Mustafa Serdar Koksal and Suleyman Yaman

An Investigation of the Epistemological Predictors of Self-Regulated Learning of Advanced Science Students

Abstract

Recent research in educational psychology has shown that beliefs about knowing and learning have an effect on learning. These epistemological beliefs, which are categorized as certainty, simplicity of knowledge, existence of quick learning, and the fixed ability to learn, are related to educationally important cognitive and affective factors, such as self-efficacy, achievement, and task value which are the sub-components of self-regulated learning. *Self-regulated learning* includes the cognitive and motivational sides of learning, and has been shown to be related to epistemological beliefs. Studies suggest that in self-regulated learning, epistemological beliefs serve as standards for task evaluation. But, there is not enough empirical evidence on the nature of the relationship between epistemological beliefs and self-regulated learning of advanced students. The focus of this study is to explore the nature of the relationship between self-regulated learning and epistemological beliefs in the biology domain of science, following the recommendations of researchers who argue that self-regulation and epistemological beliefs are dependent on both the learning domain and the context of learning. The study was conducted with 116 ninth-grade, advanced science students by using a predictive study approach. As data collection tools, we used the "Motivated Strategies for Learning Questionnaire" and Schommer's "Epistemological Beliefs Questionnaire." The results of the study show that beliefs regarding the dependence of learning on struggle and inborn characteristics (the fixed ability to learn) predict self-regulation and its motivation and the use of learning strategy components.

Keywords: advanced science students, epistemological beliefs, self-regulated learning, learning motivation

Introduction

Many recent research studies have suggested that students' epistemological beliefs have direct and indirect effect on learning (Schommer-Aikins, 2002; Topcu & Yilmaz-Tuzun, 2009). Epistemological beliefs are generally understood to be concerned with the origin, nature, limits, methods, and justification of human knowledge. Although studies on epistemological beliefs in education can be traced to Piaget's studies, Perry's original study on intellectual development of college students is generally accepted as the beginning point for epistemological studies in education (Hofer, 2002). Subsequently, Belenky, Clinchy, Goldberger, and Tarule (1986) addressed women's ways of knowing in a study based on Perry's framework, contributing the terms "separate knowing" and "connected knowing" to the epistemological literature. Then, Baxter Magolda (1992) examined gender and "epistemological reflection." In her model, Magolda determined four stages including absolute knowing, transitional knowing, independent knowing, and contextual knowing. She stated that the first three stages reflected gender differences in ways of knowing. Then, King and Kitchener (1994) introduced their "reflective judgment" model, which emphasized both personal epistemology and critical thinking, focusing on epistemological changes in ill-structured problem-solving statements. All of the models presented above, except for King and Kitchener's (1994), are based on a developmental (improvement through stages) approach, viewing epistemological beliefs as unidimensional and dependent on each other. As a departure from the developmental models, Schommer (1994) conceptualized epistemological beliefs as a system of independent epistemological beliefs, or personal epistemologies, which included five distinct *aspects* of epistemological beliefs (stability, structure, source of knowledge, control over knowledge acquisition, and quick learning) that may or may not develop in synchrony (see Hofer & Pintrich, 1997; Hofer, 2002; Schommer-Aikins, 2002 for a comprehensive review). Schommer's model has been frequently studied and supported by researchers using its well-known instrument, the Epistemological Beliefs Questionnaire (EBQ) (Lodewyk, 2007; Schreiber & Shinn, 2003).

Schommer-Aikins (2002) characterized personal epistemology as a system of beliefs, hypothesizing five independent belief aspects affected by experience: stability, structure, source of knowledge, control, and speed of knowledge acquisition. Based on evidence, empirical studies have identified four of the aspects as "Certain Knowledge (knowledge as fixed vs. knowledge that is tentative), Simple Knowledge (knowledge as isolated parts of information vs. knowledge as interrelated concepts), Quick Learning (learning that takes place quickly or not at all vs. learning that is a gradual process), and Fixed Ability (intelligence as fixed vs. intelligence that develops incrementally)" (Hofer, 2001, p. 360). There are many studies that have shown the relationship of these belief aspects with educationally important variables, such

as academic achievement, performance on ill-structured tasks (Lodewyk, 2007), self-efficacy, goal orientation (Phan, 2008), science achievement (Topcu & Yilmaz-Tuzun, 2008), information processing levels (Schreiber & Shinn, 2003), test anxiety, task value, intrinsic and extrinsic goal orientation, and control of learning (Paulsen & Feldman, 1999). One of the most important models for explaining the majority of these variables systematically is the "self-regulated learning" (self-regulation) model, which explains the use of motivational and strategic components of learning in a synchronous way. Self-regulated learning, or self-regulation, refers to the process in which learners deliberately direct their thoughts, actions, feelings, and efforts to achieve their goals (Pintrich, 1990). Self-regulated learners are able to consider their motivational state at the same time they are meta-cognitively aware, monitor their understanding, use learning strategies in a unique way, and evaluate their progress and competencies to achieve their goals (Chen, 2002; Schunk, 2000). Correspondence between the components of self-regulated learning and correlates of epistemological beliefs refers to a relationship between them. The purpose of this study is to investigate the nature of the relationship between self-regulation and epistemological beliefs.

The stated relationship in the previous paragraph has also been shown by correlational studies suggesting that there is a relationship between epistemological beliefs and the components (motivation and strategy use) of self-regulated learning (Barnard, Lan, Crooks & Patton, 2008; Köksal, 2011; Paulsen & Feldman, 1999). In one of the current studies, Lin, Deng, Chai and Tsai (in press) determined a significant relationship between the epistemological beliefs and motivation components in learning science; their findings showed that the more the students believed in the tentativeness of scientific knowledge, the more they felt test anxiety in science. Similarly, when Liang, Lee and Tsai (2010) studied the relationship between epistemological beliefs and motivation components, they found that the students who viewed scientific knowledge as tentative had intrinsic interest in learning science. Tsai, Ho, Liang and Lin (2011) also focused on the motivation component of self-regulated learning and they showed that the students who viewed scientific knowledge as uncertain had low levels of motivation in learning science. As the motivation component was shown to be associated with epistemological beliefs, the strategy used component was also shown to be related to espitemological beliefs (Dahl, Bals & Turi, 2005; Belet & Güven, 2011).

Some researchers have noticed the relationship and proposed a theoretical model to explain this relationship (Muis, 2007; Muis, Bendixen, & Haerle, 2006). Muis (2007) stated that the relationship between the two constructs (epistemological beliefs and self-regulated learning) is reciprocal and a function of the types of standards students set for a task in their learning process. He developed this model further by positing that epistemological beliefs serve as inputs to meta-cognitive processes and as standards in the task definition phase of self-regulated learning. To further support this theoretical model for explaining the relationship between epistemological beliefs and self-regulated learning components, there is a need to collect evidence to show the direction (negative, positive or nötr) of the relationship and the effects of disciplinary context on the relationship.

Both self-regulated learning and epistemological beliefs have been affected by domain or context differences. As stated by Pintrich and De Groot (1990) and Wolters and Pintrich (1998), self-regulated learning and motivation components are context and domain sensitive. Similarly, epistemological beliefs also change with domain differences in certain periods such as undergraduate years (Schommer-Aikins, 2002). In parallel to the approach of Schommer-Aikins, Muis et al. (2006) recommended using domain-specific measurements and analyses to explain why and how epistemological beliefs are related to self-regulated learning in certain disciplinary domains such as biology. The biology domain includes different dilemmas in topics such as genetic engineering, genetically modified foods, global warming and evolution. These topics are current and directly related to daily life in today's society. Applying epistemological beliefs and self-regulated learning processes to study these complicated topics includes different relationship patterns between epistemological beliefs and self-regulated learning from applying them to learn topics which have a linear nature and one correct answer, as in many chemistry and physics topics.

As another point, studies on the relationship between self-regulated learning and epistemological beliefs have been conducted with students who are not advanced students in the science domain under study (Barnard et al., 2008; Paulsen & Feldman, 1999; Paulsen & Feldman, 2007; Phan, 2008). However, it would also make sense to study advanced science students in epistemology and self-regulation studies because they have a more sophisticated knowledge of science content and more experience in science, and they are also skilled learners with knowledge of learning strategies, which they are likely to use to learn science content more frequently than less advanced students. Because of these learning factors, which are related to self-regulated learning and their higher level of knowledge on science content, they are the focus of this study.

Advanced Science Students, Epistemological Beliefs, and Self-Regulation

Advanced or gifted and talented students present different epistemological belief patterns from mainstream students. Shommer and Dunnell (1994) compared gifted and non-gifted high school students in terms of their beliefs in the fixed ability to learn simple knowledge, quick learning (learning occurs in quick processing), and certain knowledge (knowledge is not tentative). They studied 1165 high school students, classifying the students as gifted based on the criteria that students must score no less than the 97th

percentile on a standardized, individual test of intelligence or rank no less than the 95th percentile on two or more academic areas of a standardized achievement test. They found that there were no significant differences between mainstream students' epistemological beliefs, such as the belief in simple knowledge or quick learning, at the beginning and the end of high school; however, gifted students were less likely to believe in simple knowledge and quick learning by the end of high school. The study's most consistent result indicated that while gifted and talented students changed their beliefs about the existence of simple knowledge and quick learning over time, the mainstream students' beliefs remained stable over time. However, both categories of students had substantial differences in their beliefs regarding the existence of simple knowledge and quick learning by the time they were in the upper grades of high school.

In another study, Köksal and Sormunen (2009) studied understandings of 16 advanced science students on the nature of science aspects using a qualitative case study approach. To select subjects for the study, the authors used the scores on the science content section of a nation-wide examination, a questionnaire on the students' attitudes toward science and science learning, and a form to elucidate the teacher's ideas about the students. The results of the study revealed that a majority of the participants are expert in aspects of the tentativeness (scientific knowledge is changeable) of scientific knowledge. Similarly, Liu and Lederman (2002), who studied 29 Taiwanese gifted students at the junior high school level, reported that a majority of the gifted students in the study had a basic understanding of the tentativeness of scientific knowledge.

In a study by Schommer-Aikins and Neber (2002), the authors investigated the epistemological beliefs and intentions of gifted students from a self-regulation theory perspective. The participants in the study numbered 133, with 69 boys and 64 girls. To select participants, they used the Stanford–Binet test as a screening tool, choosing those students who scored in the top 2–3% of this test. These students were enrolled in several schools for gifted students. The context of this study was elementary school science and secondary school physics. The authors used Schommer's (1993) definitions of epistemological beliefs and intentions in their study. Schommer determined two aspects of learning, namely the epistemological intention aspect, defined as the intention to learn facts or usable knowledge and the epistemological beliefs aspect, defined as beliefs regarding innate ability, no hard work, quick learning, single answers, avoiding integration, and certain knowledge. The authors found significant positive correlations between epistemological intentions, which focus on acquiring facts and usable knowledge, and the strategy use component of self-regulated learning. The authors also computed a multivariate regression analysis, which found that the epistemological intention to acquire facts in science was one of the strongest predictors of the use of self-regulated learning strategies among students.

Despite the fact that Schommer-Aikins and Neber (2002) have studied epistemological beliefs in gifted students from the perspective of self-regulation, there is a need to study the relationship between self-regulation and epistemological beliefs with advanced students on a specific domain such as biology due to a lack of such studies. Schommer-Aikins (2002) indicated epistemological beliefs are domain sensitive and Muis et al. (2006) also noted a need to study the relationship between self-regulated learning and epistemological beliefs by considering a specific domain such as biology. Therefore, the purpose of this study is to investigate the relationship between self-regulation and epistemological beliefs among advanced (more content knowledge, higher scores on science content tests and being in the top 5% of the students taking a nation-wide exam) science students in the specific science domain of biology.

Research Questions

The research questions of this study include three different questions for motivation, self-regulated strategy use and self-regulated learning. The questions are presented as follows.

1. How accurately can a linear combination of the factors related to epistemological beliefs of academically advanced science students predict *motivation* for biology learning?
2. How accurately can a linear combination of the factors related to epistemological beliefs of academically advanced science students predict the use of *learning strategies*?
3. How accurately can a linear combination of the factors related to epistemological beliefs of academically advanced science students predict *self-regulated learning*?

Method

The study was conducted using a quantitative survey approach (cross-sectional research). For the purpose of the study, two instruments, the Epistemological Beliefs Questionnaire (EBQ) and the Motivated Strategies for Learning Questionnaire (MSLQ), were used to collect data about epistemological beliefs and self-regulated learning of the participants. To save time, money, and energy, the study sample was selected using convenience sampling. Study data was analyzed using multiple linear regressions with one set of predictors.

Participants.

Study participants included 116 ninth-grade, advanced science students. These students were enrolled in science high schools where students were selected based on results of nation-wide examinations and were taking more science courses or more advanced science classes than students in other high schools. The participants in this study were in the top 5% of all test-takers in science sections across the country. The advanced science students also presented the characteristics of gifted individuals (Ozaslan, Yıldız & Çetin, 2009). Descriptive values regarding the participants are shown in Table 1, on the next page.

Instruments.

In the study, we used two instruments, the Epistemological Beliefs

Table 1: Descriptive values of the participants

Gender	Grade	Age					
		14	15	16	17	18	Total
Female	9	2	17	1	0	0	20
	10	0	0	11	1	0	12
	11	0	0	1	7	0	8
	Total	2	17	13	8	0	40
Male	9	2	27	7	0	0	36
	10	0	0	20	4	0	24
	11	0	0	0	11	3	14
	Total	2	27	27	15	0	74

Table 2: MSLQ main factors, sub-factors and their items with Cronbach' alpha coefficients for the Turkish version of the scale (Buyukozturk et al. 2004)

Main factors	Sub-factors	Items	Cronbach alpha coeff.
Motivation	Intrinsic goal orientation	1,16,22,24	.59
	Extrinsic goal orientation	7,11,13,30	.63
	Control of learning beliefs	2,9,18,25	.80
	Task value	4,10, 17, 23, 26, 27	.52
	Self-efficacy for learning and performance	5,6,12,15,20,21,29,31	.86
	Test anxiety	3,8,14,19,28	.69
Learning Strategies	Rehearsal	39, 46, 59, 72	.62
	Elaboration	53, 62, 64, 67, 69,81	.74
	Organization	32, 42, 49, 63	.61
	Critical thinking	38, 47, 51, 66, 71	.74
	Metacognitive self-regulation	33, 36, 41, 44, 54, 55, 56 57, 61, 76, 78	.75
	Time and study environment management	35, 43, 52, 65, 70, 73, 77, 80	.61
	Effort regulation	79, 37, 48, 60, 74	.41
	Peer learning	34, 45, 50	.46
	Help seeking	40, 58, 68, 75	.49

Table 3: Fit indexes of the components of the questionnaire (Sungur, 2004)

Motivation Component	
$\chi 2/df$	5.3
GFI	.77
RMR	.11
Learning Strategy Component	
$\chi 2/df$	4.5
GFI	.71
RMR	.08

Questionnaire (EBQ) and the Motivated Strategies for Learning Questionnaire (MSLQ), to collect data.

Motivated Strategies for Learning Questionnaire: The MSLQ is a self-reporting instrument and has 81 items; 31 of the items assess motivational factors while the remaining items focus on learning strategy factors. The instrument uses a seven-point scale with extremes including *not at all true of me* and *very true of me*. After the scale was translated into Turkish, a validity and reliability study of the scale was carried out by Buyukozturk, Akgün, Demirel, & Özkahveci (2004). After applying the scale to 17 bilingual students in Turkey, they revised it and then applied the revised scale to 852 university students. The total inter-score correlation coefficients were found to be .85 for the motivation subpart and .86 for the learning strategies subpart and were established by considering scores from the Turkish and English forms of the scale. The authors also carried out exploratory and confirmatory factor analyses. The results of the factor analyses confirmed the consistency between the original scale and the translated version. Concurrently, they used a t–test for independent groups to analyze differences between the upper 27% and the lower 27%. The whole scale, its subparts, and Cronbach's alpha coefficients are shown in Table 2.

For each factor, the authors found a mean difference between scores in the upper 27% and the lower 27% of the groups tested using the MSLQ. According to the results of all analyses, the scale was found to be appropriate to use to determine motivational beliefs and learning strategies of university students.

By focusing on high school students, Sungur (2004) also translated and adapted the instrument into Turkish and validated it for biology learning. Sungur conducted a pilot study with 488 high school students from a broad range of schools. Based on demographic self-reporting, the gender of the students was 58.1 % male (n=254) and 41.9 % female (n=183). The mean age of the students was 16.59. The author reported

fit indexes for each component of the scale. Sungur's (2004) results are shown in Table 3.

In addition to Sungur's (2004) adaptation of the instrument for the learning of biology, Koksal (2009) also provided validity evidence of the instrument for a different group of high school students (n=213). The values provided by this study are shown in Table 4.

Table 4: Fit indexes of the self-efficacy and test anxiety components of the questionnaire for the study of Koksal (2009)

Self-efficacy	
$\chi 2$/df	2.85
GFI	.94
RMR	.14
CFI	.95
RMSEA	.09
Cronbach α	.90
Test anxiety	
$\chi 2$/df	6.72
GFI	.94
RMR	.28
CFI	.89
RMSEA	.16
Cronbach α	.76

Table 5: MSLQ main factors, subfactors and their item with Cronbach alpha coefficients for the Turkish version of the scale

Main factors	Subfactors	Cronbach alpha coeff.
Motivation	Intrinsic goal orientation	.67
	Extrinsic goal orientation	.48
	Control of learning beliefs	.53
	Task value	.76
	Self-efficacy for learning and performance	.90
	Test anxiety	.54
Learning Strategies	Rehearsal	.64
	Elaboration	.69
	Organization	.67
	Critical Thinking	.75
	Metacognitive self-regulation	.75
	Time and study environment management	.64
	Effort regulation	.35
	Peer learning	.51
	Help seeking	.35

Table 6: Definitions and item examples regarding to the factors of epistemological beliefs (Deryakulu & Büyüköztürk, 2002)

Symbol of the Factor	Factors	Item Example
Ept1	Learning depends on struggle	Being a good student generally involves memorizing facts
Ept2	Learning depends on intelligence and ability	Some people are born good learners, others are just stuck with limited ability
Ept3	Existence of one truth	Truth is unchanging

Based on the validity and reliability evidence, Cronbach's alpha coefficients for the data produced in this study have also been calculated. The results are shown in Table 5.

As Table 5 shows, three subcomponents of the *self-regulatory strategy use* subpart of the MSLQ, effort regulation, help seeking, and extrinsic goal orientation, were found to have lower alpha values than .50 (Nunnally, 1978). Therefore, they were excluded from the analysis. After the elimination of these subcomponents, the reliability coefficient of the data on the whole instrument was found to be .93, and the reliability coefficients of the motivation and learning strategies factors were found to be .80 and .91, respectively.

Epistemological Beliefs Questionnaire: The EBQ was developed by Schommer (1990) and included 63 items which loaded on four factors: 1) ***simple knowledge*** (knowledge is organized as isolated pieces), 2) ***certain knowledge*** (knowledge is certain), 3) ***fixed ability*** (the ability to learn is fixed at birth and no change occurs sooner), 4) ***quick learning*** (knowledge is acquired quickly or not at all). The instrument was prepared in the form of a five-point Likert scale. The adaptation and validation of the questionnaire were conducted by Deryakulu and Büyüköztürk (2002) in Turkey. Their study included 595 university students in several different universities in Turkey. The researchers found a three-factor solution with 35 items in a five-point Likert form. The three factors they found and re-named are the beliefs that *learning depends on struggle*, *learning depends on intelligence and ability* and the *existence of one truth*. Item examples for each of these factors are shown in Table 6.

Deryakulu and Buyukozturk then conducted a confirmatory factor analysis study with 626 university students using a three-factor questionnaire and found that the scores on the instrument presented appropriate values for different

fit indexes (χ^2/df=2.61, RMSEA=.05, RMS=.09, GFI=.88, AGFI=.87) (Deryakulu & Büyüköztürk, 2005).

In addition to the validity evidence of Deryakulu and Büyüköztürk (2005), a reliability analysis was also done for the sample of this study and the whole scale reliability value was found to be .70. Cronbach's alpha coefficients for each factor of the instrument were calculated. They are shown in Table 7.

Results

The results of the study are presented in two parts as a) descriptive and b) multiple regression analysis results. The variables of the study are explained in Table 8.

The descriptive values for each dependent variable and the skewness and kurtosis values for each variable can be seen in Table 9.

The results show that all variables have skewness and kurtosis values below - /+1.

Multiple linear regression analysis results.

In the analyses for the three different criterion variables including the two components of self-regulated learning and total self-regulated learning score, three predictors (one set of predictors) corresponding to each of the factors of epistemological beliefs questionnaire were used in a random effects model. The regression formulas can be seen in the following formulas:

Motivation= $B_0+B_1Ept1+B_2Ept2+B_3Ept3$

Learning Strategies= $B_0+B_1Ept1+B_2Ept2+B_3Ept3$

Self-Regulated Learning= $B_0+B_1Ept1+B_2Ept2+B_3Ept3$

For the first research question, which concerns the criterion variable *motivation*, it was found that the regression equation, which included all three predictors on epistemological beliefs, was significantly related to motivation for the learning of biology (R^2= .20, adjusted R^2=.18, F(3;112)=9.18, *p*=.00). The regression equation with the unstandardized and standardized weights (*B*s) is as follows:

Predicted motivation= 3.99+.53Ept1-.33Ept2-.04Ept3

$Z_{motivation}= .31Z_{Ept1}-.29Z_{Ept2}-.04Z_{Ept3}$

The multiple correlation coefficient (R=.44) indicates that approximately 44% of the variance in motivation with regard to the learning of biology in the sample can be accounted for by the linear combination of the predictors. A follow-up, partial correlation investigation showed that two significant predictors are Ept1 and Ept2. Ept1 accounted for 11% (.33=0.11) of the variance in motivation for the learning of biology, while Ept2 contributed 11% (.33=0.11) of the variance in motivation for the learning of biology.

For the second research question regarding the criterion variable *learning strategies*, it was found that the regression equation, including all three predictors of epistemological beliefs, is also significantly related to the use of learning strategies for the learning of biology (R^2= .27, adjusted R^2=.25, F(3;112)=13.86, *p*=.00). The regression equation with the unstandardized and standardized weights (*B*s) is as follows:

Predicted Learning Strategies= 2.12+.79Ept1-.31Ept2+.10Ept3

$Z_{learning\ strategies}= .40Z_{Ept1}-.24Z_{Ept2}-.08Z_{Ept3}$

The multiple correlation coefficient (R=.52) indicates that approximately 52% of the variance in the sample, with regard to the use of learning strategies

Table 7: Cronbach's alpha values for each variable considered for this study

	Statistics	
Variables	Number of Items	Cronbach's Alpha Reliability
Ept1	18	.71
Ept2	8	.58
Ept3	9	.59

Table 8: Definitions of all of variables considered in this study

Variables	Definition
Ept1	A measure of the belief that learning depends on the amount of struggle exerted
Ept2	A measure of belief that learning depends on inborn characteristics, such as intelligence and ability
Ept3	A measure of belief in the existence of one truth
Motivation	A measure of expectancy, value, and emotional reactions to learning biology subjects
Learning Strategies	A measure of the use of different cognitive strategies, such as elaboration, rehearsal, and organization in the learning of biology
Self-Regulated Learning	An active, constructive process whereby learners set goals for their learning and then attempt to monitor; regulate; and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment of the learning of biology

Table 9: Descriptive statistics for the variables of the study

Variables (N=116)	Min.	Max.	Mean	SD	Skewness	Kurtosis
Eptf1	2.79	4.83	3.90	.38	.03	.26
Eptf2	1	4.00	2.53	.57	.02	.20
Eptf3	1	5.00	3.05	.59	.07	.93
Motivation	3.41	6.63	5.06	.65	.17	.38
Learning strategies	2.88	6.46	4.70	.75	.11	.43
Self-regulated learning	3.30	6.53	4.84	.65	.10	.41

for learning biology, can be accounted for by the linear combination of the predictors. A follow-up, partial correlation investigation showed that two significant predictors are Ept1 and Ept2. Ept1 accounted for 21% (.46=0.21) of the variance in the use of learning strategies in the learning of biology, while the Ept2 contributed 8% (-.28=0.08) of the variance in the use of learning strategies in the learning of biology.

For the third research question regarding the criterion variable *self-regulated learning*, it was found that the regression equation with all three predictors of epistemological beliefs is significantly related to self-regulated learning behavior in the learning of biology (R^2= .28, adjusted R^2=.26, F(3;112)=14.35, *p*=.00). The regression equation with the unstandardized and standardized weights (*B*s) is as follows:

Predicted Self-Regulated Learning= 2.86+.68Ept1-.32Ept2+.05Ept3

$$Z_{\text{Self-regulated Learning}} = .40Z_{Ept1} - .28Z_{Ept2} + .04Z_{Ept3}$$

The multiple correlation coefficient (R=.53) indicates that approximately 53% of the variance in the use of self-regulated learning behavior in the learning of biology in the sample can be accounted for by the linear combination of the predictors. A follow-up partial correlation investigation has shown that two statistically significant predictors are Ept1 and Ept2. Ept1 has accounted for 21% (.45=0.20) of the variance in the self-regulated learning of biology, while Ept2 contributed 11% (-.33=0.11) of the variance in the self-regulated learning of biology. Bivariate and partial correlations between each predictor and criterion variables are shown in Table 10.

Discussion

The results of this study show that motivation, use of learning strategies, and self-regulation are predicted in similar direction by two factors of epistemological beliefs. Motivation and the use of learning strategies in the learning of biology were positively predicted by the belief in the dependence of learning on struggle and were negatively predicted by the belief in the dependence of learning on inheritance and intelligence. These results are in line with the proposed models on the relationship between self-regulation and epistemological beliefs. In Muis' (2007) model, epistemological beliefs were treated as standards for motivation and the use of learning strategies with the result that self-regulated learning in biology in advanced contexts might also have used epistemological beliefs as standards for motivation.

Neber & Schommer-Aikins (2002) also focused on the relationship between epistemological beliefs, intentions, and the self-regulated learning of gifted students. While the authors found that epistemological intentions are related to self-regulated learning, they did not find any relationship between self-regulation and epistemological beliefs. However, unlike this study, Neber and Schommer-Aikins' study was conducted with instruments that included context-free items, so their result might be related to the generic nature of the measurement tool. Muis et al. (2006) suggested carrying out domain-specific measurements and analyses to explain why and how epistemological beliefs are related to the components of self-regulated learning.

As another side of this study, the learning of biology is often thought to be a type of learning that requires rote memorization for mainstream high school students in spite of the existence of topics that have dilemmas (Kaya & Gürbüz, 2002). This viewpoint seems to be based on the idea that biology is concerned with unchanging truths. As indicated by Muis (2007), believing in existence of unchanging truth might be a standard for the existent motivational state of the mainstream students to see biology as a domain of rote learning. In contrast, no relationship has been found between motivation, use of learning strategies, self-regulation and belief in the existence of unchanging truth in this study. The finding of no relationship might be related to the fact that advanced science students have different learning characteristics from mainstream students (Park & Oliver, 2009). Advanced students take the characteristics of asking challenging questions, being impatient with the pace of other students, disliking routine and busy work, being critical of others, and being aware of being different into science classrooms (Park & Oliver, 2009). Additionally, the curriculum of advanced science courses provides more challenge through struggle rather than routine and busy work. Therefore, the positive relationship between self-regulation and the belief in the dependence of learning on struggle might be related to the need for challenge that advanced students exhibit, that is, the belief that their learning is dependent upon being challenged, while the negative relationship between self-regulation and the belief in the dependence of learning on intelligence and inheritance might be related to the strong belief on dependence of learning on struggle.

Conclusion

The results of this study indicate that the self-regulated learning of advanced science students is significantly predicted by two epistemological beliefs: the belief that *learning depends on the amount of struggle exerted* and *learning depends on inborn characteristics, such as intelligence and ability*. The belief that participants hold regarding the relationship between learning and struggle positively predicted self-regulation behavior; that is, **the more the**

Table 10: Bivariate and partial correlations between each predictor and criterion variables

Predictors	Criterion variables (Bivariate correlation)			Criterion variables (Partial correlation)		
	Motivation	Learning Strategies	Self-regulated Learning	Motivation	Learning Strategies	Self-regulated Learning
Ept1	.33*	.46*	.45*	.30*	.39*	.39*
Ept2	-.34*	-.28*	-.33*	-.30*	-.26*	-.30*
Ept3	.04	.20	.16	-.04	.09	.04

participants have the positive belief that learning is dependent on struggle, the more potential they have to use a constructive process to regulate their learning of biology. On the other hand, the belief that learning is dependent on inborn characteristics negatively predicts for self-regulated learning behavior. This result indicates that **the more participants believe that learning depends on inborn characteristics, the less they present self-regulated learning behavior in the learning of biology**.

Similarly, the motivation component of self-regulation behavior was positively predicted by the belief that learning is dependent on struggle while it was negatively predicted by the belief that learning is dependent on inborn characteristics. In parallel to the conclusions on self-regulation behavior, **the more the advanced science students believe that learning is dependent on struggle, the more they will be motivated to learn biology in advanced contexts**. Conversely, **the more the advanced science students believe in the dependence of learning on inborn characteristics, the less they will be motivated to learn biology**.

The third component of self-regulation, the use of learning strategies, was positively predicted by the belief that learning is dependent on struggle while it has was negatively predicted by the belief that learning is dependent on inborn characteristics. This result also showed that **the more that advanced science students believe that learning is dependent on struggle, the more they will use appropriate learning strategies to learn biology in advanced contexts**. On the other hand, **the more that advanced science students believe that learning is dependent on inborn characteristics, the less they will use appropriate learning strategies to learn biology**.

The results also explain the close similarity among self-regulated learning and its two components in explaining epistemological beliefs. The *learning depends on the amount of struggle exerted* and *learning depends on inborn characteristics, such as intelligence and ability* components of epistemological beliefs predicted self-regulation, motivation, and the use of learning strategies in similar direction. Moreover, the effect sizes of the analysis also indicate significant practical importance of the predictors on the dependent variables.

Implications

The results of the study have implications for teachers of students in advanced science courses. This study suggests that teachers might want to consider incorporating motivating factors for advanced science students in their curriculum and activities, given that advanced science students believe that learning biology is dependent on struggle. For example, teachers of these students could include activities that would increase students' self-regulated learning behavior and eventually their success in biology, because epistemological beliefs and self-regulated learning are two important predictors of a set of variables that are very important in teaching.

Again, the relationship between epistemological belief and self-regulated learning show a requirement of implication to change epistemological beliefs by using only one strategy to increase both motivation toward the learning of biology and the use of learning strategies to learn biology without applying two different strategies for motivation and learning strategies, respectively. Another implication of this study is that the results contribute to the literature of the models explaining the relationship between epistemological beliefs and self-regulated learning behavior by adding the results of a study of advanced or gifted science students at the level of high school. The results of the present study could also show the importance of teachers using epistemological change strategies such as reflective epistemic thinking (Southerland, Sinatra, & Matthews, 2001) and critical thinking based teaching (Valanides & Angeli, 2005) to increase motivation and the use of learning strategies in their curriculum for advanced science students by providing evidence of the epistemological roots of self-regulation for advanced biology students.

Suggestions

The results of the study are somewhat limited by the sample size of the study and the three grade levels, therefore, there is a need to expand the study size. Additionally, as the study method used a predictive approach and there was no attempt to provide a cause-effect relationship, the results should be carefully interpreted due to these limitations.

The study explained that epistemological beliefs are predictors of self-regulated learning and its two components (motivation and use of learning strategies), but there is a need to study other contributors (age, gender, grade etc.) to the development of epistemological beliefs of advanced science students before they enroll in advanced biology classes.

As another suggestion, because this study's result is limited to advanced science, specifically, biology students, it would be important to extend this study to other contexts, such as chemistry and physics. This would help to clarify whether the predictive power of the two components of the epistemological beliefs are specific to the learning of biology learning or can be extrapolated to other fields of scientific study.

References

Barnard, L., Lan, W. Y., Crooks, S. M., & Patton, V. O. (2008). The relationship between epistemological beliefs and self-regulated learning skills in the online course environment. *MERLOT Journal of Online Learning and Teaching*, *4*(3), 261-266.

Baxter Magolda, M. (1992). *Knowing and reasoning in college: Gender-related patterns in students' intellectual development*. San Francisco, CA: Jossey-Bass.

Belenky, M., Clinchy, B. M., Goldberger, N. R., & Tarule, J. (1986). *Women's ways of knowing: The development of self, mind, and voice*. New York, NY: Basic Books.

Belet, Ş. D. & Güven, M. (2011). Metacognitive strategy usage and epistemologicalbeliefs of primary school teacher

trainees, *Educational Sciences: Theory & Practice, 11*(1), 51–57.

Büyüköztürk, S., Akgün, O. E., Demirel, F., & Özkahveci, O. (2004). The validity and reliability study of the Turkish version of the motivated strategies for learning questionnaire. *Educational Sciences: Theory & Practice, 4*(2), 207-239.

Chen, C. S. (2002) Self-regulated learning strategies and achievement in an introduction to information systems course. *Information Technology, Learning and Performance Journal, 20*(1), 11-25.

Dahl, T. I., Bals, M. & Turi, A. L. (2005). Are students' beliefs about knowledge and learning associated with their reported use of learning strategies? *British Journal of Educational Psychology, 75*, 257–273.

Deryakulu, D., & Büyüköztürk, S. (2002). Validity and reliability study of epistemological beliefs questionnaire. *Eurasian Journal of Educational Research, 8,* 111–125

Deryakulu, D., & Büyüköztürk, S. (2005). The re-examination of the epistemological beliefs' questionnaires' factor structure: Comparing epistemological beliefs in terms of gender and program type. *Eurasian Journal of Educational Research, 18,* 57-70.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67,* 88-140.

Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. *Educational Psychology Review, 13*(4), 353.383

Hofer, B. K. (2002). Personal epistemology as a psychological and educational construct: An introduction. In B. Hofer & P. Pintrich, (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 3-15). Mahwah, NJ: Erlbaum.

Kaya, E., & Gürbüz, H. (2002). Lise ve meslek lisesi öğrencilerinin biyoloji öğretiminin sorunlarina ilişkin görüşleri (In English "Views of common and vocational high school students about problems of biology teaching"). *Erzincan Education Faculty Journal*, *4*(2), 11-21.

King, P. M., & Kitchener, K. S. (1994). *Developing reflective judgment*. 1st Ed., San Francisco, CA: Jossey-Bass.

Koksal, M. S. (2009). Vocational high school students' sense of self-efficacy and test anxiety regarding biology learning. *Inonu University Journal of the Faculty of Education*. *10*(1), 57-67.

Köksal, M. S. & Sormunen, K. (2009). *Advanced science students' understanding on nature of science in Turkey*. ESERA 2009 Conference, 31 August-4 September, Grand Cehavir Hotel and Conference Center, Istanbul, Turkey.

Köksal, M. S., (2011). Epistemological predictors of self efficacy on learning biology and test anxiety related to evaluation of learning on biology for preservice elementary teachers. *Journal of Science Teacher Education 22*(7), 661–677.

Liang, J. C., Lee, M. H., Tsai, C. C., (2010). The relations between scientific epistemological beliefs and approaches to learning science among science-major undergraduates in Taiwan. *The Asia Pacific Education Researcher, 19*(1), 43–59.

Lin, T., Deng, F., Chai, C. S., & Tsai, C. (in press). High school students' scientific epistemological beliefs, motivation in learning science, and their relationships: A comparative study within the Chinese culture. *International Journal of Educational Development, 33*, 37–47.

Liu, S., & Lederman, N. (2002). Taiwanese gifted students' views of nature of science. *School Science and Mathematics*, *102*(3), 114-123.

Lodewyk, K. R. (2007). Relations among epistemological beliefs, academic achievement and test performance in secondary school students. *Educational Psychology, 27,* 307-327.

Muis, K. R., Bendixen, L. D., & Haerle, F. (2006). Domain-generality and domain-specificity in personal epistemology research: Philosophical and empirical reflections in the development of a theoretical framework. *Educational Psychology Review, 18*, 3-54.

Muis, K. R. (2007). The role of epistemic beliefs in self-regulated learning. *Educational Psychologist*, *42*(3),173-190.

Neber, H., & Schommer-Aikins, M. (2002). Self-regulated science learning with highly gifted students: The role of cognitive, motivational, epistemological, and environmental variables. *High Ability Studies, 13*, 59–74.

Nunnally, J. C. (1978). *Psychometric Theory*, New York, NY: McGraw-Hill.

Özaslan, H., Yıldız, N. & Çetin,Y. (2009, March). *Üstün Yetenekli Öğrencilerin Yetenekleri Dışındaki Mesleklere Yönelme Nedenleri ve Sakıncaları*. (In English "Reasons for Tendency of Gifted Students' Choice of Occupations That are not related to Their Ability and Its Potential Problems) Üstün Yetenekli Çocuklar II. Ulusal Kongresi (Second National Congress on Gifted Students), Anadolu University, Eskişehir, Turkey.

Park, S., & Oliver, J. S. (2009). The transition of teachers' understanding of gifted students into instructional strategies for teaching science. *Journal of Science Teacher Education, 20*(4), 333-351.

Paulsen, M. B., & Feldman, K. A. (1999). Student motivation and epistemological beliefs. *New Directions for Teaching and Learning, 78,* 77-80.

Paulsen, M. B., & Feldman, K. A. (2007). The conditional and interaction effects of epistemological beliefs on the self-regulated learning of college students: Cognitive and behavioral strategies. *Research in Higher Education, 48,* 353-401.

Phan, H. P. (2008). Multiple regression analysis of epistemological beliefs, learning approaches and self-regulated learning. *Electronic Journal of Research in Educational Psychology, 6,* 157-184.

Pintrich, P. R. (1990). Implications of psychological research on student learning and college teaching for teacher education. In W.R. Housten (Ed.), *Handbook of research on teacher education* (pp. 826-857). New York, NY: Macmillan.

Pintrich, P. R. (2005). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 451-502). Burlington, MA: Elseiver Academic Press.

Pintrich, P. R., & De Groot, E. V. (1990). Motivation and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*(1), 33-40.

Schommer-Aikins, M. (2002). An evolving theoretical framework for an epistemological belief system. In B. Hofer & P. Pintrich (Eds.), *Personal epistemology: The psychology of belief about knowledge and knowing*, (pp. 103-118). Hillsdale, NJ: Lawrence Erlbaum.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*(3), 498-504.

Schommer, M. (1993) Epistemological development and academic performance among secondary students. *Journal of Educational psychology, 85*(3), 406-411.

Schommer, M. (1994). Synthesizing epistemological belief research: Tentative understandings and provocative confusions. *Educational Psychology Review, 6*(4), 293-319.

Schommer, M., & Dunnell, P. A. (1994). A comparison of epistemological beliefs between gifted and non-gifted high school students. *Roeper Review*, *16*(3), 207-210.

Schreiber J. B., & Shinn, D. (2003). Epistemological beliefs of community college students and their learning processes. *Community College Journal of Research and Practice 27*(8), 699-709.

Schunk, D. H. (2000) *Learning theories: An educational perspective*. New Jersey: Prentice-Hall, Inc.

Southerland, S. A., Sinatra, G. M. & Matthews, M. R. (2001). Belief, knowledge, and science education, *Educational Psychology Review, 13*(4), 325–351.

Sungur, S. (2004). *An implementation of problem based learning in high school biology courses*. Unpublished Dissertation. Middle East Technical University. Ankara.

Tsai, C. C., Ho, H. N., Liang, J. C., Lin, H. M., (2011). Scientific epistemic beliefs, conceptions of learning science and self-efficacy of learning science among high school students. *Learning and Instruction 21*(6), 757–769.

Topcu, M. S., & Yılmaz-Tüzün, O. (2008) Relationships among preservice science teachers' epistemological beliefs, epistemological world views, and self-efficacy beliefs *International Journal of Science Education, 30*(1), 65-85.

Wolters, C. A., & Pintrich, P. R. (1998). Contextual differences in student motivation and self-regulated learning in mathematics, English, and social studies classrooms. *Instructional Science, 26*, 27-47.

Valanides, N., & Angeli, C. (2005). Effects of instruction on changes in epistemological beliefs. *Contemporary Educational Psychology*, *30*, 314-330.

Mustafa Serdar KÖKSAL, Ph.D., is an Assistant Professor Doctor in the Department of Science Education, Inonu University.

Correspondence concerning this article should be addressed to Dr. Mustafa Serdar KÖKSAL, Inonu University, Faculty of Education, Department of Science Education, 44280, Campus/Malatya. E-mail: bioeducator@gmail.com

Suleyman YAMAN, Ph.D., is an Associate Professor Doctor in the Department of Science Education, Bulent Ecevit University.