

Investigating gender and achievement level differences in epistemological beliefs in physics

Derya Kaltakci-Gurel 

Department of Mathematics and Science Education, Kocaeli University, 41001, Kocaeli, Türkiye



(Received 30 July 2024; accepted 25 June 2025; published 24 July 2025)

This research investigated how freshman students' epistemological beliefs in physics are impacted by gender and academic performance in a general physics course. Data were collected from 1220 university freshman students from 22 different programs in Türkiye. In this causal-comparative research, the well-known Colorado Learning Attitudes about Science Survey (CLASS) was used to assess students' beliefs about physics and learning physics. A Turkish version of the CLASS, consisting of 20 items measuring problem-solving effort, conceptual understanding, and personal interest and real-world connection, was employed. Additionally, demographic data such as gender, cumulative grade point average (CGPA), and previous academic performance in the General Physics I Course were collected. Cronbach's alpha coefficient for the reliability analysis of the whole scale was calculated as 0.844. The two-way between-groups multivariate analysis of covariance (two-way MANCOVA) test was used to answer the research question. The results indicated that gender and achievement level in the general physics course independently had significant effects on students' scores on three CLASS survey subscales when their CGPAs were controlled. An inspection of the mean scores indicated that males showed higher scores in the three CLASS subscale scores than females. Additionally, high-achieving groups were found to have higher scores in the three subscale scores than medium-achieving and low-achieving groups. The results were discussed and suggested how the results could be applied to improve physics education.

DOI: [10.1103/nlgw-p1zj](https://doi.org/10.1103/nlgw-p1zj)

I. INTRODUCTION

Employing research on students' physics learning difficulties, physics education research (PER) designs targeted pedagogical methods and tools to optimize knowledge acquisition. Beyond mathematical challenges, previous research suggests epistemological barriers may hinder students from connecting physics concepts to their everyday experiences [1–4]. Students often bring preexisting epistemological beliefs that differ from experts' views, except in some basic understandings [5–7]. Understanding students' experiences and beliefs in physics education is crucial for optimizing curriculum design and pedagogy.

Studies in PER often examine epistemological beliefs about physics learning alongside students' perspectives, expectations, and views. However, it is important to note that these terms emerged as a significant factor called epistemological beliefs. Epistemological beliefs, encompassing students' views on the nature of physics knowledge and its acquisition, have emerged as a significant factor

influencing academic achievement [2,8–11]. Previous studies suggest that students holding more sophisticated epistemological beliefs, where knowledge is seen as dynamic and open to revision, tend to exhibit higher academic performance [12–15]. This might be because such beliefs encourage students to be more persistent in facing difficulties, engage in deeper understanding, and actively seek evidence to support their learning. Epistemological beliefs about physics have been considered to play a critical and direct role in students' learning [8,11,13,16]. These beliefs, along with attitudes and expectations toward physics, are reported to influence student motivation [17], learning strategies [18], and comprehension of physics concepts [11,19,20].

Assessing students' epistemological beliefs about physics learning is not simple, and it presents significant challenges [21,22]. Several surveys have been developed to delve into students' beliefs in physics learning, including MPEX, EBAPS, VASS, and CLASS. Among them, the Colorado Learning Attitudes about Science Survey (CLASS) [23] is one of the widely used surveys in physics to explore students' epistemological beliefs about physics and learning physics. Since its first development in 2006, the CLASS has become a valuable tool for researchers to investigate specific belief dimensions. Research employing the CLASS survey has demonstrated positive correlations between these dimensions and academic achievement in

Published by the American Physical Society under the terms of the Creative Commons Attribution 4.0 International license. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

physics [24]. The CLASS instrument offers a comprehensive framework for assessing various dimensions of student attitudes [23]. This multifaceted approach allows researchers to delve deeper into student thinking and identify potential areas for improvement in physics instruction. Researchers have employed the CLASS instrument for a variety of purposes since its creation [10,21,24–28]. These applications encompass investigations into (a) the differentiation of expert and novice belief structures, (b) the temporal evolution of attitudes (e.g., semester-long shifts), (c) the influence of variables such as gender, nationality, major, and instructional methods on attitudes and beliefs, and (d) the potential relationships between attitudes and academic achievement.

Many studies have attempted to investigate the relationship between beliefs or attitudes about physics and student achievement [6,29,30]. Several different patterns have emerged in various studies. A detailed review of the literature revealed that two factors that consistently warrant exploration in physics education research in student attitudes toward physics are gender and academic achievement [6,8,11,14,21,23,31–33]. Prior studies suggest potential differences in physics self-efficacy and epistemological beliefs between male and female students, such that female students may exhibit lower confidence in their ability to learn and perform in physics and hold different beliefs about the nature of scientific knowledge compared to their male counterparts [31–33]. This can lead to decreased motivation and engagement of females in physics learning. This highlights the importance of investigating gender-based variations in student beliefs to inform inclusive pedagogical strategies. A prior study by Adams *et al.* [23] identified significant gender differences in student responses to the CLASS survey. Kost *et al.* [24] examined the gap in performance between males and females and found that the gender differences are primarily associated with differences in previous physics knowledge and incoming attitudes and beliefs.

Additionally, research employing the CLASS survey has demonstrated positive correlations between the dimensions of the CLASS survey and academic achievement in physics [24]. Strong epistemological beliefs in physics are expected to lead to increased effort, improved problem-solving skills, and ultimately higher academic performance. Therefore, understanding students' beliefs in physics and cultivating them is crucial for optimizing curriculum and pedagogy. Understanding how epistemological beliefs vary by gender and achievement level can inform the design of physics instruction that better supports student engagement, persistence, and academic success—particularly through inclusive teaching strategies, real-world contextualization, and meta-cognitive scaffolding. To sum up, this study examined the epistemological beliefs of first-year university students in Türkiye. The significant contribution of this study lies in its being the first large-scale investigation into the combined

effects of gender and achievement on epistemological beliefs in physics among Turkish university students using the CLASS survey.

II. THEORETICAL FRAMEWORK AND RELATED LITERATURE

A. Epistemological beliefs in physics education

Epistemological beliefs are one's personal understanding of knowledge, knowing, and learning [21,23,34–36]. These beliefs are antecedents of students' attitudes and subjective norms. Epistemological beliefs are foundational in understanding how learners approach and internalize scientific knowledge. When focused on physics, these beliefs about how physics knowledge is developed and applied impact both a student's decision to engage with physics learning and their learning experience within a physics course. Research suggests that students' epistemological beliefs about the nature of physics influence how they approach and interpret physics course activities and assignments. Therefore, it is reasonable to expect these beliefs to also shape their understanding of the overall goals of a physics course and their views on learning science more broadly [13,26,37].

In physics education, epistemological beliefs are particularly relevant due to the abstract and evidence-driven nature of the discipline. Hammer [13] emphasized that students with sophisticated epistemic beliefs are more likely to embrace challenges, seek conceptual understanding, and connect physics principles to real-world phenomena. Similarly, Perkins *et al.* [38] highlighted the interplay between epistemic cognition and active learning, noting that students with advanced beliefs exhibit higher persistence and problem-solving skills. Fostering sophisticated epistemic cognition requires instructional practices that emphasize inquiry, evidence-based reasoning, and conceptual connections [8,20]. Recent research has also highlighted the role of sociocultural factors in shaping epistemological beliefs, underscoring the need for culturally adaptive approaches to support diverse learners [21].

To date, extensive research has explored students' epistemological beliefs regarding physics learning. Studies indicate that these beliefs are influenced by factors such as educational background, instructional methods, gender, and socioeconomic status [23,25,26,30,39–42].

B. Instruments measuring epistemological beliefs and the CLASS survey

Despite substantial research on epistemological beliefs in science and physics, assessing these beliefs in the context of physics learning remains complex [21]. To address this challenge, various instruments have been developed to assess students' views on the nature of physics as a scientific discipline and how it is learned [23,43,44]. Table I provides a summary of these studies, along with

TABLE I. Instruments measuring epistemological beliefs in physics.

Instruments	Subscales/dimensions	Scale properties	Reference(s)
Views About Science Survey (VASS)	Scientific dimensions -Structure -Methodology -Validity Cognitive dimensions -Learnability -Reflective thinking -Personal relevance	Five-point Likert scale 31 items	[43]
Maryland Physics Expectations (MPEX)	-Independence -Coherence -Concepts -Reality link -Math link -Effort	Five-point Likert scale 34 items	[44]
Maryland Physics Expectations (MPEX)-II	-Coherence (math, reality, other) -Concepts -Independence (epistemology, personal)	Five-point Likert scale Multiple choice items Debate items 32 items	[47]
Epistemological Beliefs Assessment for Physical Science (EBAPS)	-Structure of knowledge -Nature of knowing and learning -Real-life applicability -Evolving knowledge -Source of ability to learn	Five-point Likert scale Multiple choice items Debate items 30 items	[12,48]
Colorado Learning Attitudes about Science Survey (CLASS)	-Real world connections -Personal interest -Sense making/effort -Conceptual connections -Applied conceptual understanding -Problem-solving general -Problem-solving confidence -Problem-solving sophistication	Five-point Likert scale 42 items	[23]
Greek Epistemological Beliefs Evaluation instrument for physics (GEBEP)	-Structure of knowledge -Stability of knowledge -Source of knowing -Justification of knowing	Five-point Likert scale Debate items 25 items	[49]
Colorado Learning Attitudes about Science Survey for Experimental Physics (E-CLASS)	-Affect -Confidence -Math-physics-data connection -Physics community -Statistical uncertainty -Troubleshooting -Argumentation -Experimental design -Modeling the measurement system -Purpose of labs -Systematic error	Five-point Likert scale 60 items (in pre-test) and 106 items (in post-test)	[50]
Physics Related Personal Epistemology Questionnaire (PPEQ)	-Structure of knowledge -Justification of knowledge and knowing -Changeability of knowledge -Equations in physics -Quick learning -Source of knowledge	Five-point Likert scale 27 items	[46]

the well-known instruments used to assess epistemological beliefs in physics. However, this list is not exhaustive. A more detailed and descriptive list of instruments for assessing student beliefs and attitudes can be found on PhysPort [45] and in the study of Özmen and Özdemir [46].

Among these instruments, the Colorado Learning Attitudes about Science Survey (CLASS) [23] is a widely recognized instrument for assessing students' epistemological beliefs and attitudes toward physics [21,25,26,30,51]. The 42 Likert-scale items in the CLASS build on earlier instruments like MPEX, EBAPS, and VASS, but offer a more nuanced framework by capturing eight dimensions of epistemological beliefs, namely: real-world connections, personal interest, sense making and effort, conceptual connections, applied conceptual understanding, problem-solving general, problem-solving confidence, and problem-solving sophistication.

The CLASS has been extensively validated across various cultural and academic contexts [22,51–53]. For example, Douglas *et al.* [51] demonstrated its validity in diverse educational settings in the United States, while Kontro and Buschhütter [52] validated the survey with a Finnish population. The Turkish adaptation of the CLASS by Kaltakci-Gurel [22] further underscores its utility in non-Western contexts. The exploratory factor analysis of the CLASS data from the Turkish sample identified three factors—problem-solving effort (PSE), conceptual understanding (CU), and personal interest and real-world connection (PI&RWC)—comprising 20 items. The confirmatory factor analysis confirmed that this three-factor structure provided a good fit to the data from the Turkish sample.

The CLASS survey has also been used to investigate several purposes, such as belief change across grades, gender differences in beliefs, and the effects of instructional methods or educational background on beliefs [23,25,26,30,39,40]. However, to the best of the researcher's knowledge, there is no large-scale research examining epistemological beliefs using the CLASS survey with a Turkish sample, except for the previously conducted validation study [22]. This contributes to the significance of the study.

C. Gender disparities in epistemological beliefs

Gender differences in epistemological beliefs have been a focal point of research in science and physics education. Research on epistemological beliefs offers mixed findings regarding gender differences. Some studies suggest no difference between males and females [36,42,54,55], while others indicate that students' beliefs vary by gender [21,23,40,55–58]. For example, the creators of the CLASS instrument [23] found gender differences in responses to nearly half of the survey questions. Their research indicated that, after completing an introductory calculus-based physics course, female students, on average, demonstrated less expertlike epistemological beliefs than their male counterparts. The study found that female students in the

same classes tended to score lower than male students on aspects of physics beliefs related to real-world applications, personal interest, problem-solving confidence, and problem-solving sophistication. While females scored slightly higher in the area of sensemaking and effort, significant gender gaps persisted, particularly concerning real-world connections and personal interest, even in calculus-based courses, though these gaps were smaller than in other physics courses. Madsen *et al.* [59], using the CLASS, examined how students' views about physics changed during an introductory calculus-based physics course. Their findings revealed that both male and female students shifted toward less expertlike beliefs by the end of the semester. However, this negative shift was more pronounced for female students who showed greater declines in all measured categories in the CLASS. While their initial scores were similar to or even lower than those of males, the larger negative shifts experienced by females widened the gender gap in expertlike beliefs from the beginning to the end of the course, suggesting that the course had a differential impact on the attitudes and beliefs of male and female students. These disparities are attributed to societal stereotypes, classroom dynamics, and the historical underrepresentation of women in STEM fields. Kost *et al.* [24] examined the gap in performance between males and females and found that the gender differences are primarily associated with differences in previous physics knowledge and incoming attitudes and beliefs. Chen *et al.* [21] provided additional insights, showing that while female students excel in collaborative and effort-driven environments, they often score lower on measures like problem-solving confidence. These findings underscore the importance of mentorship programs, stereotype threat reduction, and inclusive curricula in addressing gender-specific barriers in physics education.

In science education, many studies have also investigated gender differences in epistemological beliefs using instruments other than the CLASS, and consistent gender differences have not been observed. While some studies have reported that female students demonstrate more sophisticated epistemological beliefs than their male counterparts [55,58], others have indicated the converse [57] or found no significant gender-based differences [36]. Given these contradictory results, an investigation of gender differences in epistemological beliefs within the Turkish context is warranted.

D. Achievement levels and epistemological beliefs

Prior studies have established a link between epistemological beliefs and academic achievement [35,60]. Research has demonstrated a connection between physics-related epistemological beliefs and conceptual understanding and performance in physics among secondary school and university students [61]. Stathopoulou and Vosniadou [49] showed that beliefs about the construction, stability, and structure of physics knowledge predicted physics

understanding. Perkins *et al.* [62], using the CLASS to assess beliefs and the FMCE and FCI to measure learning, found significant correlations between specific belief categories and normalized learning gains in an introductory physics course, suggesting that students with more favorable initial beliefs tended to achieve greater learning gains. Similarly, Chu *et al.* [63] found that students' conceptual development of sound and wave motion was linked to both their cognitive understanding and their epistemological beliefs about physics. In his quasi-experimental study where epistemological beliefs are measured by the CLASS and conceptual understanding is measured by the FCI, Sahin [64] explored the impact of problem-based learning (PBL) on students' epistemological beliefs and their conceptual understanding of Newtonian mechanics, also examining the relationship between these two factors. Epistemological beliefs were measured by the CLASS, and conceptual understanding was measured by the FCI. In the study, the PBL group demonstrated significantly greater learning gains in conceptual understanding compared to the traditional learning group. However, PBL did not significantly affect epistemological beliefs; both groups exhibited similar beliefs. A positive correlation emerged between beliefs and conceptual understanding, meaning that students who began the semester with more expert-like epistemological beliefs tended to achieve higher conceptual understanding scores by the end. Chen *et al.* [21] used the CLASS to explore epistemological beliefs among Chinese physics students, revealing significant correlations between beliefs and academic performance.

Achievement levels have also been found to be strongly correlated with variations in epistemological beliefs. High-achieving students are more likely to hold sophisticated beliefs, viewing knowledge as dynamic, evidence-based, and interconnected [8,15]. These beliefs enable them to engage in deeper learning strategies, persist through challenges, and integrate theoretical knowledge with practical applications. Adams *et al.* [23] demonstrated that high-achieving students consistently score higher on CLASS subscales related to conceptual understanding and problem-solving sophistication. Zhao *et al.* [11] also highlighted that advanced epistemic cognition correlates with analytical thinking, curiosity, and persistence—traits essential for success in physics. Instructional practices tailored to students' achievement levels play a critical role in shaping epistemological beliefs. Inquiry-based and problem-based learning approaches have been shown to enhance epistemic cognition among low- and medium-achieving students by encouraging active participation and critical thinking [6,14].

E. Intersection of gender, achievement levels, and epistemological beliefs

While gender and achievement levels independently influence epistemological beliefs, their combined effects remain underexplored. Madsen *et al.* [59] suggested that even high-achieving female students may exhibit lower

confidence due to sociocultural influences. Similarly, Hazari *et al.* [32] noted that instructional practices emphasizing inclusivity and real-world relevance could bridge these gaps, promoting more equitable learning environments. Extensive research indicates that no large-scale study has yet investigated epistemological beliefs within a Turkish sample using the CLASS survey. Examining the separate effects of gender and achievement levels, as well as their interaction, on epistemological beliefs in physics contributes to the significance of this study.

F. Aims and research question

This study utilizes the Turkish-adapted version of the CLASS survey with a 20-item three-factor model (see Sec. III C for details) to explore the interplay between student beliefs about physics and physics learning, gender, and academic achievement when cumulative grade point averages (CGPAs) are controlled. By analyzing CLASS data, the research aims to

1. Investigate potential gender-based disparities in student beliefs about physics.
2. Investigate the students' beliefs about physics according to their academic achievement levels in this discipline.
3. Uncover potential interactions between gender and academic performance that might influence student beliefs in physics.

Understanding these relationships can inform the development of targeted instructional strategies that address the specific needs of diverse learners in physics classrooms. By fostering a learning environment that acknowledges and supports different epistemological perspectives, we can promote more inclusive and effective physics education for all students.

In this respect, the main research question and the subquestions were as follows:

1. How do gender and academic performance in the physics course influence freshman students' epistemological beliefs in the subscales of the CLASS survey—namely, problem-solving effort (PSE), conceptual understanding (CU), and personal interest and real-world connection (PI&RWC)—when their CGPAs are controlled?
 - 1.1. What is the impact of gender on freshman students' epistemological beliefs in PSE, CU, and PI&RWC when their CGPAs are controlled?
 - 1.2. What is the impact of academic performance in the General Physics I course on freshman students' epistemological beliefs in PSE, CU, and PI&RWC when their CGPAs are controlled?
 - 1.3. What is the impact of the interaction of gender and academic performance in the physics course on freshman students' epistemological beliefs in PSE, CU, and PI&RWC when their CGPAs are controlled?

III. RESEARCH METHODOLOGY

A. Research design

This study adopted a causal-comparative research design (CCRD) to explore potential causes or consequences of preexisting differences in beliefs about physics and learning physics among student groups [65,66]. CCRDs are appropriate when investigating cause-and-effect relationships in situations where manipulating the independent variable is impractical or impossible, as is the case with inherent student characteristics like gender and preexisting achievement levels. This design compares preexisting groups where the “cause” has already occurred, offering stronger evidence for causal inferences than purely correlational studies, though not with the same level of certainty as experimental designs. By carefully considering and addressing potential covariates, one can make a stronger argument for a cause-and-effect interpretation. Recognizing that perfect group equivalence is rarely attainable with preexisting groups and that potential covariates are inherent in such designs, this study aimed to mitigate their influence through careful consideration and analysis prior to the study.

Covariates are variables that are suspected to be influencing scores on the dependent variable. These covariates need to be chosen carefully based on the theory and previous research [67,68]. Thorough research in previous studies revealed that CGPA can be a potential covariate in epistemological beliefs [35,60]. By acknowledging and controlling for CGPA, one can obtain more accurate and meaningful insights into the factors that influence epistemological beliefs and their impact on learning. In order to address the confounding role of CGPA, several strategies can be used. These are statistical controls with analysis of covariance to statistically control for CGPA, matching participants on CGPA before assigning them into groups, and finally analyzing data separately with stratified analysis for different CGPA groups. In the present study, statistical control was employed due to the measurement level of the covariates and its common usage in similar research contexts. In this statistical analysis, removing the influence of covariates increases the likelihood of detecting any true differences between groups. Therefore, participants’ CGPAs were considered a covariate and were controlled statistically in this study. To assess beliefs, this study utilized the CLASS instrument, previously adapted into Turkish by the researcher [22], to survey freshmen enrolled in a General Physics II course at a state university in Türkiye.

B. Participants

Data for this study were collected by surveying a total of 1220 university freshman students from 22 different programs at one of the large, research-focused state universities in Türkiye. The university was selected based on convenience due to its ease of access to the researcher.

Additionally, the university has a strong focus on theoretical and fundamental physics. The subjects consisted of 463 females (38%) and 753 males (62%). All subjects had taken the General Physics I course in their first semester. In order to investigate the impacts of gender and achievement level on epistemological beliefs toward physics learning, the survey was administered as a written questionnaire to students at the beginning of the second semester of the first year of their four-year academic programs. The test took subjects 15 min on average to complete. The data were gathered, recorded, and then analyzed.

C. Instrument and procedures

The Colorado Learning Attitudes about Science Survey (CLASS) is a very well-known survey instrument used to assess students’ beliefs about physics and learning physics. It expands upon existing surveys (MPX, VASS, EBAPS) by incorporating additional aspects of student attitudes and beliefs deemed relevant in educational settings. The original CLASS survey, developed by Adams *et al.* [23], was validated by a group of other researchers [22,51,52].

The CLASS survey employs a five-point Likert scale (strongly disagree to strongly agree) for student responses to statements like “A significant problem in learning physics is being able to memorize all the information I need to know.” Initially developed and tested with over 5000 students and physics faculty experts, the 42-item CLASS survey underwent a data-driven analysis to identify underlying constructs. This analysis resulted in the establishment of eight categories: (i) real-world connection, (ii) personal interest, (iii) sensemaking/effort, (iv) conceptual connections, (v) applied conceptual understanding, (vi) problem-solving general, (vii) problem-solving confidence, and (viii) problem-solving sophistication.

The CLASS survey, initially available in English, has undergone translations to facilitate its use in diverse cultural contexts. These translations include Arabic, Chinese, Finnish, German, Japanese, Portuguese, Spanish, Swedish, and Turkish. The instrument was adapted into Turkish in the previous study [22]. Due to some overlapping items indicating a lack of clear boundaries between constructs, the CLASS has undergone scrutiny through various psychometric reevaluation studies [22,51,52]. Turkish psychometric evaluation resulted in a proposed 20-item three-factor model based on confirmatory and exploratory factor analysis (Table II). The factors were “problem-solving effort (PSE)” (seven items), “conceptual understanding (CU)” (six items), and “personal interest and real-world connection (PI&RWC)” (seven items). Items originally categorized as problem-solving confidence, general problem solving, and problem-solving sophistication that focused on the effort students put into solving physics problems were grouped into a single PSE factor. Items measuring the ability to connect and apply physics concepts (originally in the conceptual connections

TABLE II. CLASS categories with the number of statements and sample statements. This table is adapted from the original CLASS V.3 [23] and psychometric evaluation of Kaltakci-Gurel [22]. Model fit discussions for the exploratory and confirmatory factor analysis for the psychometric evaluation can be seen in Ref. [22].

Category	Sample statements and statement numbers from original CLASS
PSE (7 items) (15, 24, 26, 34, 36, 39, 42)	15. <i>If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.</i> 34. <i>I can usually figure out a way to solve physics problems.</i> 36. <i>There are times I solve a physics problem more than one way to help my understanding.</i>
CU (6 items) (1, 5, 6, 13, 32, 40)	1. <i>A significant problem in learning physics is being able to memorize all the information I need to know.</i> 5. <i>Knowledge in physics consists of many disconnected topics.</i> 40. <i>I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.</i>
PI&RWC (7 items) (3, 14, 25, 28, 30, 35, 37)	3. <i>I study physics to learn knowledge that will be useful in my life outside of school.</i> 14. <i>I think about the physics I experience in everyday life.</i> 37. <i>The subject of physics has little relation to what I experience in the real world.</i>

and applied conceptual understanding categories) were combined into the CU factor. Items related to personal interest in physics and its connection to the real world (originally the personal interest and real-world connection categories) were combined into a single PI&RWC factor. In the current study, the Turkish translation of the CLASS with 20 items and three factors was used as a data collection tool together with some demographic information, including gender, CGPA, and prior academic performance in the general physics I course.

Internal consistency of the instrument was evaluated using Cronbach's alpha for each of the three factors separately and for the entire 20-item scale. The factors PSE ($\alpha = 0.670$), CU ($\alpha = 0.654$), and PI&RWC ($\alpha = 0.771$) demonstrated acceptable reliability. Notably, the overall scale achieved a higher level of internal consistency with a Cronbach's alpha of 0.844.

D. Data analysis

The two-way between-groups multivariate analysis of covariance (two-way MANCOVA) test was used to answer the research question. This technique allowed us to simultaneously test for the effect of each of our independent variables [gender and achievement level in the general physics course (ALGPCG)] on the dependent variables (PSE, CU, and PI&RWC in physics) in the CLASS survey scores and also to identify any interaction effects by removing the influence of covariate (i.e., CGPA). SPSS uses regression procedures to remove the variation in the dependent variables that is due to the covariate and then performs the standard multivariate techniques on the corrected or adjusted scores. Analysis of covariance is recommended when it is impossible to randomly assign participants to the different groups, but instead, existing groups must be used [67]. Because these groups may differ in multiple ways, covariance analysis (e.g., MANCOVA)

can be employed to mitigate some of these discrepancies. Appropriate covariates can help minimize the confounding effects of preexisting group differences. Although the sample sizes for the gender and achievement level groups were not equal, the use of MANCOVA allowed us to statistically control for these discrepancies, particularly with CGPA as a covariate, thereby minimizing potential group bias.

The gender data, obtained as demographic data in the CLASS survey, was collected by asking students directly. Due to regulations in Türkiye, survey applications only allow for "female" and "male" as gender options; however, participants did have the choice to leave the question unanswered. Students' performance in their General Physics I course was also collected as demographic data in the CLASS survey. For analysis, the independent variable "Achievement Level in General Physics Course (ALGPCG)" was obtained by dividing course achievement performances into three as: "low-achieving" (LA), "medium-achieving" (MA), and "high-achieving" (HA) groups. Freshman university students' General Physics I course grades were assigned as "HA" if the ALGPCG was ≥ 3.0 ; "MA" if $2.0 \leq \text{ALGPCG} < 3.0$; and "LA" if $\text{ALGPCG} < 2.0$. These thresholds align with common practice in educational research, where GPA is frequently used as a measure of academic success [33,69,70]. Furthermore, these cut-offs reflect typical grading scales and provide a meaningful framework for understanding student performance. Out of 1220 subjects surveyed in the study, 408 (33%) were found to be in the LA group, 424 (35%) were in the MA group, and 388 (32%) were in the HA group. Table III illustrates the sample distribution according to gender and ALGPCG.

The covariate, cumulative grade point average (CGPA), represents a student's overall academic performance across all the courses he or she has taken in their degree program. It is calculated by averaging all the GPAs earned in each semester, resulting in a value between 0.0 and 4.0. The

TABLE III. Sample distribution according to gender and ALGPCG. LA, low-achieving; MA, medium-achieving; HA, high-achieving.

Subjects	Overall sample		Missing	Sample used for statistical analysis	
	<i>N</i>	%		<i>N</i>	%
Gender	1220	100	4	1147	94
Female	463	38.1		427	35
Male	753	61.9		720	59
ALGPCG	1220	100	0	1147	94
Mean: 1.9836					
SD: 0.80791					
LA group (ALGPCG < 2.0)	408	33.4		352	28.8
MA group ($2.0 \leq \text{ALGPCG} < 3.0$)	424	34.8		412	33.8
HA group (ALGPCG ≥ 3.0)	388	31.8		383	31.4
CGPA	1147	94	73	1147	94
Mean: 2.5983					
SD: 0.7958					

mean CGPA was calculated as 2.598, with a standard deviation of 0.796 for the sample.

E. Ethical issues

This research adhered to all ethical principles outlined in the Declaration of Helsinki, including respecting participants' autonomy through informed consent and ensuring their well-being by protecting data confidentiality and minimizing any potential risks. Before providing written consent, participants received detailed information about the study's purpose, procedures, their right to withdraw at any time without penalty, and the confidential handling of their data. Data confidentiality was ensured through anonymization by removing directly identifying information and assigning unique, randomly generated identification codes. To mitigate any potential influence of power dynamics, participation was entirely voluntary and unrelated to course grades or academic standing; students were assured that their decision would not affect their relationship with instructors or their academic evaluation. The study was approved by the institutional review board of the university where the current study was conducted.

IV. RESULTS

To investigate the research question, the two-way between-groups multivariate analysis of covariance

(MANCOVA) test was conducted in IBM SPSS.30. The two-way between-groups MANCOVA is an analytical technique that extends the principles of the two-way ANCOVA for situations where there are two or more dependent variables [67,68]. The main aim of the two-way between-groups MANCOVA is to understand if there is an interaction between the two independent variables on the two or more dependent variables after controlling for the covariate(s). In other words, this statistical test aims to understand whether the effect of one independent variable on the dependent variables (collectively) is dependent on the value of the other independent variable when covariates are controlled. For the two-way between-groups MANCOVA test, preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, outliers, homogeneity of variances, homogeneity of regression, multicollinearity and singularity, and homogeneity of variance-covariance matrices.

In order to examine the main effects and interaction effects of gender and ALGPCG (low, medium, and high achieving) on the multivariate pattern of the three subscales of the CLASS survey (namely, PSE, CU, and PI&RWC in physics) scores, a two-way between-groups MANCOVA was conducted. The analysis revealed a significant main effect of gender on the multivariate pattern of PSE, CU, and PI&RWC in physics scores [Wilks' lambda = 0.969, $F(3, 1138) = 12.133$, $p < 0.001$] and a significant main

TABLE IV. Two-way between-groups MANCOVA results.

Independent variables	Wilks' lambda	<i>F</i>	d.o.f.1	d.o.f.2	Significance	Eta squared
Intercept	0.338	742.878	3	1138	<0.001	0.662
CGPA	0.995	2.067	3	1138	0.103	0.005
Gender	0.969	12.133	3	1138	<0.001	0.031
ALGPCG	0.934	13.116	6	2276	<0.001	0.033
Gender $\times$ ALGPCG	0.998	0.417	6	2276	0.868	0.001

TABLE V. Univariate effects of gender and ALGPCG on dependent variables PSE, CU, and PI&RWC (CGPA is a covariate).

Independent variables	Dependent variables	Type III sum of squares	d.o.f.	Mean square	<i>F</i>	Significance	Eta squared
Gender	PSE	263.707	1	263.707	14.393	<0.001	0.012
	CU	419.656	1	419.656	25.058	<0.001	0.022
	PI&RWC	729.976	1	729.976	26.094	<0.001	0.022
ALGPCG	PSE	453.175	2	226.588	12.367	<0.001	0.021
	CU	1148.261	2	574.130	34.282	<0.001	0.057
	PI&RWC	1080.484	2	540.242	19.312	<0.001	0.033
Gender $\times$ ALGPCG	PSE	14.019	2	7.009	0.383	0.682	0.001
	CU	28.096	2	14.048	0.839	0.432	0.001
	PI&RWC	3.522	2	1.761	0.063	0.939	0.000

TABLE VI. Descriptive statistics related to CLASS subscale scores according to gender and ALGPCG.

CLASS subscales	Achievement levels in general physics course (ALGPCG)	Gender	N	Mean	SD
Problem-solving effort (PSE)	LA group (ALGPCG < 2.0)	Female	143	23.29	4.61
		Male	209	23.99	4.32
		Total	352	23.70	4.45
	MA group ($2.0 \leq \text{ALGPCG} < 3.0$)	Female	159	24.01	3.97
		Male	253	25.30	4.73
		Total	412	24.80	4.49
	HA group (ALGPCG ≥ 3.0)	Female	125	25.63	3.99
		Male	258	26.63	3.90
		Total	383	26.30	3.96
	Total	Female	427	24.24	4.30
		Male	720	25.39	4.45
		Total	1147	24.97	4.43
Conceptual understanding (CU)	LA group (ALGPCG < 2.0)	Female	143	18.04	4.46
		Male	209	18.85	4.33
		Total	352	18.52	4.40
	MA group ($2.0 \leq \text{ALGPCG} < 3.0$)	Female	159	18.78	4.00
		Male	253	20.12	4.20
		Total	412	19.60	4.17
	HA group (ALGPCG ≥ 3.0)	Female	125	21.00	3.34
		Male	258	22.63	3.95
		Total	383	22.10	3.83
	Total	Female	427	19.18	4.16
		Male	720	20.65	4.43
		Total	1147	20.10	4.39
Personal interest & real-world connection (PI&RWC)	LA group (ALGPCG < 2.0)	Female	143	20.08	5.55
		Male	209	21.64	5.46
		Total	352	21.01	5.54
	MA group ($2.0 \leq \text{ALGPCG} < 3.0$)	Female	159	21.38	5.60
		Male	253	23.08	5.48
		Total	412	22.42	5.58
	HA group (ALGPCG ≥ 3.0)	Female	125	22.90	4.94
		Male	258	24.62	4.76
		Total	383	24.06	4.88
	Total	Female	427	21.39	5.50
		Male	720	23.21	5.36
		Total	1147	22.54	5.48

effect of ALGPCG [Wilks' lambda = 0.934, $F(6, 2276) = 13.116$, $p < 0.001$] with small (partial eta squared = 0.01) and partial eta squared = 0.033) effect sizes, respectively. However, the interaction effect between gender and ALGPCG did not reach statistical significance (Wilks' lambda = 0.998, $F(6, 2276) = 0.417$, $p = 0.868$), indicating that the combined influence of gender and ALGPCG did not significantly impact students' CLASS survey subscale scores. Table IV shows the two-way between-groups MANCOVA results in detail.

Univariate tests for between-subjects effects were conducted to further examine the individual effects on PSE, CU, and PI&RWC in physics scores. When the results for the dependent variables were considered, a separately adjusted alpha level of 0.017 was applied using a Bonferroni adjustment. Since a number of separate analyses were conducted in this step, an adjusted alpha level of 0.017 was set by dividing alpha 0.05 by 3, which is the number of dependent variables. According to the analyses, gender exhibited significant effects on PSE [$F(1, 1140) = 14.393$, $p < 0.001$, partial eta squared = 0.012], CU [$F(1, 1210) = 25.058$, $p < 0.001$, partial eta squared = 0.022], and PI&RWC [$F(1, 1140) = 26.094$, $p < 0.001$, partial eta squared = 0.022]. Similarly, ALGPCG influenced PSE [$F(2, 1140) = 12.367$, $p < 0.001$, partial eta squared = 0.021], CU [$F(2, 1140) = 34.282$, $p < 0.001$, partial eta squared = 0.057], and PI&RWC [$F(2, 1140) = 19.312$, $p < 0.001$, partial eta squared = 0.033]. An interaction effect occurs when the effect of one independent variable on the dependent variable depends on the level of a second independent variable. However, the interaction effect between gender and ALGPCG was not significant for none of the subscales (Table V).

In summary, gender and ALGPCG independently exerted significant influences on students' scores on three CLASS survey subscales, while their interaction did not contribute significantly to the observed variance. Although statistical significance was found for three dependent variables for both independent variables, the eta squared values, which show the practical significance [67,71], were found to be small for the gender and the ALGPCG. Eta squared value is one way that assess the importance of findings in presenting effect size (also known as "strength of association"). Effect size is a statistical measure that quantifies the strength of the relationship between two variables. It is an important concept in research because it helps to determine the practical significance of a finding [67,68]. There are many different types of effect sizes (e.g., Cohen's d , Pearson's r , and eta squared), and the choice of which one to use depends on the specific research question. Eta squared, used in this study, represents the proportion of variance of the dependent variable that is explained by the independent variable. It ranges from 0 to 1, with values of 0.01, 0.06, and 0.14 generally considered to represent small, medium, and large effects, respectively [67].

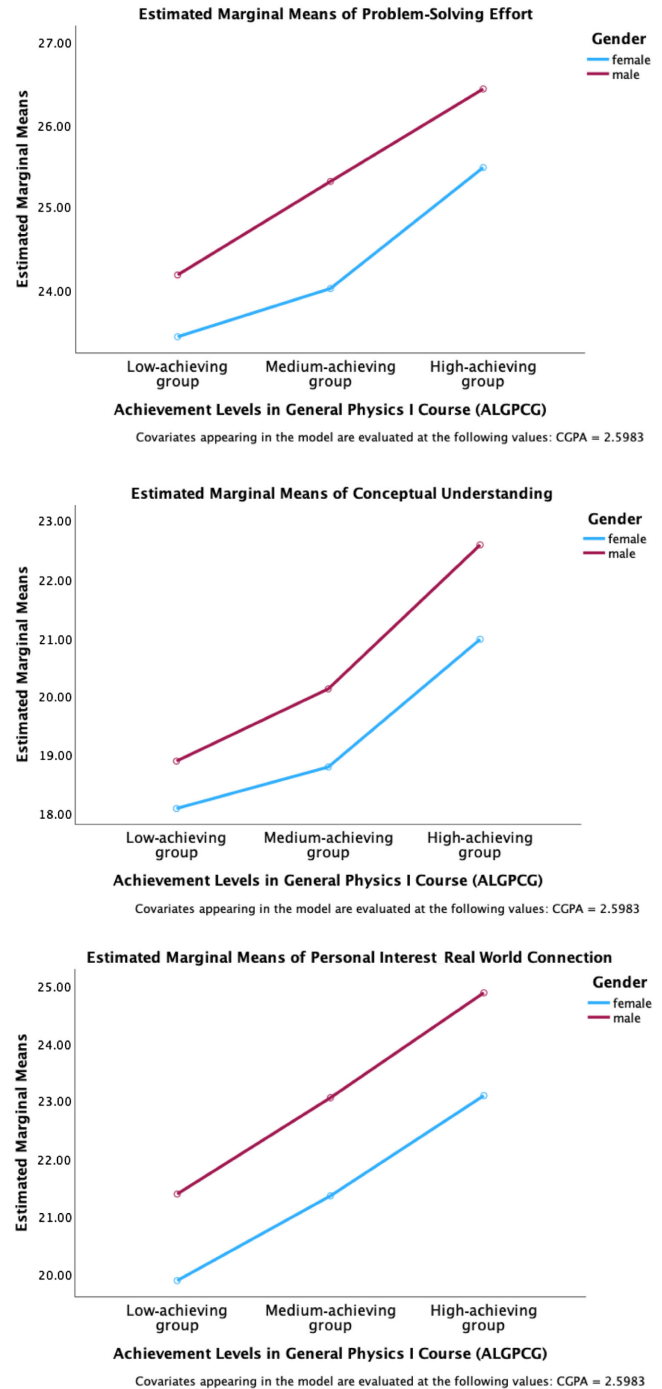


FIG. 1. Mean differences of PSE, CU, and PI&RWC on gender and ALGPCG. "Marginal Means" refer to the means of the dependent variables adjusted for the covariate (CGPA), as computed by the MANCOVA.

Some descriptive statistics related to PSE, CU, and PI&RWC scores according to gender and ALGPCG are illustrated in detail in Table VI, and the mean differences are visualized in Fig. 1. An examination of Table VI and Fig. 1 reveals that male students consistently scored higher than female students across all three CLASS subscales

(PSE, CU, and PI&RWC). An inspection of the mean scores indicated that males showed higher scores in PSE ($M = 25.39$, $SD = 4.45$); CU ($M = 20.65$, $SD = 4.43$); and PI&RWC ($M = 23.21$, $SD = 5.35$) scores than females in PSE ($M = 24.24$, $SD = 4.30$); CU ($M = 19.18$, $SD = 4.16$); and PI&RWC ($M = 21.39$, $SD = 5.50$) and these differences are practically small because of the small effect sizes. Additionally, males consistently score higher than females across all achievement levels, and both genders demonstrate growth with achievement, but the gap persists.

An inspection of the mean scores also indicated that HA groups showed higher scores in PSE ($M = 26.30$, $SD = 3.95$), CU ($M = 22.10$, $SD = 3.83$), and PI&RWC ($M = 24.06$, $SD = 4.88$) scores than MA and LA groups, and these differences are practically small to medium because of the small to moderate effect sizes.

V. DISCUSSION

Physics education research strives to create inclusive and effective learning environments for all students. However, persistent gender disparities in student engagement and achievement in physics remain a concern [72,73]. Understanding these disparities necessitates exploring the underlying factors, including students' beliefs and attitudes toward physics. This causal-comparative research examined the impacts of gender and academic achievement levels on Turkish freshman students' epistemological beliefs in the subscales of a well-known CLASS survey. Using data collected from 1220 first-year university students, the two-way between-groups MANCOVA analysis revealed that gender and achievement level in the General Physics I Course (ALGPCG) had significant effects on students' scores on the three CLASS survey subscales. More specifically, the results indicated that male and high-achieving students demonstrated more expertlike epistemological beliefs, particularly in problem-solving effort, conceptual understanding, and personal interest, and real-world connection subscales of the CLASS survey. While statistically significant for all three dependent variables with both independent variables, the eta squared values indicating practical significance were small for gender ($\eta^2 \approx 0.012$ – 0.022) and small to moderate for ALGPCG ($\eta^2 \approx 0.021$ – 0.057). The results of the current research indicate that Turkish freshmen students' epistemological views, as measured by the CLASS instrument, are relatively achievement level-oriented, such that HA groups showed higher scores in PSE, CU, and PI&RWC than MA, and LA groups, with the most practical significance appearing in the achievement levels in the CU subscale. While these effect sizes suggest that gender and academic achievement are not the only determinants of epistemological beliefs, they reinforce the idea that educational and sociocultural factors play a significant role. Prior research suggests that even small statistical effects can have

meaningful implications in educational settings, particularly when they reflect systemic disparities [59,72]. For instance, slight differences in epistemological beliefs between genders may contribute to larger gaps in motivation or retention in physics, suggesting that inclusive teaching strategies may still be warranted. The moderate effects associated with achievement level suggest that students' performance in prior coursework meaningfully influences their beliefs, and targeted interventions could support students with weaker academic backgrounds in developing more expertlike beliefs. Given these findings, reforming physics instruction should not focus solely on shifting epistemological beliefs but rather on creating learning environments that accommodate diverse belief profiles. Some research suggests that student learning gains can improve even when epistemological beliefs remain unchanged, further supporting the idea that interventions should prioritize active engagement, conceptual scaffolding, and relevance to students' experiences [12,23]. On the other hand, many other studies express that epistemological understanding is crucial for learning and teaching [8,11,13,21,35,73]. Importantly, this understanding is not innate or stable; it can develop over time and be influenced by factors like age, gender, and education [15,74]. The data of the current research indicate that gender and academic achievement levels are factors affecting Turkish freshman students' epistemological beliefs toward physics learning.

Gender and equity in science and physics education have been studied for decades. Longstanding research highlights the significant role of gender [36,58,75]. These studies have consistently investigated how gender intersects with various factors, including cognitive abilities, attitudes, and sociocultural influences. Findings indicate that gender-related differences in physics learning are not uniform and are significantly influenced by these intersecting variables. For example, Madsen *et al.* [59] examined 30 factors that might influence the gender gap in physics education. Their research revealed no single factor sufficient to explain the disparity. Instead, the gap likely arises from a complex interplay of factors, making it challenging to address with a simple solution. The research examining gender differences in epistemological beliefs, therefore, reveals no consistent patterns [36,57,58]. In the current study, Turkish male students were found to demonstrate more expertlike epistemological beliefs compared to females in PSE, CU, and PI&RWC. Consistent with the present study, Chen *et al.* [21] found no overall gender differences in epistemological beliefs among 817 Chinese university students. However, upon examining universities with a strong focus on theoretical and fundamental knowledge, male students majoring in science or physics education exhibited significantly stronger epistemological beliefs than their female counterparts. Similarly, Adams *et al.* [23] studied over 5000 students taking the CLASS survey and found significant gender differences. Females

scored lower on subscales related to “real-world connections,” “personal interest,” “problem-solving confidence,” and “problem-solving sophistication” but slightly higher on “sensemaking/effort.” In previous studies with Turkish elementary students, epistemological beliefs were found to be mostly related to gender. Ozkal *et al.* [57] found male students had more desirable epistemological beliefs than females, whereas Topçu and Yılmaz-Tüzün [58] revealed that female students developed better epistemological beliefs than those of male students. These studies, along with the current research, highlight the persistent but inconsistent gender disparity in epistemological beliefs in physics. The finding of a small gender effect aligns with this mixed landscape and highlights the need for continued research that considers mediating and contextual variables.

The gender disparities in epistemological beliefs in physics found in this study might stem from the gender gap pronounced in physics interest and confidence. Specifically, previous studies indicated that female students often exhibit lower confidence in problem solving and perceive physics as less relevant to their everyday lives [24,33,59,72]. This disparity in confidence and perceived relevance may be exacerbated by, or even originate from, fewer opportunities for females to actively participate in physics classes. This lack of active engagement could then hinder the development of sophisticated epistemological beliefs. To reduce these gender disparities, physics instruction should incorporate inclusive and engaging teaching strategies. Research suggests that active learning techniques, such as peer instruction, collaborative problem solving, and inquiry-based learning, can increase female students’ confidence and interest in physics [76,77]. These methods help create an interactive and supportive learning environment that benefits all students, particularly those who may lack confidence in their abilities. Additionally, the integration of real-world applications and interdisciplinary connections can make physics more relevant to female students. Studies have shown that female students are more likely to engage with physics when it is presented in a context that highlights its societal impact and interdisciplinary applications [72,78–80]. This suggests that incorporating real-world problem solving and applications in medical physics, environmental science, and technology could increase female students’ interest and motivation. Another key strategy is the explicit discussion of epistemological beliefs in physics education. Research has shown that explicitly addressing the nature of scientific knowledge and its evolving structure can help students develop a more sophisticated understanding of physics [12,20]. Implementing metacognitive activities, such as reflective writing, self-explanation tasks, and structured group discussions about problem-solving strategies, can help female students recognize their own cognitive development and increase their confidence in physics learning. As Chan and Elliott [54] pointed out, epistemological

beliefs are context sensitive, and cross-cultural studies often reveal variations due to differing cultural values. Therefore, researchers should employ epistemological instruments and analyze results with careful consideration of cultural context. While several studies have investigated gender differences in elementary science or high school physics in Türkiye [19,42,57,58,80], limited research was found focusing on Turkish university students. The current study revealed that males possess more desirable epistemological beliefs than females at the university level, a finding possibly linked to limited instructional and practical opportunities for females in university programs. However, due to the small effect size, the observed statistically significant gender difference must be interpreted cautiously. Nevertheless, this research represents an initial step in understanding gender-based epistemological beliefs within the Turkish university education context, and further investigation is crucial to fully comprehend the origins of this disparity.

Previous research has shown a link between academic success and well-developed beliefs about knowledge [80–82]. The current study’s finding that high-achieving students exhibit more sophisticated epistemological beliefs aligns with prior research suggesting that students who perceive physics knowledge as coherent and evolving tend to achieve higher academic success [14,15,62]. The findings indicate that lower-achieving students exhibit weaker epistemological beliefs, strongly suggesting a need for instructional interventions that foster deeper conceptual understanding. Scaffolded problem-solving frameworks offer one approach, where students are guided through problem-solving steps with increasing independence. Research suggests that structured scaffolding can improve students’ conceptual understanding and problem-solving abilities, particularly for those who struggle with physics [7]. Mastery-oriented feedback can also enhance students’ epistemological beliefs and learning outcomes. Instead of solely focusing on correct answers, instructors should provide feedback that emphasizes conceptual understanding, problem-solving strategies, and the iterative nature of learning. Prior studies have found that students who receive mastery-oriented feedback demonstrate greater persistence and deeper learning in physics [83,84]. Differentiated instruction, providing students with tailored learning experiences based on their epistemological beliefs and academic performance, could also be an effective approach. Adaptive learning environments, providing customized problem sets, explanatory videos, and personalized feedback can significantly enhance students’ engagement and learning outcomes [85]. By incorporating these instructional techniques, physics education can better support students at different achievement levels. Therefore, fostering sophisticated epistemological beliefs is crucial for improving students’ physics achievement. Educational stakeholders, including teachers, administrators, and policymakers, should prioritize the development of these beliefs throughout formal schooling.

The nonsignificant interaction effect between gender and achievement level means there is no evidence that achievement affects epistemological beliefs differently for males and females. Therefore, the relationship between achievement and epistemological beliefs is consistent across genders. The absence of a significant interaction might reflect shared curricular structures or instructional approaches that impact students similarly regardless of gender.

The current study, however, has some limitations to consider in any attempt to generalize the findings. The limited scope of this study, focusing solely on students from a single Turkish university, necessitates future research to incorporate diverse samples, thereby enhancing the generalizability of the findings. Furthermore, it must be acknowledged that the causal-comparative design, by its nature, does not allow for direct manipulation of the independent variables or random assignment of participants. Consequently, while we observed significant associations, we cannot definitively establish causal relationships. Therefore, the results should be interpreted carefully, and future research should examine, through experimental studies, how instructional interventions influence epistemological beliefs over time and across diverse cultural contexts. To gain a more nuanced understanding of students' epistemological beliefs and their connections to other variables, future investigations are strongly encouraged to incorporate qualitative methodologies. Mixed-methods studies combining quantitative and qualitative analyses could provide deeper insights into how students develop their epistemological beliefs in physics. Despite these limitations and the practically small to medium effect sizes, this research offers a preliminary exploration of gender-related and achievement level-related epistemological beliefs among Turkish university students, highlighting the need for further investigation into the underlying causes of these disparities.

VI. CONCLUSION

Epistemological beliefs are key to comprehending how students tackle and integrate scientific concepts. How students perceive the development and application of physics knowledge directly affects whether they choose

to engage with physics education and how they learn in a physics course. Therefore, knowing how epistemological beliefs vary among genders and across achievement levels can help us tailor physics teaching more effectively. In this research, the CLASS survey of beliefs about physics was administered to a wide range of first-year university students from 22 different programs in one of the state universities in Türkiye. It was found that in a general physics course, both gender and achievement level independently exerted significant effects on students' scores on epistemological beliefs as measured by the CLASS survey. However, there is no interaction between gender and achievement level, suggesting that the interaction of gender and achievement level does not significantly impact students' CLASS survey subscale scores.

The results of this research have substantial implications for introductory physics teaching. In part, the research provides evidence suggesting that students with different genders or achievement levels need different instructional designs. The findings suggest that males and high-achieving students demonstrate more expertlike epistemological beliefs, reinforcing the need for targeted pedagogical interventions. Gender-based disparities can be addressed through active learning strategies, interdisciplinary connections, and explicit discussions of epistemological beliefs. Higher academic performance is associated with more sophisticated epistemological beliefs about knowledge acquisition. These beliefs likely influence student behavior, making them more persistent, curious, and evidence-driven learners. This necessitates exploring strategies to nurture these valuable epistemological beliefs in students. Lower-achieving students may benefit from scaffolded problem solving, mastery-oriented feedback, and differentiated instruction. These findings highlight the importance of aligning instructional design with students' epistemological perspectives based on their individual differences. Hence, while planning their physics courses, instructors should pay attention to these differences.

DATA AVAILABILITY

The data are not publicly available. The data are available from the author upon reasonable request.

-
- [1] D. Hestenes, M. Wells, and G. Swackhamer, Force concept inventory, *Phys. Teach.* **30**, 141 (1992).
 - [2] L. Lising and A. Elby, The impact of epistemology on learning: A case study from introductory physics, *Am. J. Phys.* **73**, 372 (2005).
 - [3] D. Kaltakçı Gürel and N. Didiş Körhasan, A critical look at the physics education research in Turkey and in the world, *Bartın Univ. J. Faculty Educ.* **7**, 935 (2018).
 - [4] N. Didiş Körhasan and C. Çıtak, Examination of undergraduate students' physics expectations, *Eur. J. Phys.* **45**, 045701 (2024).
 - [5] K. E. Gray, W. K. Adams, C. E. Wieman, and K. K. Perkins, Students know what physicists believe, but they

- don't agree: A study using the CLASS survey, *Phys. Rev. ST Phys. Educ. Res.* **4**, 020106 (2008).
- [6] K. K. Perkins, W. K. Adams, S. J. Pollock, N. D. Finkelstein, and C. E. Wieman, Correlating student beliefs with student learning using the Colorado Learning Attitudes about Science Survey, in *Collected Papers of Carl Wieman* (2008), pp. 718–721, [10.1142/9789812813787_0100](https://doi.org/10.1142/9789812813787_0100).
- [7] M. Şahin, Effect of problem-based learning on university students' epistemological beliefs about physics, and physics learning, and conceptual understanding of Newtonian mechanics, *J. Sci. Educ. Technol.* **19**, 266 (2010).
- [8] G. M. Franco, K. R. Muis, P. Kendeou, J. Ranellucci, L. Sampasivam, and X. Wang, Examining the influences of epistemic beliefs and knowledge representations on cognitive processing and conceptual change when learning physics, *Learn. Instr.* **22**, 62 (2012).
- [9] N. Didiş-Körhasan and D. Kaltakçı-Gürel, Student teachers' physics knowledge and sources of knowledge to explain everyday phenomena, *Sci. Educ. Int.* **30**, 298 (2019).
- [10] P. Zhang and L. Ding, Large-scale survey of Chinese precollege students' epistemological beliefs about physics: A progression or a regression?, *Phys. Rev. ST Phys. Educ. Res.* **9**, 010110 (2013).
- [11] L. Zhao, W. He, X. Liu, K.-H. Tai, and J.-C. Hong, Exploring the effects on fifth graders' concept achievement and scientific epistemological beliefs: Applying the prediction-observation-explanation inquiry-based learning model in science education, *J. Balt. Sci. Educ.* **20**, 664 (2021).
- [12] A. Elby, Helping physics students learn how to learn, *Am. J. Phys.* **69**, S54 (2001).
- [13] D. M. Hammer, Epistemological beliefs in introductory physics, *Cognit. Instr.* **12**, 151 (1994).
- [14] S. Pamuk, S. Sungur, and C. Oztekin, A multilevel analysis of students' science achievements in relation to their self-regulation, epistemological beliefs, learning environment perceptions, and teachers' personal characteristics, *Int. J. Sci. Math. Educ.* **15**, 1423 (2017).
- [15] M. Schommer, Epistemological development and academic performance among secondary students, *J. Educ. Psychol.* **85**, 406 (1993).
- [16] S. Yerdelen-Damar and A. Eryılmaz, The impact of the metacognitive 7E learning cycle on students' epistemological understandings, *Kastamonu Educ. J.* **24**, 603 (2016), <https://dergipark.org.tr/en/pub/kefedergi/issue/22590/241294>.
- [17] J. Guo, X. Hu, H. W. Marsh, and R. Pekrun, Relations of epistemic beliefs with motivation, achievement, and aspirations in science: Generalizability across 72 societies, *J. Educ. Psychol.* **114**, 734 (2022).
- [18] K. M. Edmondson and J. D. Novak, The interplay of scientific epistemological views, learning strategies, and attitudes of college students, *J. Res. Sci. Teach.* **30**, 547 (1993).
- [19] S. Ayata, G. Oylumluoğlu, and M. M. Alpaslan, Contributions of epistemological beliefs on energy literacy in lower-secondary school students in Turkey, *J. Balt. Sci. Educ.* **23**, 421 (2024).
- [20] E. F. Redish and D. Hammer, Reinventing college physics for biologists: Explicating an epistemological curriculum, *Am. J. Phys.* **77**, 629 (2009).
- [21] L. Chen, S. Xu, H. Xiao, and S. Zhou, Variations in students' epistemological beliefs towards physics learning across majors, genders, and university tiers, *Phys. Rev. Phys. Educ. Res.* **15**, 010106 (2019).
- [22] D. Kaltakci-Gurel, Turkish adaptation and psychometric evaluation of the Colorado Learning Attitudes about Science Survey (CLASS) in physics, *Eur. Educ. Res.* **4**, 355 (2021).
- [23] W. K. Adams, K. K. Perkins, N. S. Podolefsky, M. Dubson, N. D. Finkelstein, and C. E. Wieman, New instrument for measuring student beliefs about physics, and learning physics: The Colorado Learning Attitudes about Science Survey, *Phys. Rev. ST Phys. Educ. Res.* **2**, 010101 (2006).
- [24] L. E. Kost, S. J. Pollock, and N. D. Finkelstein, Characterizing the gender gap in introductory physics, *Phys. Rev. ST Phys. Educ. Res.* **5**, 010101 (2009).
- [25] S. P. Bates, R. K. Galloway, C. Lopston, and K. A. Slaughter, How attitudes and beliefs about physics change from high school to faculty, *Phys. Rev. ST Phys. Educ. Res.* **7**, 020114 (2011).
- [26] B. A. Lindsey, L. Hsu, H. Sadaghiani, J. W. Taylor, and K. Cummings, Positive attitudinal, with physics by inquiry curriculum across multiple implementations, *Phys. Rev. ST Phys. Educ. Res.* **8**, 010102 (2012).
- [27] I. Soulios and D. Psillos, Enhancing student teachers' epistemological beliefs about models and conceptual understanding through a model-based inquiry process, *Int. J. Sci. Educ.* **38**, 1212 (2016).
- [28] M. G. Reyes and S. Rakkapao, Item response curve analysis of Likert scale on learning attitudes towards physics, *Eur. J. Phys.* **41**, 045703 (2020).
- [29] R. Moll and M. Milner-Bolotin, The effect of interactive lecture experiments on student academic achievement and attitudes towards physics, *Can. J. Phys.* **87**, 917 (2009).
- [30] M. Milner-Bolotin, T. Antimirova, A. Noack, and A. Petrov, Attitudes about science and conceptual physics learning in university introductory physics courses, *Phys. Rev. ST Phys. Educ. Res.* **7**, 020107 (2011).
- [31] S. Cwik and C. Singh, Gender differences in students' self-efficacy in introductory physics courses in which women outnumber men predict their grade, *Phys. Rev. Phys. Educ. Res.* **18**, 020142 (2022).
- [32] Z. Hazari, R. Tai, and P. Sadler, Gender differences in introductory university physics performance, *Sci. Educ.* **91**, 847 (2007).
- [33] D. Kaltakçı-Gürel, Exploring pre-service teachers' conceptual understanding and confidence in geometrical optics: A focus on gender and prior course achievement, *Educ. Sci.* **13**, 452 (2023).
- [34] D. Hammer and A. Elby, Tapping epistemological resources for learning physics, *J. Learn. Sci.* **12**, 53 (2003).
- [35] B. K. Hofer and P. R. Pintrich, The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning, *Rev. Educ. Res.* **67**, 88 (1997).

- [36] Y. Ulu and S. Yerdelen-Damar, Metacognition and epistemic cognition in physics are related to physics identity through the mediation of physics self-efficacy, *Phys. Rev. Phys. Educ. Res.* **20**, 010130 (2024).
- [37] A. Elby, Another reason that physics students learn by rote, *Am. J. Phys.* **67**, S52 (1999).
- [38] K. Perkins, W. Adams, S. Pollock, N. Finkelstein, and C. Wieman, Correlating student beliefs with student learning using the Colorado Learning Attitudes about Science Survey, in *Proceedings of the 2004 Physics Education Research Conference, Sacramento, CA* (AIP, New York, 2007).
- [39] H. Alhadlaq, F. Alshaya, S. Alabdulkareem, K. K. Perkins, W. K. Adams, and C. E. Wieman, Measuring students' beliefs about physics in Saudi Arabia, in *Proceedings of the 2009 Physics Education Research Conference* (AIP, New York, 2009).
- [40] J. A. Chen and F. Pajares, Implicit theories of ability of grade 6 science students: Relation to epistemological beliefs and academic motivation and achievement in science, *Contemp. Educ. Psychol.* **35**, 75 (2010).
- [41] F. Ç. Mercan, Epistemic beliefs about justification employed by physics students, and faculty in two different problem contexts, *Int. J. Sci. Educ.* **34**, 1411 (2012).
- [42] Ş. Özkan and C. Tekkaya, How do epistemological beliefs differ by gender and socio-economic status?, *Hacettepe Univ. J. Educ.* **41**, 339 (2011), <https://dergipark.org.tr/tr/download/article-file/87409>.
- [43] E. Redish, J. Saul, and R. Steinberg, Student expectations in introductory physics, *Am. J. Phys.* **66**, 212 (1998).
- [44] I. Halloun and D. Hestenes, Interpreting VASS dimensions and profiles for physics students, *Sci. Educ.* **7**, 553 (1998).
- [45] PhysPort-supporting physics teaching with research-based resources available at <https://www.physport.org/>.
- [46] K. Özmen and Ö. F. Özdemir, Conceptualisation, and development of the physics related personal epistemology questionnaire (PPEQ), *Int. J. Sci. Educ.* **41**, 1207 (2019).
- [47] A. Elby, T. McCaskey, R. Lippmann, and E. F. Redish, Version II (MPEX-II), Retrieved from <http://www.physics.umd.edu/perg/tools/attsur.htm> (2001).
- [48] B. White, A. Elby, J. Frederiksen, and C. Schwartz, Epistemological beliefs assessment for physical science (EBAPS), Retrieved from http://www2.physics.umd.edu/~elby/EBAPS/EBAPS_items.htm (1999).
- [49] C. Stathopoulou and S. Vosniadou, Exploring the relationship between physics-related epistemological beliefs and physics understanding, *Contemp. Educ. Psychol.* **32**, 255 (2007).
- [50] B. Zwickl, N. Finkelstein, and H. Lewandowski, Development and validation of the Colorado Learning Attitudes about Science Survey for experimental physics, in *Proceedings of the 2012 Physics Education Research Conference, Philadelphia, PA* (AIP, New York, 2012).
- [51] K. A. Douglas, M. S. Yale, D. E. Bennett, M. P. Haugan, and L. A. Bryan, Evaluation of Colorado Learning Attitude about Science Survey, *Phys. Rev. ST Phys. Educ. Res.* **10**, 020128 (2014).
- [52] I. Kontro and D. Buschhüter, Validity of Colorado Learning Attitudes about Science Survey for a high-achieving, Finnish population, *Phys. Rev. Phys. Educ. Res.* **16**, 020104 (2020).
- [53] K. Heredia and J. E. Lewis, A psychometric evaluation of the Colorado Learning Attitudes about Science Survey for use in chemistry, *J. Chem. Educ.* **89**, 436 (2012).
- [54] K. Chan and R. G. Elliot, Exploratory study of Hong Kong teacher education students' epistemological beliefs: Cultural perspectives and implications on beliefs research, *Contemp. Educ. Psychol.* **27**, 392 (2002).
- [55] F. Kurt, Investigating students' epistemological beliefs through gender, grade level, and fields of study, Master's thesis, Middle East Technical University, 2009.
- [56] H. Neber and M. Schommer, Self-regulated science learning with highly gifted students: the role of cognitive, motivational, epistemological, and environmental variables, *High Ability Stud.* **13**, 59 (2002).
- [57] K. Ozkal, C. Tekkaya, S. Sungur, J. Çakıroğlu, and E. Çakıroğlu, Elementary students' scientific epistemological beliefs in relation to socio-economic status and gender, *J. Sci. Teach. Educ.* **21**, 873 (2010).
- [58] M. S. Topçu and Ö. Yılmaz-Tüzün, Elementary students' metacognition and epistemological beliefs considering science achievement, gender and socioeconomic status, *Elem. Educ. Online* **8**, 676 (2009), <https://dergipark.org.tr/tr/download/article-file/90828>.
- [59] A. Madsen, S. B. McKagan, and E. C. Sayre, Gender gap on concept inventories in physics: What is consistent, what is inconsistent, and what factors influence the gap?, *Phys. Rev. ST Phys. Educ. Res.* **9**, 020121 (2013).
- [60] M. Windschitl, Student epistemological beliefs and conceptual change activities: How do pair members affect each other?, *J. Sci. Educ. Technol.* **6**, 37 (1997).
- [61] D. B. May and E. Etkina, College physics students' epistemological self-reflection and its relationship to conceptual learning, *Am. J. Phys.* **70**, 1249 (2002).
- [62] K. K. Perkins, W. K. Adams, S. J. Pollock, N. D. Finkelstein, and C. E. Wieman, Correlating student beliefs with student learning using the Colorado Learning Attitudes about Science Survey, *AIP Conf. Proc.* **790**, 137 (2005).
- [63] H. E. Chu, D. F. Treagust, and A. L. Chandrasegaran, Naive students' conceptual development and beliefs: The need for multiple analyses to determine what contributes to student success in a university introductory physics course, *Res. Sci. Educ.* **38**, 111 (2008).
- [64] M. Sahin, Effects of problem-based learning on university students' epistemological beliefs about physics and physics learning and conceptual understanding of Newtonian mechanics, *J. Sci. Educ. Technol.* **19**, 266 (2010).
- [65] J. Fraenkel, N. Wallen, and H. Hyun, *How to Design and Evaluate Research in Education*, 10th ed. (McGraw-Hill Comp, New York, NY, 2018).
- [66] J. H. McMillan and S. Schumacher, *Research in Education: A Conceptual Introduction*, 5th ed. (Longman Inc., New York, NY, 1997).
- [67] J. Pallant, *SPSS Survival Manual*, 4th ed. (Allen & Unwin, Australia, 2011).
- [68] B. G. Tabannick and L. S. Fidel, *Using Multivariate Statistics*, 6th ed. (Pearson, United Kingdom, 2001).

- [69] T. Panyajamorn, S. Suanmali, and Y. Kohda, Using MOOC and gamification hybrid learning models in rural public schools in Thailand, *J. Phys. Teach. Educ. Online* **19**, 18 (2022).
- [70] I. N. Kourilenko, Reflective assessment, feedback, and student achievement in foreign language studies: A mixed methods study, doctoral dissertation, Seattle Pacific University, 2013.
- [71] J. Cohen, *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed. (Lawrence Erlbaum Associates Publishers, Hillsdale, NJ, 1988).
- [72] Z. Hazari, G. Sonnert, P. M. Sadler, and M. C. Shanahan, Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study, *J. Res. Sci. Teach.* **47**, 978 (2010).
- [73] S. Sharma, P. K. Ahluwalia, and S. K. Sharma, Students' epistemological beliefs, expectations, and learning physics: An international comparison, *Phys. Rev. Phys. Educ. Res.* **9**, 010117 (2013).
- [74] M. Schommer, The influence of age and education on epistemological beliefs, *Br. J. Educ. Psychol.* **68**, 551 (1998).
- [75] J. B. Kahle and J. Meece, Research on gender issues in the classroom, in *Handbook of Research in Science Teaching and Learning*, edited by D. L. Gabel (Macmillan, New York, NY, 1994), pp. 543–557.
- [76] C. H. Crouch and E. Mazur, Peer instruction: Ten years of experience and results, *Am. J. Phys.* **69**, 970 (2001).
- [77] M. Lorenzo, C. H. Crouch, and E. Mazur, Reducing the gender gap in the physics classroom, *Am. J. Phys.* **74**, 118 (2006).
- [78] D. Kaltakci-Gurel, Development of an optics interest and experience scale (OIES) and exploring gender differences in prospective teachers' interest and experience, *J. Balt. Sci. Educ.* **17**, 935 (2018).
- [79] H. B. Carlone and A. Johnson, Understanding the science experiences of successful women of color: Science identity as an analytic lens, *J. Res. Sci. Teach.* **44**, 1187 (2007).
- [80] M. M. Alpaslan, Examining relations between physics-related personal epistemology and motivation in terms of gender, *J. Educ. Res.* **112**, 397 (2019).
- [81] M. Schommer, Effects of beliefs about the nature of knowledge on comprehension, *J. Educ. Psychol.* **82**, 498 (1990).
- [82] M. Schommer and K. Walker, Are epistemological beliefs similar across domains?, *J. Educ. Psychol.* **87**, 424 (1995).
- [83] C. S. Dweck, *Mindset: The New Psychology of Success* (Random House, Berkshire, 2006).
- [84] E. A. Linnenbrink and P. R. Pintrich, The role of self-efficacy beliefs in student engagement and learning in the classroom, *Read. Writ. Q.* **19**, 119 (2003).
- [85] L. Deslauriers, L. S. McCarty, K. Miller, and G. Kestin, Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom, *Proc. Natl. Acad. Sci. U.S.A.* **116**, 19251 (2019).