A Comparative Study of Middle School and High School Students' Views about Physics and Learning Physics

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Abstract. Previous studies of student epistemological beliefs about physics and learning physics focused on college and post-college students in Western countries. However, little is known about early-grade students in Asian countries. This paper reports Chinese middle and high school students' views about the nature of physics and learning physics, measured by the Colorado Learning Attitudes Survey about Science (CLASS). Two variables—school level and gender—are examined for a series of comparative analyses. Results show that although middle school students received fewer years of education in physics, they demonstrated more expert-like conceptions about this subject matter than high school students. Also, male students in general exhibited more expert-like views than their female counterparts. While such a gender difference remained constant across both middle and high schools, for the most part it was a small-size difference.

Keywords: physics and learning physics, epistemology, middle school, high school, physics education.
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INTRODUCTION

Besides the usual goal of improving student conceptual understanding and problem solving skills, many physics courses also seek to cultivate among students expert-like views and attitudes about the subject matter. These views and attitudes that pertain to the nature of physics and the process of learning are referred to as epistemological beliefs and have received much attention in recent studies of physics education research.[1-3] A driving force for this line of research originates from the increasing body of evidence suggesting that a learner's beliefs about a subject matter can exert direct and significant impact on his/her learning and particularly on his/her approaches to studying the subject matter.[1,2] As a result, these beliefs may affect student learning outcomes.[1,2]

Among different methods of studying epistemological beliefs in school science, a traditional and perhaps the most commonly used technique is to directly observe the ways students respond to domain related tasks either in natural learning environments (such as classrooms) or in research lab settings (such as student interviews). In physics this method is consistently used for in-depth small-scale case studies of student epistemological beliefs.[1,2] Another typical method is to use research-based written surveys to measure common belief patterns among many students.[4-7] Given the established validity and reliability of these surveys, this method can allow us to conveniently obtain a large data set for quantitative analysis and, with additional information, to empirically test student epistemological beliefs in relation with other variables, such as learning outcomes.

Several survey tools have been developed to measure student beliefs about physics and learning physics. These include the Colorado Learning Attitudes Survey about Science (CLASS) [4], Epistemological Beliefs Assessment for Physical Sciences (EBAPS) [5], the Maryland Physics Expectations Survey (MPEX) [6], and the Views about Science Survey (VASS) [7]. Of these surveys, CLASS is the most broadly used instrument, perhaps because it contains language suitable for typical students taking any level of physics courses [4], and perhaps also because the items therein are phrased in a way that misinterpretation of their meanings is unlikely by either students or practicing physicists, therefore usable with a broad spectrum of populations.[4]

Previous studies using the CLASS to gauge student views about physics and learning physics have predominantly shown that after a course of a typical physics curriculum student beliefs become noticeably less expert-like.[4] More interestingly, even many reform-based physics curricula fail to raise student results on the CLASS despite the success in increasing student learning gains measured by concept inventories or course examinations.[4] So far only a handful of exceptions have been reported in the literature. These exception cases suggest that in order to improve student epistemological beliefs, instruction needs to explicitly and reflectively address the nature of physics and the process of learning.[3] In contrast, however, one recent study has found that modelingbased physics instruction, which implicitly taps into epistemology by offering students the opportunity of scientific practice through model building, evaluation, and deployment, also promote more expert-like views about physics and learning physics.[8]

Although these previous studies have contributed to our understanding of student epistemological patterns, the majority of them were conducted with college or post-college students who were required to take physics courses of some sort toward the completion of their degree. Since physics is not a required curriculum at the pre-college level in the U.S., many early-grade students either choose not to study it or are not offered such a course in their schools. Consequently, research on this population regarding their views about physics and learning physics is rare. In addition, most studies in this area were carried out in Western countries mainly in America and Europe. But little is known about students of Asian countries in this regard. In fact, to the best of our knowledge, there has been no published work using the CLASS to measure student epistemological beliefs in Asian nations. Therefore, research in this direction is needed to explore how international students studying physics during their early ages view the nature of this subject matter and the process of learning.

RESEARCH QUESTIONS

In this paper, we report a comparative study of Chinese middle school and high school students' epistemological views about physics, measured by the CLASS. Also, we explore the gender effect, together with the school-level effect, on student CLASS results. Specifically, we seek to answer the following research questions. (1) What are the epistemological patterns of Chinese pre-college students measured by the CLASS? (2) How do middle school students compare to high school students on CLASS? (3) How does gender play a role in pre-college students' epistemological views; in particular, is there an interaction between gender and school-level in their effect on student CLASS scores?

METHODOLOGY

The population of interest in the study is Chinese middle school (8^{th}-9^{th} grades) and high school (10^{th}-12^{th} grades) students studying physics as a compulsory science course. In China, physics is a required course separate from other sciences starting at the 8^{th} grade and through the end of high school. During this period, students take physics each year and go through two cycles of learning. One is in middle school where students learn basic concepts in lectures and labs to describe, explain, and predict everyday phenomena. Topics covered in this cycle are fairly extensive, including mechanics, waves, thermal physics, electricity, magnetism, and optics, but are less in-depth. The second cycle begins in the first year of high school; students attend traditional lectures and labs and learn to understand and solve physics problems by using basic algebra. While topics are similar to what is covered in middle school, the depth is greater.

In this study, we used the CLASS to measure students' beliefs and attitudes about physics and learning physics. The survey was first translated into Mandarin independently by two researchers—the author and a non-physics education researcher fluent in both English and Chinese. The two versions of translation were scrutinized by a third researcher who then revised them into one single version. Next, another bilingual researcher who did not know the CLASS at that time translated the revised Mandarin version back to English. A group of researchers, including several physicists in China, compared the back-translated English survey with the original survey to further refine the Mandarin version. After rounds of discussion and revision, as well as private communications with the CLASS authors, the translation was finalized.

The CLASS consists of 42 statements, on which students rate their agreement levels by using a 5-point scale, ranging from strongly agree to strongly disagree. For scoring purposes, this 5-point scale is reduced into a 3-point scale, collapsing "agree" and "strongly agree" into one point, "disagree" and "strongly disagree" into another, and leaving "neutral" as the mid-point. Twenty-seven items are grouped into 8 categories (see Table II), and the remaining 15 items are either not categorized or not used for scoring [4]. The percentage of a student's responses that agree with experts' responses is calculated and referred to as favorable percentage [4].

The paper-and-pencil CLASS survey was administered to 521 middle school and 797 high school students in four Chinese provinces during the fall semester of 2011, close to the midterm of their respective physics courses. Basic student demographic information was also recorded, such as gender and school level. The breakdown for gender composition is shown in Table I. Student written data was collected, tabulated and analyzed for comparative analyses.

TABLE I. Participating students' demographic information.

School	Male	Female	No Response	Total
Middle	248	273	0	521
High	400	387	10	797
Total	648	660	10	1318

TABLE II. CLASS results for all students, middle and high school students. Parenthetical numbers indicate standard errors.

CLASS categories	All students	Mid. Sch.	High Sch.	M – H differ.	M. *vs.* H. t-test	Effect size
Overall	55.4 (0.4)	59.2 (0.6)	52.9 (0.6)	6.3	t=7.27, p<.0001	0.4
Real world connection	68.8 (0.9)	76.2 (1.2)	64.0 (1.2)	12.3	t=7.28, p<.0001	0.4
Personal interest	52.1 (0.7)	59.1 (1.1)	47.5 (0.9)	11.6	t=8.04, p<.0001	0.5
Senses making/effort	62.9 (0.7)	68.6 (1.0)	59.2 (0.9)	9.4	t=7.08, p<.0001	0.4
Concept. understanding	60.7 (0.7)	65.0 (1.0)	57.9 (0.9)	7.1	t=5.43, p<.0001	0.3
App. concept. Understand.	45.8 (0.6)	48.2 (1.0)	44.2 (0.8)	4.0	t=3.11, p=.0019	0.2
PS general	61.6 (0.7)	67.5 (1.0)	57.8 (0.8)	9.7	t=7.54, p<.0001	0.4
PS confidence	61.7 (0.8)	68.2 (1.2)	57.4 (1.1)	10.8	t=6.58, p<.0001	0.4
PS sophistication	46.9 (0.8)	52.5 (1.1)	43.3 (1.0)	9.2	t=6.05, p<.0001	0.3

DATA ANALYSIS AND RESULTS

Overall CLASS Results

Table 2 shows the Chinese pre-college students' performance on the CLASS. As seen, the overall favorable percentage for all the surveyed students is 55.4%, comparable to the CLASS scores of American college students taking introductory physics courses (with reported averages varying from 51% to 65%) [8-9], and slightly higher than the typical results of Croatian high school students (avg. ~51%).[4] Students' favorable percentages for the 8 categories of CLASS are also shown in Table II. They range from 45.8% (applied conceptual understanding) to 68.8% (real world connection), and all but one category—problem solving confidence—are higher than those reported for the Croatian high school students.[9]

Comparisons between High School and Middle School Students

Also listed in Table 2 is the breakdown in the overall and 8 categorical favorable percentages for the middle school and high school students. As seen, although the middle school students had learned significantly less material and perhaps had less in-depth physics knowledge than did high school students, they demonstrated more expert-like attitudes and beliefs on all the categories. In fact, the overall favorable percentage for the middle school students is nearly 60%; close to the American college students' pretest overall average on the CLASS. On the other hand, the high school students showed more novice-like beliefs about physics and learning physics. Their average favorable percentages on the 8 categories are statistically lower than those of middle school students (all p values <0.002). The analysis of effect size further suggests that the significant differences between the middle school and high school students are of medium or large size for nearly all the categories, except for "applied conceptual understanding" in which the difference is smaller. Notably, the three categories with an average difference of over ten percentage points between the middle and high school students are "real world connection", "personal interest" and "problem solving confidence". In other words, as the students progress to higher levels of schooling, their interest in physics, their tendency to view the subject matter as a refinement of daily-life experience, and their confidence in dealing with problems become significantly less aligned with physicists' opinions.

Gender Differences

To study the gender effect on student beliefs about physics and learning physics, we further looked into the responses of male and female students separately. As shown in Table III, male students provided more favorable responses than did female students on the overall CLASS as well as on the 8 individual categories. In particular, a two-sample t-test indicates a significant gender difference for the majority of the 8 categories, except for "real world connection" and "sense making/effort". However, a closer look at the effect size reveals that although male students' responses are more expert-like, their differences from female students on most of the categories are of a small effect size (see the last column in Table III).

Another interesting question to ask is: how does the gender difference in middle school, as revealed by the CLASS results, compare to that in high school? A two-way ANOVA involving both variables—gender and school level—was conducted to investigate whether one variable interacts with the other in their effect on student CLASS scores. Results show that there is no statistically meaningful interaction between the two variables for both the overall CLASS scores and the 8 individual categories (all p values >0.18). In other words, the gender difference (or the gender similarity on "real world connection" and "sense making/effort") remains constant as students proceed from middle school to high school.

TABLE III. CLASS results for all male and female students. Parenthetical numbers indicate standard errors.

CLASS categories	Male	Female	M – F differ.	M. *vs.* F. t-test	Effect size
Overall	57.3 (0.6)	53.5 (0.6)	3.8	t=4.35, p<.0001	0.2
Real world connection	70.1 (1.2)	67.4 (1.2)	2.7	t=1.53, p=.126	0.1
Personal interest	54.8 (1.0)	49.3 (1.0)	5.5	t=3.78, p=.0002	0.2
Sense making/effort	64.0 (0.9)	61.7 (0.9)	2.3	t=1.76, p=.078	0.1
Concept. understanding	62.3 (1.0)	59.2 (0.9)	3.1	t=2.30, p=.0214	0.1
App. concept. Understand.	49.1 (0.9)	42.6 (0.9)	6.5	t=5.11, p<.0001	0.3
PS general	64.3 (0.9)	58.9 (0.9)	5.4	t=4.12, p<.0001	0.2
PS confidence	65.4 (1.1)	58.0 (1.2)	7.3	t=4.51, p<.0001	0.2
PS sophistication	51.9 (1.1)	42.0 (1.1)	9.9	t=6.25, p<.0001	0.4

DISCUSSION AND CONCLUSIONS

This study addresses a both interesting and important topic regarding Chinese pre-college students' views about physics and learning physics, measured by the CLASS. While previous research along this line has provided useful insights into college and post-college students' epistemological ideas about physics in Western countries, little is known about early-grade students in Asian countries on this matter. Since students in China are required to study physics as a separate science course starting in middle school and continuing into high school, it is important for researchers to seize this unique opportunity to investigate how early-age teaching and learning of physics affects students' conceptions about this subject matter.

In the present study, a comparative analysis is made between Chinese middle school and high school students in their performances on the CLASS. Additionally, gender differences are investigated. The results of our study show that although middle school students received fewer years of education in physics than those in high school, their conceptions about what physics is and how physics should be learned seemed to be more expert-like. Based on this result alone, it would be premature to conclude that pre-college physics instruction had caused students' epistemological beliefs to become less sophisticated and more naïve, as we have not yet conducted finer-grained analyses at each grade level or examined such results in concert with the features of grade-level appropriate course instruction. Classroom instruction likely has played a significant role in the results we have observed. But a question remains for future studies; that is, in what ways and to what extent does pre-college education at each grade level affect students' epistemological views about physics?

This study also shows that female students hold less expert-like views about physics than their male counterparts. Although the gender difference is small on most categories of the CLASS, it is statistically meaningful and stays constant across middle school and high school. This can be interpreted as both good and bad news. On the positive side, the years of teaching and learning have not widened the gender gap in student views about physics. On the flip side, little has been achieved over the years to bring the female students up to the same level as their male counterparts. It will be interesting to further explore how pre-college physics instruction has influenced the gender-related results revealed in this study.

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