Online Science Education Journal http://dergipark.gov.tr/ofed

2023; 8(2): 22 - 30.

Investigating Girl and Boy High School Students' Epistemological Beliefs in Biology and Physics

Muhammet Mustafa Alpaslan*, *Muğla Sıtkı Koçman University, Faculty of Education, Turkey*

*Corresponding Author: mustafaalpaslan@mu.edu.tr

To cite this article: Alpaslan, M. M. (2023). Investigating girl and boy high school students' epistemological beliefs in biology and physics. *Online Science Education Journal, 8*(2), 22-30.

Article Info

Article History

Received:
31 May 2023

Accepted:
11 October 2023

Keywords

Biology education
Epistemological beliefs
Gender
Physics education

Abstract

Epistemological beliefs are associated with students' motivation, learning strategies, career choices, and academic achievement. The study aimed at examining the epistemological beliefs of high school students in physics and biology. A total of 503 high school students studying at five schools in the Aegean Region in Turkiye participated in the study. The 5-point Likert-type Epistemological Beliefs Scale and the previous semester's grade were used as data sources in physics and biology. Repeated ANOVAs were used to address the research questions. ANOVA results showed that the students had higher scores than the biology course against the physics course in the sub-dimension of the source of knowledge, the certainty of knowledge and the justification of knowledge. The results of this study are important in terms of teaching physics and biology lessons and reveal that students' ideas about scientific knowledge for different course branches are different, and this difference exists in the early years of high school.

INTRODUCTION

Epistemological beliefs refer to an individual's ideas about knowing and knowledge (Hofer & Pintrich, 1997). Research on epistemological beliefs has suggested that students' ideas about knowledge and knowing are domain-specific (Muis et al., 2006). Studies concerning the domain-specificity of epistemological beliefs were mostly interested in students' ideas in hard versus soft science domains (e.g., mathematics vs history; Buehl, & Alexander, 2006). Few studies have examined the discipline-specificity of epistemological beliefs and reported that students' epistemological beliefs might differ across scientific disciplines (e.g., biology vs physics; Topcu, 2013). However, studies addressing the discipline-specificity of epistemological beliefs focused on university-level students (e.g., Topcu, 2013), or a few dimensions of epistemological beliefs (e.g., Tsai, 2006). Therefore, a need emerges to determine the discipline- specificity of epistemological beliefs in high school students, who just started taking such specialized science courses like physics and biology (Muis et al., 2006). In addition, research reported that students' epistemological beliefs influence their motivation, career choice, learning strategies, achievement and interest (e.g., Lee et al., 2021; Trautwein & Lüdtke, 2007). Therefore, it is helpful to examine girls' epistemological beliefs in physics and biology, and that different dimensions of epistemological beliefs contribute to their achievement in physics and biology.

Theoretical Framework

Perry (1970) conducted the first studies on epistemological beliefs in university students. Perry (1970) sought answers to the questions of how university students know, what their ideas about knowing are, and what role thinking and logical inferences play in knowing. Since Perry's (1970) work, many different theoretical models have been hypothesized. These theories can be categorized into three groups as developmental views (e.g., King & Kitchener, 1994; Perry, 1970), multi-dimensional views (e.g., Hofer & Pintrich, 1997) and epistemic resource views (Hammer & Elby, 2002). The developmental views define epistemological beliefs as a developmental cognitive element and argue that a person's epistemological view is more likely to develop from a naive level to a sophisticated level with education and age. Models that describe epistemological beliefs in multiple dimensions have emerged because developmental models that examine epistemological beliefs in one dimension would not be sufficient to examine the complex nature of epistemological beliefs. The epistemic resource view argues that since knowledge is a socio-contextual product, an individual's ideas about knowledge may change according to the social context, and therefore, research on epistemological beliefs should investigate the individual's contextual variables.

One of the important theories on epistemological beliefs was theorized by Hofer and Pintrich (1997). They describe epistemological beliefs in four identifiable dimensions, which are based on the nature of knowledge or the nature of knowing. The two dimensions are about the nature of knowledge as the certainty of knowledge and the development of knowledge. The certainty of knowledge deals with the perceived stability and the strength of supporting evidence whereas the development of knowledge is about the relative connectedness of knowledge. The other two dimensions deal with the process of knowing as the justification of knowledge and the source of knowledge. The justification of knowledge describes how individuals proceed to evaluate and warrant knowledge claims while the source of knowledge is either that knowledge exists in an external source or is constructed by learners. Hofer and Pintich (1997) claimed that epistemological beliefs are influenced by the nature of the domain and students' learning experiences in that domain.

Studies have shown that epistemological beliefs play a direct and important role in learning. It was found that epistemological beliefs were associated with motivation, self-regulation and academic achievement (Alpaslan, 2019; Ata & Alpaslan, 2019; Wang et al., 2022). For instance, Wu and Tsai (2011) sought deeper insight into learners' informal reasoning on a socio-scientific issue (SSI) and explored the relationship between students' epistemological beliefs (cognitive structures as well) and informal reasoning. Participants were 68 (22 female) 10th grade students. Both questionnaire-based and tape-recorded interview data were used. Self-reported questionnaire (26 items in 4 scales) developed by Conley et al. (2004) was used to determine students' epistemological beliefs. Students, in general, showed relatively sophisticated epistemological beliefs and scored highest on the simplicity of knowledge scale. The correlation between epistemic beliefs and informal reasoning was 0.27 on developmental and 0.33 on justification scales ($p < .05$). The result revealed that students' views on knowledge and knowing tended to influence their scientific reasoning.

In a recent meta-analytic study, Greene et al. (2018) reviewed the relations of epistemological beliefs with academic achievement. From 132 non-experimental studies, they found that epistemological beliefs are statistically related to academic achievement. The effect size was small but positive ($r=.16$, $p < .05$), indicating that the more sophisticated view will yield a higher achievement score. In another study, Guo et al. (2022) investigated the relations of epistemological beliefs with motivation, achievement and aspiration in science from PISA 2015 data. They investigated the relationship data of 514.119 students from 72 countries and found that beliefs on the justification of knowledge and certainty of knowledge were positively related to self-efficacy, intrinsic value and utility value. Evidence from these studies underscores that students' epistemological beliefs play important direct or indirect roles in their learning.

Epistemological beliefs and Their Discipline Specificity

Recently, many researchers have claimed that students' epistemological beliefs may be different across disciplines (Muis et al., 2006). For example, Hofer (2000) found that students viewed knowledge in science to be more certain than knowledge in psychology. In science education, few studies examined students' epistemological beliefs in different disciplines of science. Tsai (2006), for example, examined students' ideas about the certainty of knowledge in biology and physics with 428 high school students. Tsai (2006) reported that the students considered biological knowledge more tentative than physical knowledge. Tsai concluded that exposure to specific knowledge might lead students to develop different epistemological beliefs.

In another study, Topcu (2013) examined Turkish pre-service teachers' epistemological beliefs in chemistry, biology and physics disciplines. Topcu (2013) reported that students had different epistemological beliefs across all disciplines, stating that students viewed knowledge in biology and chemistry as more tentative in physics. The students tended to view physics as authority-dependent while biology was more dependent on personal evaluation. Topcu (2013) suggested there was a need for studies with different contexts and younger students.

Gender in Physics and Biology

Issues with female participation in science education have been well-documented over many years and are still persistent and pervasive today (Hite, 2021). Although the number of female students in higher education has been increasing, such a change does not apply to all academic fields (Yazilitas et al., 2013). Research reported that girls would favor biology and geography while boys would favor hard science subjects such as physics and chemistry (e.g., Warrington & Younger, 2000). In Turkiye, the situation is not different. According to the Council of Turkish Higher Education (CTHE, 2015) report, more girls than boys enrolled in biology major in the 2014-2015 academic year in Turkish universities (2702 out of 4072). In addition, according to the same report, as a major of study, more girls chose biology than those who chose physics (2702 vs 365). Tsai (2006) examined gender differences in biology and physics in terms of tentativeness of knowledge. Tsai (2006) that reported girls and boys viewed biological knowledge as more tentative than physical knowledge. Thus, it is important to examine gender-related differences in physics and biology to promote female students' physical-related careers.

When students enter high school, they are more likely to be exposed to a division change in specific academic disciplines; like science as physics, and biology. Students at the high school level then start developing more specific beliefs across disciplines; ideas about physical knowledge versus biological knowledge (Muis et al., 2006). The purpose of this study was to determine if epistemological beliefs differ in physics and biology for girls and boys. For this purpose, the following research questions were sought to address:

1. Do students' epistemological beliefs differ in physics and biology?
2. Do male and female students differ in their epistemological beliefs in physics and biology?
3. Do epistemological beliefs predict male and female students' achievement in physics and biology?

METHOD

Research Design

A correlational research model was utilized to address research questions. Correlational studies are used to examine the relations amongst two or more variables and to test the cause-effect relationships between them (Fraenkel & Wallen, 2006). Because the correlational research model requires quantitative data, self-report questionnaires were used to collect data for the study.

Data Collection and Sample

In this study, convenience sampling was used (Creswell, 2007). Because of convenience to the researcher, five public high schools located in a city in Southwestern Turkiye were chosen. A total of 503 (246 girls and 257 boys) 9^{th} and 10^{th} grade students had their parental forms signed and volunteered to participate in the study. The students in the schools were moderate achievers and socio-economically diverse. Data were collected in March 2019 and in regular class hours of students under the supervision of their teacher in one class hour.

Instrument

Epistemic Beliefs Questionnaire

In this study, the Epistemic Beliefs Questionnaire (EBQ; Conley et al., 2004) was employed to map students' epistemological beliefs in physics and biology. The EBQ can be adaptable to physics and biology and has been validated in Turkiye. EBQ, a self-report instrument in a 5-point Likert, comprises 26 items to measure the students' views about scientific knowledge in the four dimensions defined by Hofer and Pintrich (1997). The Turkish version of the questionnaire was used in some recent studies in Turkiye (Alpaslan et al., 2016). Since the purpose of the study was to identify students' epistemological beliefs in physics and biology, the words "science" and "scientists" with 'physics" and "physicists" in the physics booklet and "biology" and "biologists" in the biology booklet were replaced. The EBQ comprised four dimensions including source of knowledge (5 items), certainty of knowledge (6 items), development of knowledge (6 items) and justification of knowledge (9 items). The items in the certainty of knowledge and the source of knowledge dimensions were reversed so that higher scores represented more sophisticated beliefs. As the EBQ was previously validated in Turkiye, a Confirmatory Factor Analysis (CFA) was run to verify its dimensionalities for physics (EBQ-P) and biology (EBQ-B) with AMOS 18. According to Hu and Bentler's (1999) criteria (moderate fit for CFI>.95 or RMSEA<.06, and good fit for CFI>.90 and RMSEA<.08), the results of CFA for EBQ-P were in a good model fit, χ^2 (293, N=503) = 897.28, p<.001, SRMR =.050, RMSEA =.056, CFI =.94. The results of CFA for EBQ-B were in a moderate model fit, χ^2 (293, N=503) = 939.45, p<.001, SRMR =.062, RMSEA =.067, CFI =.90. As for the reliability of the instrument, Cronbach's Alpha ranged from .69 to .81 for EBQ-F and from .71 to .82 for EBQ-B.

Achievement in Physics and Biology

In this study, it was decided to take students' physics and biology grades in the previous semester that the study took place as their achievement scores as achievement tests would take extra time of participants. The students' final grades ranged from 1 (failed) to 100 (excellent). Students were asked to write down their physics and biology grades in the previous semester. Although it raised a concern that students might exaggerate their scores, some studies showed that self-reported GPAs are highly correlated with actual GPAs (Crede & Kuncel, 2013).

Data Analysis

To address the research questions, a one-way repeated-measures analysis of variance (ANOVA) was used to identify possible discipline and gender differences in each of the two disciplines. In addition, multiple regressions were used to examine whether epistemological beliefs predicted students' achievement in physics and biology, and the degree to which each dimension of epistemological beliefs contributed to male and female students' achievement in physics and biology. Analyses were computed with SPSS 21.

RESULTS

Means and standard deviations were provided in Table 1. The highest mean value in physics and biology was in justification of knowledge whereas the lowest one was in certainty of knowledge. These results showed that students were more likely to believe that knowing physics and biology requires experimenting and evidence. Additionally, they were less likely viewed that knowledge in physics and biology would change. Girls had higher course grades in both physics and biology than did boys. The mean scores for physics and biology were all above the mid-point of the 5-point Likert-type scales (means were above the mid-point). One-way repeated ANOVA results revealed a statistically significant effect for science disciplines. Students reported more sophisticated beliefs on the source of knowledge (F (1, 502) = 29.610, *p*<.00005), the certainty of knowledge (F (1, 502) = 4.174, *p*=.041), and justification of knowledge (F (1, 502) = 19.729, *p*<.00005) in biology than physics. Within the disciplines, boys reported higher levels of sophistication in justification of knowledge in physics than did girls (F (1, 502) = 6.305, *p*=.012).

Table 1. Means and standard deviations for variables in the study by disciplines and gender

		All students		**Girls (n_1=246)**		**Boys(n_2=257)**	
		M	***SD***	***M***	***SD***	***M***	***SD***
Physics							
	Source	3.54	.79	3.48	.85	3.59	.72
	Certainty	3.12	.66	3.08	.62	3.17	.66
	Justification	3.86	.71	3.93	.65	3.78	.76
	Development	3.57	.62	3.56	.65	3.57	.59
	Grade	61.6	14.1	62.6	13.0	60.6	15.2
Biology							
	Source	3.32	.77	3.35	.79	3.28	.74
	Certainty	3.05	.69	3.04	.73	3.05	.64
	Justification	3.70	.76	3.72	.74	3.67	.79
	Development	3.53	.65	3.58	.67	3.49	.62
	Grade-B	64.9	13.9	68.4	12.3	61.2	14.6

Note. Means for all variables reflect the five-point Likert scale except Grade was in a 100-point scale.

Between the disciplines, one-way repeated ANOVA results revealed a statistically significant difference for girls and boys. Girls reported more sophisticated beliefs on the source of knowledge (F (1, 245) = 32.819, *p*<.01), the certainty of knowledge (F (1, 245) = 5.800, *p*=.017), and justification of knowledge (F (1, 245 = 18.170, *p*<.01) in biology than physics. Unlike girls, boys reported more sophisticated beliefs on the source of knowledge (F (1, 256) = 4.383, *p*=.037) and justification of knowledge (F (1, 256) = 4.241, *p*=.04) in biology than in physics.

Standardized regression coefficients for the prediction of science grades were provided in Table 2. Multiple regression results revealed that epistemological beliefs statistically significantly predicted course grade for physics (F (4, 498) = 9,572, $p < .0005$, $R^2 = .06$) and biology (F (4, 498) = 7,437, $p < .0001$, $R^2 = .05$). In physics, justification of knowledge (β=0.17) and development of knowledge (β=0.15) statistically significantly predicted physics grade. In biology, the source of knowledge (β=0.10), justification of knowledge (β=0.14) and development of knowledge (β=0.12) statistically significantly predicted biology grade.

For girls, multiple regression results revealed that epistemological beliefs statistically significantly predicted course grades for physics (F (4, 242) = 10,022, p < .0005, R^2 = .11) and biology (F (4, 242) = 9,569, p < .0001, R^2 = .11). For girls, in physics and biology, justification of knowledge (β=0.18 and β=0.28) and development of knowledge (β=0.20 and β=0.11) statistically significantly predicted physics and biology grades, respectively: yet, the others were not. For boys, multiple regression results revealed that epistemological beliefs statistically significantly predicted course grade for physics (F (4, 253) = 2,879, p = .024, R^2 = .05) and biology (F (4, 253) = 2,585, p = .04, R^2 = .04). For boys, in physics, only the source of knowledge (β=0.17) statistically significantly predicted physics grade, and in biology only development of knowledge (β=0.13) statistically significantly predicted biology grade.

Table 2. Standardized regression coefficients in the study by disciplines and gender

		All students		Girls (n_1=246)		Boys(n_2=257)	
		β	***t***	***β***	***t***	***β***	***t***
Physics							
	Source	.01	.07	.06	1.48	.17*	5.02
	Certainty	.05	1.29	.05	1.35	.06	1.38
	Justification	.17*	4.98	.18**	5.14	.04	1.10
	Development	.15*	3.77	.20**	6.48	.09	1.84
	R^2	.06**		.11**		.05**	
Biology							
	Source	.10*	2.03	.01	0.17	.04	1.11
	Certainty	.03	0.63	.08	1.77	.07	1.72
	Justification	.14**	3.45	.28**	4.02	.06	1.47
	Development	.12*	2.21	.11*	2.16	.13*	2.44
	R^2	.05**		.11**		.04*	

Note: *p <.05 and ** p <.01

DISCUSSION

The purpose of the study was to examine disciplinary and gender-related differences in high school students' epistemological beliefs in physics and biology. Self-report questionnaires were used to map ninth and tenth grade students' epistemological beliefs in physics and biology. Once the validity and reliability of the instrument were checked, more than one statistical technique were used to address the aforementioned research questions.

Descriptive results showed that students were at a moderate level of epistemological beliefs in physics and biology. Their mean score was higher in justification of knowledge in both disciplines, indicating that they were more likely to view experiments as a way to test ideas in physics and biology. This result is not surprising because previous studies have reported that aged 16 students tend to believe the experimented results more believable than theoretical results and the experimentation as a more convincing way to test ideas (Alpaslan et al., 2017; Driver et al., 1996). However, the mean scores implied that they were less likely to believe that scientific knowledge would not be changed in physics and biology. The reason for this might be that the scientific knowledge in ninth and tenth grade curricula covers more beginner level topics in biology and physics. These topics are more consistent with what students might observe or experience in daily life, which leads students to believe that they would be less likely to be changed. In addition, in middle school students took biology and physics courses under the same course as "science". For this reason, the dimensional variation in students' epistemological beliefs in middle schools would be the same across disciplines.

The previous studies reported that students might hold different epistemological beliefs across different disciplines (Muis et al., 2006; Topcu, 2013; Tsai, 2006). Consistent with the previous studies, this study provided evidence that students' epistemological beliefs varied between disciplines. More specifically, students reported viewing physical knowledge as more certain, authority-dependent rather than the learner, and less coming from reasoning and experimenting than biological knowledge. A plausible explanation for this can be the fact that the traditional physics instruction at schools relies on mostly teaching how to use formulas in physics problems (Meltzer, 2002). This sort of instruction would lead students to view that knowledge in physics requires mastering how to use formulas in physics problems (Redish & Steinberg, 1999). This view might have led the students to view physical knowledge as more certain and coming from authority.

The mean scores of both girls and boys were consistent with the descriptive results for all students. Both girls and boys had the highest mean scores in justification of knowledge while the lowest mean scores in the certainty of knowledge. This implies that gender did not affect the variation amongst the dimensions of epistemological beliefs. However, a comparison of girls' epistemological beliefs in biology and physics showed that they had more sophisticated beliefs on the source of knowledge, certainty of knowledge, and justification of knowledge in biology than in physics. These results indicated that girls believed that biological knowledge more likely came from the individual itself not from authority than physics knowledge. They also viewed biological knowledge more tentative than physics knowledge. Lastly, they viewed experimentation would be more important to test ideas in biology than physics. Similarly, boys viewed biological knowledge that came from the individual itself and experimentation as a way to test ideas more than they did in physics knowledge. These results were consistent with the previous findings and studies reported that girls and boys viewed biological knowledge more tentative, experiment-based reasoning, and internally constructed (Tsai, 2006).

Conclusion

Results of the study suggest that epistemological beliefs are multidimensional constructs that may vary across disciplines and gender. Furthermore, regardless of discipline and genders, a more sophisticated view is the predictor of a better academic achievement. This study extended the findings of previous studies regarding gender differences in science education that girls favored and often had better attitudes toward biological sciences than physical science. Regression results demonstrated that epistemological beliefs predicted students' academic achievement in physics and biology. For all students, justification of knowledge and development of knowledge significantly contributed to physics achievement. In biology, in addition to these two dimensions, the source of knowledge was a significant predictor of academic achievement. Justification of knowledge is related to the view that experimentation would be required to test ideas in science. Viewing experimentation as a way of knowing scientific knowledge might lead students to make meaningful learning and therefore, their performance in exams would be better. Similarly, the development of knowledge predicted students' academic achievement in both physics and biology. Development of knowledge refers to the connectedness of knowledge, which the more sophisticated view means knowledge as a system of related constructs, like meaning learning requires the connectedness of knowledge. Therefore, it is not surprising that higher achievers were those who view physics and biology knowledge are products of the related systems.

Recommendations

Science educators need to find ways to foster students more sophisticated views on the tentative and experiment-based reasoning nature of physical knowledge. Sin (2014) argues that traditional physics teaching strategies focus on the acquisition of certain knowledge and discuss how knowledge is constructed in physics. Therefore, it is important to integrate epistemological views with science content to foster epistemological understanding, (Kittleson, 2011). Fostering epistemological understanding can be done by giving argumentation or problem-based learning more space in educational practices. Thus, biology and physics teachers in Turkiye should be trained and encouraged to use innovative and student-centered instruction including argumentation in their classrooms.

Limitations

This study has some limitations. First, the ninth and tenth grade students were excluded were the study because in Turkiye after tenth grade students select areas of courses like social science and natural science and including students who selected the natural science might mislead the result. Therefore, there is a need for longitudinal studies that track and examine how students' epistemological beliefs would form during their high school years. Additionally, some studies reported that epistemological beliefs vary across high or low achiever schools (Acar, 2019; 2022). Students from five high schools were included in the study. There is a need for a more diverse and larger sample to determine the disciplinary differences in epistemological beliefs.

REFERENCES

Acar, Ö. (2019). Investigation of the science achievement models for low and high achieving schools and gender differences in Turkey. *Journal of Research in Science Teaching, 56*(5), 649-675. https://doi.org/10.1002/tea.21517

Acar, Ö. (2022). Modelling of the relationships between students' grade-level, epistemic beliefs, metacognition, and science achievement in low and high - achieving schools. *Educational Studies*, Advance online publication. https://doi.org/10.1080/03055698.2022.2122702

Alpaslan, M, M., Yalvac, B., Loving, C, C., & Willson, V. (2016). Exploring the relationship between high school students' physics-related personal epistemologies and self-regulated learning in Turkey. *International Journal of Mathematics and Science Education, 14(*2), 297-317. https://doi.org/10.1007/s10763-015-9685-7

Alpaslan, M. M., Yalvac, B. & Loving, C. C. (2017). High school physics students' personal epistemologies and school science practice. *Science & Education, 26* (7-9), 841-865. https://doi.org/10.1007/s11191-017-9930-2

Alpaslan, M. M. (2019). Examining relations between physics-related personal epistemology and motivation in terms of gender, *Journal of Educational Research,112(*3), 397-410. https://doi.org/10.1080/00220671.2018.1540966

Ata, R. & Alpaslan, M. M. (2019). Turkish adaptation of internet based epistemological beliefs scale and an investigation with pre-service teachers. *Mersin University Journal of the Faculty of Education, 15*(3), 893-908. https://doi.org/10.17860/mersinefd.516351

Buehl, M. M., & Alexander, P. A. (2006). Examining the dual nature of epistemological beliefs. *International Journal of Educational Research, 45*, 28–42. https://doi.org/10.1016/j.ijer.2006.08.007

CTHE (2015). Number of undergraduate students according to classification of fields of education and training. Retrieved from https://istatistik.yok.gov.tr/yuksekogretimIstatistikleri/2015/2015_T17.pdf

Conley, A. M., Pintrich, P. R., Wekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational Psychology*, *29*, 186-204. https://doi.org/10.1016/j.cedpsych.2004.01.004

Credé, M., & Kuncel, N. R. (2013). Self-reported grades and GPA. In J. Hattie & E. M. Anderman (Eds.), *International guide to student achievement* (pp. 49–50). Routledge.

Creswell, J.W. (2007). *Qualitative inquiry and research design: Choosing among five approaches.* Sage.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Open University Press.

Fraenkel, J. R., & Wallen, N. E. (2006). *How to design and evaluate research in education.* McGraw-Hill.

Guo, J., Hu, X., Marsh, H. W., & Pekrun, R. (2022). Relations of epistemic beliefs with motivation, achievement, and aspirations in science: Generalizability across 72 societies. *Journal of Educational Psychology, 114*(4), 734–751. https://doi.org/10.1037/edu0000660

Greene, J. A., Cartiff, B. M., & Duke, R. F. (2018). A meta-analytic review of the relationship between epistemic cognition and academic achievement. *Journal of Educational Psychology*, *110*(8), 1084. https://doi.org/10.1037/edu0000263

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 169–190). Mahwah: Lawrence Erlbaum.

Hite, R. (2021). Differences and similarities in scientists' images among popular USA middle grades science textbooks. *European Journal of Mathematics and Science Education, 2(2), 63-83.* https://doi.org/10.12973/ejmse.2.2.63

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology, 25, 378-405.* https://doi.org/10.1006/ceps.1999.1026

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(1), 88–140.* https://doi.org/10.3102/00346543067001088

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

King P. M., & Kitchener K. S. (1994). *Developing reflective judgment.* Jossey-Bass

Kittleson, J. M. (2011). Epistemological beliefs of third-grade students in an investigation rich classroom. *Science Education, 95*(6), 1026-1048. https://doi.org/10.1002/sce.20457

Lee, S. W. Y., Luan, H., Lee, M. H., Chang, H. Y., Liang, J. C., Lee, Y. H., ... & Tsai, C. C. (2021). Measuring epistemologies in science learning and teaching: A systematic review of the literature. *Science Education, 105*(5), 880-907. https://doi.org/10.1002/sce.21663

Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible ''hidden variable'' in diagnostic pretest scores. *American Journal of Physics, 70,* 1259-1268. https://doi.org/10.1119/1.1514215

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. https://doi.org/10.1007/s10648-006-9003-6

Ozkan, S. & Tekkaya, C (2011). How epistemological beliefs differ by gender and socio-economic status? *Hacettepe Universitesi Egitim Fakultesi Dergisi, 41, 339-348.* http://www.efdergi.hacettepe.edu.tr/shw_artcl-704.html

Perry W. G. (1970). *Forms of intellectual and ethical development in the college years.* Holt, Rinehart and Winston.

Redish, E. F., & Steinberg, R. N. (1999). Teaching physics: Figuring out what works. *Physics Today, 52*(1), 24-30. https://doi.org/10.1063/1.882568

Sin, C. (2014). Epistemology, sociology, and learning and teaching in physics. *Science Education, 98, 342-365.* https://doi.org/10.1002/sce.21100

Topçu, M. S. (2013). Preservice teachers' epistemological beliefs in physics, chemistry, and biology: A mixed study. *International Journal of Science and Mathematics Education*, *11*(2), 433-458. https://doi.org/10.1007/s10763-012-9345-0

Trautwein, U. & Lüdtke, O. (2007). Epistemological beliefs, school achievement, and college major: a large-scale longitudinal study on the impact of certainty beliefs. *Contemporary Educational Psychology, 32,* 348-366. https://doi.org/10.1016/j.cedpsych.2005.11.003

Tsai, C.C. (2006). Biological knowledge is more tentative than physics knowledge: Taiwan high school adolescents' views about the nature of biology and physics. *Adolescence, 41, 691-703.* https://pubmed.ncbi.nlm.nih.gov/17240775/

Wang, H. H., Hong, Z. R., She, H. C., Smith, T. J., Fielding, J., & Lin, H. S. (2022). The role of structured inquiry, open inquiry, and epistemological beliefs in developing secondary students' scientific and mathematical literacies. *International Journal of STEM Education*, *9*(1), 1-17. https://doi.org/10.1186/s40594-022-00329-z

Warrington, M., & Younger, M. (2000). The other side of the gender gap. *Gender and Education, 12,* 493-508. https://doi.org/10.1080/09540250020004126

Wu, Y. T., & Tsai, C. C. (2011). High school students' informal reasoning regarding a socio-scientific issue, with relation to scientific epistemological beliefs and cognitive structures. *International Journal of Science Education, 33,* 371-400. https://doi.org/10.1080/09500690903505661

Yazilitas, D., Svensson, J., Vries, G., & Saharso, S. (2013). Gendered study choice: a literature review. A review of theory and research into the unequal representation of male and female students in mathematics, science, and technology. *Educational Research and Evaluation: An International Journal on Theory and Practice, 19,* 525-545. https://doi.org/10.1080/13803611.2013.803931