs were significantly related ($\beta = 0.22$). Those ability beliefs were also related to students' task value ($\beta = 0.25$ and $\beta = 0.55$, respectively) and intrinsic goal orientation ($\beta = 0.43$ and $\beta = 0.26$, respectively) in physics. Only control of learning beliefs was significantly related to extrinsic goal orientation ($\beta = 0.41$). Boys' academic achievement in physics was related to self-efficacy ($\beta = 0.19$), task value ($\beta = 0.16$), intrinsic goal orientation ($\beta = 0.12$), and extrinsic goal orientation ($\beta = 0.15$).

Path coefficients in the constructed model for two groups of students were compared by using Wald test. The statistically significant differences were displayed in Table 5 with bolded. Accordingly, the relations of self-efficacy with source, $\chi^2(1) = 4.69$, $p < .05$, and justification of knowledge, $\chi^2(1) = 5.28$, $p < .05$, among girls were stronger than those among boys, while its relation with development of knowledge, $\chi^2(1) = 7.28$, $p < .01$, was stronger in favor of boys than girls. Similarly, source and justification of knowledge were better predictors of control of learning, $\chi^2(1) = 7.21$, $p < .01$; $\chi^2(1) = 9.19$, $p < .01$, respectively; and task value, $\chi^2(1) = 7.54$, $p < .01$; $\chi^2(1) = 5.80$, $p < .05$, for girls than for boys. While the path coefficient between certainty of knowledge and task value for boys was negative, it was positive for girls. The relations of intrinsic goal orientation with beliefs on justification, $\chi^2(1) = 7.05$, $p < .01$, and certainty of knowledge, $\chi^2(1) = 9.41$, $p < .01$, were stronger for boys than for girls, while its relation with development of knowledge was stronger for girls than for boys, $\chi^2(1) = 7.22$, $p < .01$.

The relation between self-efficacy and control of learning beliefs was stronger for girls than for boys, $\chi^2(1) = 10.99$, $p < .01$. Similarly, the relations of self-efficacy with task value was stronger for girls than for boys, $\chi^2(1) = 10.09$, $p < .01$. Task value was a better predictor of intrinsic goal orientation among girls than it was among boys, $\chi^2(1) = 12.08$, $p < .01$. The path coefficients between control of learning beliefs and task value, $\chi^2(1) = 10.02$, $p < .01$; self-efficacy and intrinsic goal orientation, $\chi^2(1) = 8.87$, $p < .01$; control of learning and extrinsic goal orientation, $\chi^2(1) = 7.26$, $p < .01$; and intrinsic and extrinsic goal orientations, $\chi^2(1) = 6.71$, $p < .01$, were stronger in favor of boys over girls.

Discussion

With this study, the research gap in the examination of gender difference on the relations between personal epistemology and motivation was addressed through the constructed model. The results of this study indicated that personal epistemology and motivation are important elements that predict students' achievements in physics. The findings of this study are consistent with Muis's (2007) assumption that students' ideas about knowledge and knowing are predictors of motivational constructs. The results of this study suggest that fostering students' personal epistemology in physics positively increases their motivation and consequently their achievement in physics.

The findings of this study suggest that increasing students' motivation toward learning physics, for both girls and boys, would be more successful when more attention was paid on their ideas about knowledge and knowing in physics. More specifically, the analysis revealed that the more students viewed knowledge as internally constructed (source of knowledge), the higher self-efficacy they had when learning physics. In addition, sophisticated students regarding source of knowledge were reported to have a higher level of control of learning and intrinsic motivation. Ricco, Pierce, and Medinilla (2010) reported a negative relation between source of knowledge and intrinsic goal orientation and self-efficacy. However, Kapucu and Bahcivan (2015) reported that students' ideas about source of knowledge were positively associated with their self-efficacy beliefs in physics. Consistent with Kabucu and Bahcivan, the results showed a positive correlation among source of knowledge and self-efficacy, intrinsic goal orientation, and control of learning dimensions of motivation. Moreover, it was found that students' ideas on source of knowledge indirectly predicted their achievement physics.

Kapucu and Bahcivan (2015) reported the more sophisticated ideas students had in justification of knowledge, the higher level of self-efficacy they had in learning physics. Kizilgunes et al. (2009) demonstrated that students with more sophisticated beliefs on justification of knowledge tended to be more intrinsically motivated. Consistent with Kapucu and Bahcivan and Kizilgunes et al., the results of this study also suggest that students who believed the important role of evidence on theory building (justification of knowledge) were more self-efficacious in learning physics. In addition, the results revealed that justification of knowledge not only contributed to students' motivation in physics, but also indirectly predicted their achievement in physics. Paulsen and Feldman (2005) demonstrated that students' ideas on development of knowledge were positively related to their intrinsic goal orientation, self-efficacy, control of learning, and task value. Similarly, Muis and Franco (2009) reported that development of knowledge was positively associated with intrinsic goal orientation. Consistent with these studies, results of this study suggest that students who believed physics knowledge is intricate and deep (development of knowledge) tended to have intrinsic and extrinsic goal orientations, to appreciate the value of learning task and to become self-efficacious.

Consistent with the previous studies (Mousoulides & Philippou, 2005), in this study it was found that that self-efficacy is a strong predictor of achievement in physics. Lynch (2006) demonstrated that students' who reported high level of intrinsic and extrinsic goal orientations, self-efficacy, and task value accumulated a higher semester grade in physics. Likewise, Behrozi, Yeilagh, and Mansourian (2013) reported dimensions of motivation including self-efficacy and task value were predictors of achievement. Consistent with these studies, the results showed that students who had higher-level self-efficacy, task value, and goal orientation had a higher achievement in physics.

Gender

So far, the previous studies addressing gender differences found that female students seemed to report higher levels of test anxiety (Britner, 2008), less interest (Hoffmann, 2002), and less cognitive ability in physics than did boys (Jurik, Groschner & Seidel, 2014). Furthermore, Louis and Mistele (2012) found that boys' achievement scores were higher in physics than were girls' scores, although no difference was observed in self-efficacy. These studies contributed to our understanding of the gender issue in physics education. Rather than examining the gender difference on mean scores of self-efficacy, motivation, and academic achievement, this study advances our understanding of the gender difference by examining how the relations differ for gender groups. Therefore, results of this study are important to explain how self-efficacy, motivation, and academic achievement differ for boys and girls.

The findings of this study indicate that the relations between personal epistemology and motivation explained more percentages of variances in girls' academic achievement in physics than it did in boys (21% vs. 14%). To increase girls' achievement in physics, the relations of personal epistemology and motivation with achievement in physics may offer a clue as for what has to be done in teaching physics. This result suggests that when a girl who believes that knowledge in physics is internally constructed and evaluated by evidence and experimenting (source and justification of knowledge), she would tend to become more self-efficacious, assign value to learning physics, and eventually have a high achievement in physics. To help girls be more successful in physics, we should design and implement educational practices that encourage them to develop sophisticated ideas about the nature of knowing (source and justification of knowledge) in physics classrooms.

Results of this study showed that the explained variances of self-efficacy, task value, and intrinsic goal orientation by the dimensions of personal epistemology were higher for girls than for boys (40% vs. 39%, 38% vs. 30%, and 44% vs. 35%, respectively), whereas for control of learning it was in favor of male students (35% vs. 45%). The reason for the weaker relations between personal epistemology and control of learning may be related to the fact that girls reported to have less absolutist views—believing knowledge is certain and does not need to be justified—than did boys (Mason, Boldrin, & Zurlo, 2006). Control of learning addresses students' ideas about their personal effort to learn the materials would provide positive outcomes; thus, girls may not believe in evaluation of their teachers regarding their grade, and this may weaken the relations between personal epistemology and control of learning for girls. Path coefficients indicated that there were strong relations between source of knowledge and self-efficacy and justification of knowledge and self-efficacy for female students. These results are important and may explain gender difference on female and male students' self-efficacy and why students' motivational constructs including self-efficacy decrease over time of schooling. Previous studies examining female students' self-efficacy reported that real-life and societal application of course materials they learn are important for female students to develop their self-efficacy in mathematics and science (Gottfried, 2015). This may be directly related to personal epistemology because real-life application of course materials addresses the nature of knowing and may give an idea to female students that knowledge is internally constructed and evaluated by evidence and experimenting. And then, this idea may help female students be self-efficacious and promote their curiosity to learn physics.

Providing real life–based instructions of physics has potential to increase both female and male students' personal epistemology and motivation toward physics. Yet, because findings of this study indicated that the relations between personal epistemology and motivation were stronger for girls than for boys, such instructions would decrease the gender-related gap in motivation in physics. For gender-related issues in career choice, Watt (2016) stated that female students tent to be more interested to help others and make social contributions. Physics is the discipline that provides knowledge and application that help us save the environment and people who need help (e.g., deaf students). Therefore, real-life application of how physics can help us solve problems regarding the environment and disabled people may promote female students' motivation and career interest in physics and physics-related careers.

The relation between personal epistemology and motivation may explain why female students' motivation in physics appear to decrease through the college years. On the one hand, studies examining self-efficacy in science at early aged students found significant differences between female and male students' self-efficacy in science in favor of female students (Britner & Pajares, 2001) or no significant difference between girls and boys (Pajares & Graham, 1999). On the other hand, when female students get older, their self-efficacy in physics decreases (Murphy & Whitelegg, 2006) and the gender difference turns to the favor of male students (D'Lima et al., 2014). The underlying reason of this decrease on female students' self-efficacy may be related to the decrease of real-life application of physics knowledge and giving greater emphasis regarding theoretical and mathematical applications of physics knowledge (formula-based teaching) and less emphasis regarding its real-time application when the level of schooling increases (Sin, 2014). The lack of real-life application directly hinders female students from developing more sophisticated ideas on source of knowledge and justification of knowledge and then may indirectly decrease female students' self-efficacy in physics.

Implications

An important implication that results of this study suggest is that the more sophisticated views on the nature of knowing girls have, the more they would get motivated to learn physics for the sake of interest and have a higher level of self-efficacy in physics. For girls to foster their personal epistemology on source and justification of knowledge, physics instruction should focus on more implications of physics knowledge in real-life situations. Gottfried (2015) discussed that applied implications would be important for girls to foster their interest in STEM fields. The results of this study suggest that applied instruction is important for girls to develop more sophisticated ideas on personal epistemology and consequently, these ideas would increase their self-efficacy and intrinsic goal orientation in physics. STEM-based instruction can be an example of applied instructions to foster female students' personal epistemology and eventually their self-efficacy. There is a bunch of evidence that has showed that STEM-based instruction would increase female students' self-efficacy and academic achievement than traditional instructions (Erdogan & Stuessy, 2015; Gottfried, 2015).

For students to develop more sophisticated personal epistemology, many scholars recommend that teaching activities in physics classrooms should reflect epistemological aspects of authentic inquiry experiences (Alpaslan, Yalvac, & Loving, 2017; Sin, 2014). However, traditional teaching strategies in physics have focused on acquisition of certain and absolute knowledge (Sin, 2014). Consequently, this ignores the process of knowledge production in physics, and would lower both girls' and boys' self-efficacy and other motivational constructs in physics. This study suggests that to promote goal orientation in physics for both girls and boys, instructions should first focus on the epistemological nature of instruction by giving more constructivist-oriented teaching practices including project-based learning and argumentations. However, one of the reasons why argumentation and project-based learning are missing in classroom teaching practices is that students view them as competitions (Ryu & Sandoval, 2012). To respond to this issue, Britner (2008) suggested that rather than giving criticism and competition, teachers should encourage collaboration and supportive environment; by doing so, teachers also promote learning goal orientation for the sake of interest in physics.

Limitations of the study

Some the limitations including measurement errors in structural equation modeling, grade-level difference, and school difference have been highlighted by previous studies addressing motivation and personal epistemology. In this study, a great effort was undertaken to minimize these limitations such as using latent factors over observed ones for measurement error, focusing on only ninth-grade students and collecting data from all available schools in the city. However, this study has some other limitations. Only 16% of variance in achievement in physics could be explained, and 84% is unexplained. Therefore, some other factors in addition to personal epistemology and motivation might be required when expanding the model in future studies. Parents' educational level and learning strategies, for example, have been reported to be related to students' personal epistemology (Ozkan & Tekkaya, 2011) and motivation (Muis & Franco, 2009). Including such factors may give us into insight to better describe the nature of learning physics at high school students. In addition, studies have reported that students' interest and motivation in physics decreased as they grew older up to the end of high school age (Hoffmann, 2002). The researcher who wants to generalize the findings of this study should approach this with this caution.

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