

## Variations in students' epistemological beliefs towards physics learning across majors, genders, and university tiers

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Students' epistemological beliefs have been confirmed to influence students' physics learning in an essential way. The Colorado Learning Attitudes about Science Survey (CLASS) is an assessment instrument for evaluating students' beliefs towards physics learning. In the present study, 817 students participate in our investigation with the mandarin CLASS version through three years of the undergraduate program among ten universities in China. We compare student performances on the CLASS across different majors, genders, and university tiers via the three-way analysis of variance. From the results, the main effect of major is found to be statistically significant. Students majoring in education consistently have a better performance of attitudes toward physics learning than those majoring in noneducation, regardless of gender and university tier. There are no main effects of gender and university tier, while the interaction between gender and university tier is detected significantly. No three-way interaction is detected among major, gender, and university tier. Therefore, this paper identifies how students' epistemological beliefs towards physics learning are related to various disciplines in universities, different genders, and qualitatively dissimilar content learning. For future work, it is worth investigating how students' epistemological beliefs towards physics learning are affected by the variable of year level and how the variable of year level interacts with major, gender, and university tier. According to the significant effect of major, it will make sense to investigate the correlation between epistemological beliefs and career interests or career expectations in future research.

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### I. INTRODUCTION

Over the last two decades, students' epistemological beliefs towards physics have attracted growing attention from physics educators. Epistemological beliefs represent a student's "personal knowledge or understandings that are antecedents of attitudes and subjective norms" [1]. Students' epistemological beliefs towards physics is about the nature of doing and knowing physics that can be linked to both their decision to engage in physics learning and their learning state of a physics course. In a large number of studies in physical education research (PER), epistemological beliefs towards physics learning are also studied in parallel with students' perspectives, expectations, beliefs, and views, which are all referred to as epistemological beliefs [2–7]. It has been reported that when learning content knowledge in a physics course, students would

bring a series of personal epistemological beliefs except for some relatively novice understanding [8]. As is broadly reported, these epistemological beliefs are different from those of experts [9–12].

The epistemological beliefs towards physics learning can impact students in a variety of ways [2–7]. In prior research, physics educators have studied different levels of expectations from novices to experts and detect the positive connections between student expectations and academic achievements [2,6,13]. It is found that physics-associated epistemological beliefs are linked to students' physics conceptual comprehension and behavior [13]. Past research results indicate that students' epistemological beliefs concerning physics can play a crucial and direct role in their learning [4,14–16]. Because students' epistemological beliefs, attitudes, and expectations towards physics would affect student motivation [15], learning strategies [17], students' capability of comprehending physics concepts [18], and students' self-evaluation of their learning [19]. As well, students' epistemological beliefs, attitudes, and expectations influence the way students build their own knowledge domain and their own comprehension of the material in physics courses [4,20]. Especially, students' beliefs play a significant role from making decisions to take physics courses to the retention in the subject.

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A lot of work has been done to address students' epistemological beliefs towards physics learning [2,8,14,21–23]. Researchers notice the impact of learning methods and instruction practices on student attitudes. For instance, the result of a previous study illustrates that various learning methods enhance student attitudes to different extents [24]. The influence of teaching strategies on student attitudes is reported by the researchers [8,11]. In Sahin's research [8], the author intends to survey the influences of problem-based learning (PBL) strategies on freshmen's physics epistemological beliefs, and their conceptual comprehension of Newtonian mechanics. The results show that both the PBL group and traditional group exhibit similar beliefs. A study reports that students' attitudes about science have a positive shift after the semester [25]. The change of students' attitudes is moderated by their educational background, specifically, if they have taken a physics course before they come into university [25]. Another research was conducted among first-year college students in the first term of an introductory calculus-based physics course within academic years 2007 and 2008 with the purpose of evaluating their expectations at the starting of the curriculum [26]. These precourse expectations show significant positive correlation with students' final exam scores on their general problem-solving ability. Furthermore, the investigation of attitudes and principles concerning physics has been conducted on a broad range of student groups, ranging from final-year senior middle school students and undergraduates, to postgraduates and workers at Edinburgh [27]. The result in another study displays that student epistemological beliefs towards physics generally become less expert-like even though students receive several years of traditional education [6]. In addition, it is found that girls' and boys' perceptions of the key facets of motivation and sustained engagement in relation to physics seem to be qualitatively the same [28].

Assessing students' epistemological beliefs about physics learning is not straightforward and more difficult. Several surveys have been developed with the purpose of evaluating and determining students' beliefs about how physics performs as science and how to learn physics [20,29–32]. Among a wide variety of related surveys, there are four well-known instruments evaluating students' beliefs about the physical science and student learning, including the Maryland Physics Expectation survey (MPEX) [12], the Colorado Learning Attitudes about Science Survey (CLASS) [25,31,32], the Epistemological Beliefs Assessment about Physical Science (EBAPS) [33], and the Views About Science Survey (VASS) [34]. Each instrument focuses on a particular aspect of student epistemological beliefs or expectations. Some survey student expectations in depth and others probe into the breadth of student beliefs [24].

As mentioned above, previous studies have demonstrated some significant relational mechanisms among epistemology, teaching, and learning in the domain of

physics. According to previous results, students' epistemological beliefs concerning physics learning can affect their learning. As well, their epistemological beliefs concerning physics learning could be affected by various factors, such as educational background, pedagogical method, and gender [6,14,25,28]. However, these factors have been examined individually in each prior study, but not in a collective report. There is a need to investigate the difference of students' epistemological beliefs towards physics learning across majors, genders, and university tiers. As to major, we attempt to investigate the variations and commonalities of multiple perspectives from university students including those who are planning to be physics teachers or science teachers in middle school or primary school and those who are not. In contrast to the latter, the former receive instructions towards not only science content knowledge, but also pedagogics and psychology. Their epistemological beliefs towards physics learning may be different. Therefore, students majoring in science fields and majoring in science education and physics education constitute our research samples. For the university tier, various tiers of universities present different teaching emphasis in China. Notably, the first-tier universities focus on cultivating students' theoretical and fundamental insights, while the second-tier universities tend to foster students' both applied knowledge and occupational preparation. We assume that there should be differences in students' epistemological beliefs towards physics learning between the two university tiers. Gender is another variable which is highly studied by researchers and we are interested in whether gender causes differences in students' epistemological beliefs towards physics learning among our participants. Among the existing well-known instruments for assessing student attitudes and beliefs mentioned above, the CLASS, which builds on three existing instruments of MPEX [12], EBAPS [33], and VASS [34], attracts more and more attention from science education researchers [35]. It was intentionally created to cover all science courses and is appropriate for students at all stages with its understandable language [29]. It is the most widely used survey of attitudes at present. According to the data of Google Scholar on November 15, 2018, the article about creating the instrument of the CLASS which was published in Ref. [29] has been cited in 564 articles. Therefore, we choose to apply CLASS to examine students' epistemological beliefs about physics learning across majors, genders, and university tiers. The CLASS also is available in multiple languages, including that which is necessary for this study. We propose the following research questions:

1. How do university students majoring in education and noneducation perform on CLASS?
2. How do students of the first-tier universities and the second-tier universities perform on CLASS?
3. How do university students of different genders perform on CLASS?

## II. METHODOLOGY

### A. CLASS

As the drive to enhance student attitudes towards physics has occurred in recent decades, the CLASS has turned into a crucial instrument to evaluate the effectiveness of curriculum reform [29]. The CLASS aims at evaluating students' perception of physics courses and learning physics, rather than whether students enjoy physics. The CLASS assessment consists of a filter statement in which students are required to choose category 4 as the acceptable answer and 41 statements which are classified into the following categories: Personal interest (PI), real world connections (RWC), problem solving general (PSG), problem solving confidence (PSC), problem solving sophistication (PSS), sense making or effort (SM/E), conceptual connections (CC), and applied conceptual understanding (ACU) [7]. The creators of the CLASS have defined PI as "I think about physics in my life," RWC as "physics describes the world," CC as "physics is based on a conceptual framework," SM/E as "I put in the effort to make sense of physics ideas," and the other four categories of PSG, PSC, PSS, and ACU as "equations represent concepts," namely, *Math Physics Connection* [11]. Additionally, another researcher follows this work and specifically defines problem solving as "the capability of understanding the problem with a particular schema and solving the problem with schema's techniques and equations" [36].

The CLASS has been applied in much research in PER [6,37,38]. The statements of the CLASS are clear and concise, so that it is applicable in various physics courses [39]. Research is carried out with the CLASS among various participants' groups, from middle school students to university staff. Related studies are conducted not only in North American or European institutes, but also in other countries such as China, Thailand, and Saudi Arabia [25,27,40]. The CLASS instrument has been translated into various languages; for instance, in Zhang and Ding's investigation, researchers have strictly translated CLASS into Mandarin for assessing Chinese students [6].

Additionally, the CLASS has been applied for evaluating the epistemological beliefs of students in different areas of science. A wide variety of particular survey tools related to CLASS have been modified. For instance, CLASS-Phys, CLASS-Chem, and CLASS-Bio are created to apply in the domains of physics, chemistry, and biology [1,6,41]. Also, the CLASS has been applied to evaluate the expertlike thinking of students majoring in engineering [42] and computer science [43].

### B. Student participants

As we intend to investigate the difference of students' epistemological beliefs towards physics learning among various participants' groups, we apply the Mandarin

CLASS as a written questionnaire to students across different majors, genders, and university tiers from 10 different Chinese universities. The students participating in our study are from two different tiers of universities. According to the criteria of admission in China, the first-tier universities enroll about the top 10% of students performing on the University Entrance Examination in each province in China, while those who are nearly the top 40% are enrolled in the second-tier universities. Participants in the study major in different science fields, including physics education, science education, electrical and electronics, computer science, communications engineering, mechatronics engineering, and environmental engineering. These majors are classified into the education and noneducation categories. Explicitly, students majoring in physics or science education form the education group and they intend to be physics teachers or science teachers after graduation. Those who major in electrical and electronics, computer science, communications engineering, mechatronics engineering, and environmental engineering constitute the noneducation group. All participants need to take compulsory courses related to physics (at least two times a week and lasting 80 min each) such as mechanics, electromagnetism, optics, thermal physics, atomic physics, etc.

There are a total of 948 students participating in the CLASS test at the end of the second semester of the 2017 academic school year. According to the timetables of students' course scheduling by schools, we provide the CLASS questionnaire in a paper version to students after class. The test takes about 10 min. Students are required to leave it blank if they are unsure of the meaning of the statements. The data are gathered, recorded, and then analyzed. Regarding the validity of the CLASS questionnaire, item 31 in the CLASS questionnaire is used for validating if students answer in a sincere manner and students who have not selected option 4 in item 31 are not included in the data analysis. Also, the questionnaires with multiple questions which have continuously selected the same option or consecutive loop numbers are not included in the statistics. Therefore, there are 817 valid questionnaires, and the efficiency of the questionnaire is 86.18% (817/948). A breakdown of the students in terms of gender, year level, and university tier is listed in Table I. There are 484 male students and 333 female students. In addition, the participants are either from the first-tier universities ( $N = 548$ ) or the second-tier universities ( $N = 269$ ). The majority of them are in the education group ( $N = 684$ ), and the others are in the noneducation group. Among them, there are 325 students in year 1, 307 students in year 2, and 185 students in year 3.

## III. FINDINGS

In the present study, we use SPSS statistics to establish the reliability evidence for the assessment of the CLASS. Summative descriptions are provided briefly to support the

TABLE I. A breakdown of participants in terms of gender, year level, and university tier.

Gender	Year level	Types of higher institutions		
		Tier 1	Tier 2	Total
Male	Year 1	87	75	162
	Year 2	195	8	203
	Year 3	88	31	119
Male count		370	114	484
Female	Year 1	63	100	163
	Year 2	66	38	104
	Year 3	49	17	66
Female count		178	155	333
Total		548	269	817

use of CLASS for our investigation. The reliability (Cronbach's alpha) coefficient for the CLASS is 0.765, indicating a sufficient consistency in the outcomes of our study.

As mentioned above, the results of CLASS may be affected by three independent variables (major, gender, and university tier), which may also interact. The three-way analysis of variance (ANOVA) is used to examine the main effects and interaction effects of student performances across majors, genders, and university tiers. First, the main effects of each variable are examined to see if the variable has an impact on the CLASS results. Second, the interaction effects are analyzed to gain a more complete understanding of whether each main effect is affected by another variable. For instance, if there is a main effect of major, with no interaction effect between major and gender, we can conclude that the main effect of major does not depend on gender. However, if there is no main effect of major, but the interaction effect between major and gender exists, we can conclude that the variable of major affects CLASS results and that the effect of major depends on gender. In the case of interactions among variables, we conduct Sidak pairwise comparisons to investigate the

difference in the effect of one variable at different levels of the other. Furthermore, we compare various categories of student epistemological beliefs across majors, genders, and university tiers, using the three-way analysis of variance (ANOVA) and Sidak pairwise comparisons.

### A. Students' overall performances on CLASS across majors, genders, and university tiers

Table II illustrates the descriptive statistics of student performances on the CLASS for all participants and for those in each group labeled according to the different variables of major, gender, university tier, and year level. The overall mean score of students on CLASS is higher than 3 (mean score = 3.29, SD = 0.30). For major, students majoring in education (mean score = 3.37, SD = 0.29) perform better than those with noneducation majors (mean score = 3.28, SD = 0.30). In terms of gender, the group of male students has a similar mean score as the group of female students. Further, the mean score of students in the first-tier universities (mean score = 3.28, SD = 0.30) is a little lower than that of students in the second-tier universities (mean score = 3.33, SD = 0.28). When it comes to year level, it is found that the mean scores do not differ a lot among students from the first year to the third year in the universities. As there are only 8 male students in the group of year 2 and 17 female students in the group of year 3 in our research sample, we do not include year level in the coming interaction analysis to make sure our analysis is statistically valid.

To explore the difference of students' epistemological beliefs towards physics learning among various groups of participants, we compare student performances on the CLASS across different majors, genders, and university tiers. The data are categorized into 8 groups of students derived from 2 majors  $\times$  2 genders  $\times$  2 university tiers. The mean score of each group is calculated and plotted in Fig. 1. Overall, students majoring in education consistently have a better performance of attitudes toward physics learning than those majoring in noneducation, regardless of gender and university tier. Within the first-tier universities,

TABLE II. The descriptive statistics of student performances on the CLASS.

		N	Mean score	The highest	The lowest	Overall mean score (standard deviation)
			(standard deviation)	score	score	
Major	Education	684	3.37 (0.29)	4.20	2.24	3.29 (0.30)
	Noneducation	133	3.28 (0.30)	4.12	2.59	
Gender	Male	484	3.30 (0.28)	4.12	2.41	
	Female	333	3.28 (0.32)	4.20	2.24	
University tier	Tier 1	548	3.28 (0.30)	4.20	2.25	
	Tier 2	269	3.33 (0.28)	3.95	2.59	
Year level	Year 1	325	3.30 (0.29)	3.98	2.24	
	Year 2	307	3.31 (0.30)	4.20	2.39	
	Year 3	185	3.27 (0.30)	4.12	2.59	

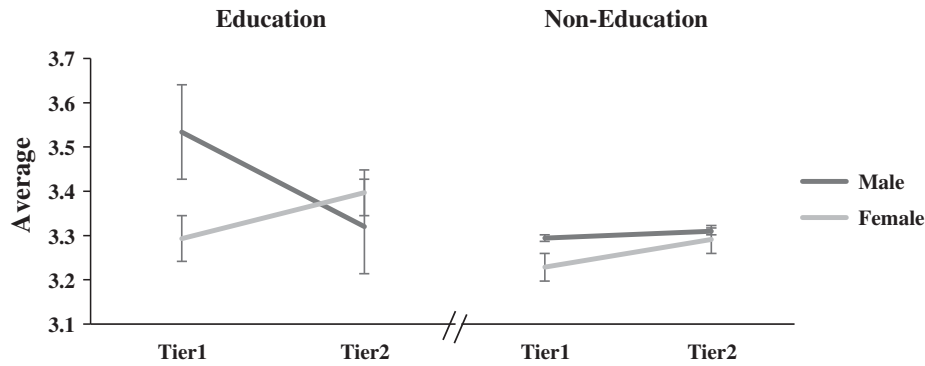


FIG. 1. Students' overall performances on the CLASS across different majors, genders, and university tiers.

students majoring in education demonstrate a higher level of attitudes toward physics learning regardless of genders, followed by the noneducation majors. Students from the second-tier universities do not perform much differently among groups in terms of majors and genders. Besides, the performance of male students is equivalent to that of female students in general. However, within the education group of the first-tier universities, male students perform better than female students.

Next, the correlation analysis is carried out based on the trivariate model to present a perspective on the relationships among three variables in our study. We conduct a normality test based on the Kolmogorov-Smirnov test for each group, and the results show normal distributions for all data sets (all  $p > 0.08$ ). To test the homogeneity of variance, we conduct the Levene's test and there are no significant differences in variance among the groups ( $p > 0.10$ ). Therefore, after evaluating the above two prerequisites, we conduct a three-way ANOVA (2 majors  $\times$  2 genders  $\times$  2 university tiers) with student performances on the CLASS as the dependent variable. From the results of the three-way ANOVA in Table III, there is a significant main effect of major ( $F = 7.900$ ,  $p = 0.005$ ), indicating whether students major in education or noneducation affect their epistemological beliefs towards physics learning. However, this main effect is not qualified by the interactions between major and gender ( $F = 0.285$ ,  $p = 0.593$ ), and between major and university tier ( $F = 1.563$ ,

$p = 0.212$ ). The interactions suggested that the main effect of major does not differ either between genders or between university tiers.

There are no main effects of gender ( $F = 2.727$ ,  $p = 0.099$ ) and university tier ( $F = 0.045$ ,  $p = 0.831$ ), indicating that students' epistemological beliefs towards physics learning do not depend on either gender or university tier, while the interaction between gender and university tier is detected as statistically significantly ( $F = 5.897$ ,  $p = 0.015$ ). This interaction suggests that the main effect of gender might differ between university tiers, or the main effect of university tier might differ between genders. There is no three-way interaction among major, gender, and university tier ( $F = 3.216$ ,  $p = 0.073$ ). Thus, the interaction of gender and university tier does not depend on major.

To further investigate how the two variables of gender and university tier interact with each other, we conduct Sidak pairwise multiple comparisons, collapsing majors while, respectively, keeping the two university tiers separate and keeping the two genders separate. According to the analysis, for one aspect, among the first-tier university students, there is a significant difference between two genders ( $F = 5.539$ ,  $p = 0.019$ ), indicating that male students (mean score = 3.30, SD = 0.29) achieve a noticeably higher performance on epistemological beliefs towards physics learning than female students (mean score = 3.23, SD = 0.34). However, no statistically

TABLE III. Three-way ANOVA for overall epistemological beliefs towards physics learning.

Source	Type III sum of squares	df	Mean square	F	$p$ value
Major	0.682	1	0.682	7.900	0.005
Gender	0.235	1	0.235	2.727	0.099
University tier	0.004	1	0.004	0.045	0.831
Major $\times$ Gender	0.025	1	0.025	0.285	0.593
Major $\times$ University tier	0.135	1	0.135	1.563	0.212
Gender $\times$ University tier	0.509	1	0.509	5.897	0.015
Gender $\times$ University tier $\times$ Major	0.278	1	0.278	3.216	0.073

significant difference has been detected between two gender groups among the second-tier university students ( $F = 0.607, p = 0.436$ ). For the other aspect, there is no statistically significant difference between two tiers of universities among either male students ( $F = 2.735, p = 0.099$ ) or female students ( $F = 3.386, p = 0.066$ ).

**B. Categories of epistemological beliefs towards physics learning across majors, genders, and university tiers**

As mentioned, the CLASS measures various categories of student epistemological beliefs towards physics learning, including personal interest, real world connection, problem solving general, problem solving confidence, problem solving general, problem solving confidence, problem

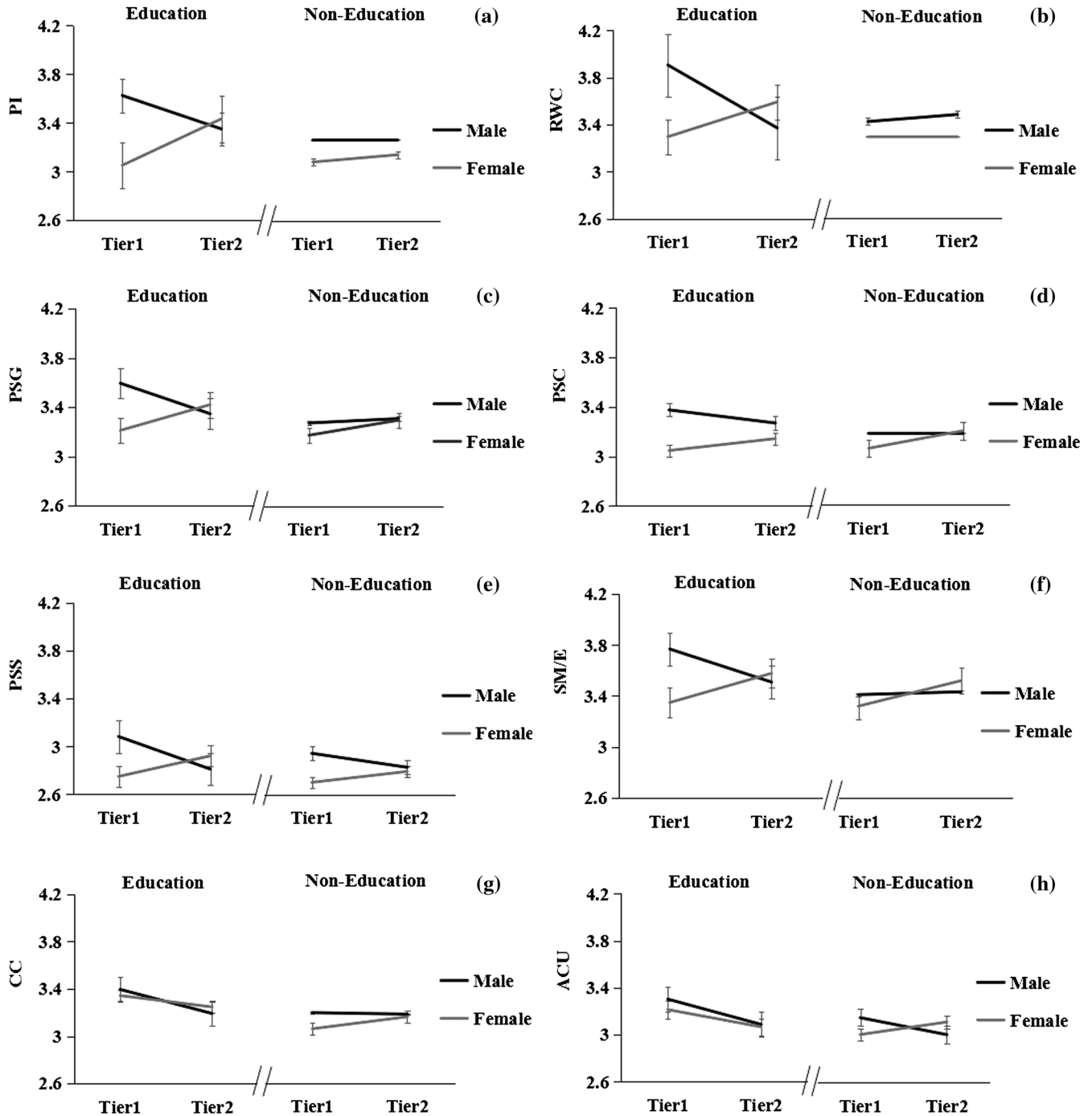


FIG. 2. Categories of epistemological beliefs towards physics learning measured by the CLASS. (a) personal interest (PI), (b) real world connection (RWC), (c) problem solving general (PSG), (d) problem solving confidence (PSC), (e) problem solving sophistication (PSS), (f) sense making/effort (SM/E), (g) conceptual connections (CC), and (h) applied conceptual understanding (ACU). Each data point represents the average score of each group. Error bars represent standard errors.

solving sophistication, sense making/effort, conceptual connections, and applied conceptual understanding. To identify how different categories of students' epistemological beliefs towards physics learning are related to various disciplines in universities, different genders, and qualitatively dissimilar content learning, student performances on these categories are compared across majors, genders, and university tiers.

Similarly, students' scores of each category are averaged for each of the 8 groups and plotted in Fig. 2. As shown in Fig. 2, except for two categories of conceptual connections and applied conceptual understanding, the patterns emerging from the other six categories resemble students' overall performances on the CLASS in Fig. 1. Overall, male students majoring in education have higher scores in all categories of students' epistemological beliefs towards physics learning in the first-tier universities than those in the second-tier universities. In contrast, female students majoring in education have lower scores of epistemological beliefs towards physics learning for most categories in the first-tier universities than those in the second-tier universities, except for the CC and the ACU category. Besides, within the first-tier universities, male students majoring in education perform better than female students, except for those in the CC and the ACU category. While, there are not many differences between genders for students majoring in noneducation in the first-tier universities for each category. Furthermore, students from the second-tier universities do not differ too much among groups in terms of majors and genders for each category of epistemological beliefs towards physics learning.

A three-way ANOVA is conducted for each category of epistemological beliefs towards physics using major, gender, and university tier as independent variables. The results are summarized in Table IV.

The results of three-way ANOVA on two categories of problem solving general and sense making/effort are extremely similar with the result of students' overall epistemological beliefs towards physics learning on the CLASS. Their main effects on the independent variable of major are significant and there are significant interaction

effects between gender and university tier. For two categories of personal interest and real world connection, expect for the above similar significant effects, the main effects on gender are detected statistically significantly and there are three-way interactions among majors, genders, and university tiers. Students performance on the category of problem solving general is greatly different from that on the category of problem solving sophistication. No significant main effect is detected on each of the independent variables for the category of problem solving sophistication. Only the interaction effect between gender and university tier is detected statistically significantly and there are no other significant interaction effects. For the other three categories of conceptual connections, problem solving confidence, and applied conceptual understanding, expect that there is a significant main effect of major for the category of conceptual connections, no other main effects and interaction effects are detected significantly based on the results of three-way ANOVA shown in Table IV.

To display our results in a concise manner, we conduct a further analysis, Sidak pairwise multiple comparisons, for each category with significant interaction effects. It is seen that, concerning to two categories of personal interest and real world connection, the effects of gender are found to be significant in the first-tier universities on both education majors (PI:  $F = 10.136$ ,  $p = 0.002$ ; RWC:  $F = 5.257$ ,  $p = 0.022$ ) and noneducation majors (PI:  $F = 5.050$ ,  $p = 0.002$ ; RWC:  $F = 5.552$ ,  $p = 0.019$ ). While in the second-tier universities, the effects of major are statistically significant, with higher scores of students majoring in education than those of students majoring in noneducation (PI:  $F = 9.969$ ,  $p = 0.002$ ; RWC:  $F = 5.794$ ,  $p = 0.002$ ). It is also observed that, concerning three categories of problem solving general, problem solving sophistication, sense making/effort, the effects of gender are found to be significant in the first-tier universities (PSG:  $F = 4.793$ ,  $p = 0.029$ ; PSS:  $F = 5.704$ ,  $p = 0.017$ ; SM/E:  $F = 6.309$ ,  $p = 0.012$ ), with better performances for male students.

In summary, the university tier is detected to be statistically significant among female students in three

TABLE IV. The results of a three-way ANOVA for each category of epistemological beliefs towards physics learning. The table lists the  $p$  values of the ANOVA results for all of the eight categories, which are less than 0.05, indicating the significant main effects of the independent variables or the significant interaction effects between independent variables at significance level = 0.05. See category definitions in text and Fig. 2 caption.

	ALL	PI	RWC	PSG	SM/E	PSS	CC	PSC	ACU
Major	0.005	0.013	0.027	0.039	0.037		0.033		
Gender		0.009	0.020						
University tier									
Major × Gender									
Major × University tier									
Gender × University tier	0.015	0.018	0.012	0.033	0.005	0.020			
Gender × University tier × Major		0.047	0.004						

categories of personal interest, problem solving general, along with sense making/effort. In terms of major, no statistical significance is detected in three categories of problem solving confidence, problem solving sophistication, and applied conceptual understanding. However, in the other five categories, students majoring in education perform noticeably better than those majoring in noneducation. Especially, the effect of major is found to be statistically significant among male students in the first-tier universities for the category of real world connection, and among female students in the second-tier universities for two categories of personal interest as well as real world connection.

#### IV. DISCUSSION

##### A. Differences in epistemological beliefs towards physics learning across majors in higher education

As evident from the above findings, a main effect of major was detected and this main effect revealed no differences between genders or between university tiers, resulting from no interaction effects between major and gender, and between major and university tier. For more details of the effect of major, no statistical significance is detected in three categories of problem solving confidence, problem solving sophistication, and applied conceptual understanding. However, in the other categories, students majoring in education have noticeably more sophisticated epistemological beliefs than those majoring in noneducation. Further, there is significant effect on major within male students in the first-tier universities for the real world connection category, and among female students in the second-tier universities for the categories of personal interest as well as real world connection.

In our study, according to the different science fields, students who major in electrical and electronics, computer science, communications engineering, mechatronics engineering, and environmental engineering are classified into the noneducation group, while those who major in physics education and science education constitute the education group. All participants experience physics learning over the period of secondary schooling in China. Through the college entrance examination, they are accepted by the university and major in physics-related disciplines. Students' different performances on the CLASS between education and noneducation groups may not be caused by the secondary schooling. Bates *et al.* found that the CLASS scores of middle school students who were ready to specialize in physics were similar with freshmen majoring in physics, but middle school students who did not plan to major in physics-related disciplines performed worse in the CLASS [27]. This displays that physics-related majors cultivate expertlike viewpoints in their K – 12 education. Therefore, the reason that students majoring in education achieve better performance on the CLASS may be attributed to instruction in universities. That is, the instructional

methods in the classes for education majors and non-education majors are different with various curriculum materials or instructional techniques. There was evidence suggesting that various teaching methods contributed to be an important aspect of students' attitudes towards science [44,45]. In contrast to students majoring in noneducation, those majoring in education receive instruction towards not only science content knowledge, but also pedagogics and psychology. Students in the education group who are preservice teachers seem to develop a more positive attitude to physics, as they will become physics teachers or science teachers after graduation. They may be eager to experience learning activities and learn excellent strategies making for effective teaching in the class from the point of view of pupils [46].

##### B. Differences in epistemological beliefs towards physics learning across genders

Prior research reported that gender had an impact on students' beliefs regarding physics and studying physics [29]. Therefore, it was important to study whether gender was related to students' beliefs about what experts believe. According to Gray *et al.*, it was believed that female students displayed a wider gap between their "physicist" thoughts and their "personal" thoughts compared with male students in the same course. This gap indicated that although female students were better at recognizing what ideas physicists felt, they were less likely to believe that these ideas were valid or related to their experiences [9]. Hence, a solid body of literature displayed that female students achieved noticeably lower levels of enthusiasm and participation with physics than males [47,48].

However, the data in the present study do not strongly support the above opinions. According to the results in this research, students' epistemological beliefs towards physics learning vary significantly between genders only within the first-tier universities. But they vary little between genders among students in the second-tier universities as well as students in different majors regardless of university tier. Although male students majoring in education perform better than female students in general in the first-tier university, both groups of male and female students majoring in noneducation have similar mean scores in the first-tier universities. Hence, the three-way ANOVA result suggests that students' epistemological beliefs towards physics learning do not depend on gender, because of no main effect on the pattern of gender. They demonstrate similar levels of abilities and learning confidence about physics. It means that the variable of gender contributes a minor part in students' epistemological beliefs. This research extends the present understanding in gender differences of students' epistemological beliefs towards physics learning. Previous research displayed that teachers conveyed gender-biased viewpoints of students' capability in certain physics modules [49], while in this



research male and female students regard themselves to be equally capable. The result has substantive significance for educational investigators and practitioners and is able to shield teachers from bias of classroom practices according to gender-differentiated expectations [28].

### C. Differences in epistemological beliefs towards physics learning across university tiers

As is known to all, the planned content learning at the different tiers of higher education is qualitatively different. In China, the first-tier universities put great emphasis on training students to attain not only theoretical but also fundamental insights. However, students in the second-tier universities have a greater opportunity to receive both applied knowledge and occupational preparation. As reported in the previous research, on a basis of the knowledge categorization model, students in the second-tier universities might not meet the same requirements to grasp theoretical or hypothetical concepts as those in the first-tier universities [50]. However, concerning students' epistemological beliefs towards physics learning, student performance might not differ a lot between different tiers of universities. From our results, there is no main effect of the university tier. Although the interaction effect is detected significantly between university tier and gender, the further Sidak pairwise multiple comparisons suggest that there is no significant difference between two tiers of universities among either male students or female students. Our data indicate that the university tier is not the factor affecting students' epistemological beliefs towards physics learning. In other words, the epistemological beliefs from students who mainly obtain theoretical concepts differ little from those who are involved in occupational preparation.

## V. CONCLUSIONS AND FUTURE WORK

We use the Mandarin CLASS version to study university students' epistemological beliefs towards physics learning. A total of 817 students participate in the study through three years of the undergraduate program among ten universities in China. We compare student performances on the CLASS across various majors, genders, and university tiers. The main effect of major is found to be statistically significant. Students majoring in education consistently have a better performance of attitudes toward physics learning than those majoring in noneducation, regardless of gender and university tier. There are no main effects of gender and university tier, while the interaction between gender and university tier is detected statistically significantly. There is no three-way interaction among major, gender, and university tier, suggesting that the interaction of gender and university tier does not depend on major.

A three-way ANOVA is conducted for each category of epistemological beliefs towards physics. The results indicate that student performance on two categories of problem solving general and sense making/effort are similar with that on overall epistemological beliefs towards physics learning. For two categories of personal interest and real world connection, expect for the above similar significant effects, the main effects on gender are detected statistically significantly and there are three-way interactions among major, gender, and university tier. However, the data show weak main effects on each independent variable and poor interaction effects among three independent variables for the other four categories of the problem solving general, conceptual connections, problem solving confidence, and applied conceptual understanding.

Based on the research results, future work will investigate the following three aspects: (i) How do student performances on each category of the CLASS correlate with each other? Especially, the correlation of student performances among four categories of PSG, PSC, PSS, and ACU is worth studying, as all of them are under the same category of math physics connection [11]. (ii) How are students' epistemological beliefs towards physics learning affected by the variable of year level and how does the variable of year level interact with major, gender, and university tier? In the current research, the one-way ANOVA result suggests that students in different year level do not perform significantly differently ( $F = 0.684$   $p = 0.505$ ). Because of the small amounts of male students in year 2 (only 8) and female students in year 3 (only 17), we do not include year level in the interaction analysis. The issue about how year level interact with major, gender, and university tier will be what to look for in later research. (iii) Whether students' epistemological beliefs towards physics in the education group and noneducation group correlate highly with their career interests or career expectations? From our result, there is a significant main effect of major and the main effect does not differ either between genders or between university tiers. Based on the actual employment intension that most students in the education group will be physics teachers or science teachers after graduation, it makes sense to investigate the correlation between epistemological beliefs and career interests or career expectations in future research.

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