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Research Article

Taiwan Junior High School Adolescents' Epistemological Beliefs toward Mathematics and Science

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Few previous studies have compared students' epistemological beliefs in mathematics with those in science. To ascertain the discipline and gender differences on students' epistemological beliefs, this study conducted a survey with 495 Taiwanese ninth graders in junior high school. Findings show that female students express the stronger belief that science learning occurs in a quick fashion as compared with the view that mathematics learning occurs in a quick fashion , both male and female students express the stronger belief that mathematics knowledge is certain as compared with the view that science knowledge is certain, and male students express the stronger belief that science knowledge is simple and the ability to learn science is fixed as compared with the view that mathematics knowledge is simple and the ability to learn mathematics is fixed. Male students were also in more agreement in their belief about quick learning, certain knowledge, simple knowledge, and the innate ability of mathematics, as well as certain knowledge, simple knowledge, and the innate ability of science, than were female students. This study also revealed that students' beliefs about knowledge are domain-specific, but some evidence of domain-general beliefs also exists.

1. Introduction

1.1. Epistemological Beliefs toward Mathematics and Science. During the last two decades, the study of students' epistemological beliefs, which refers to students' beliefs and views about how knowledge is developed and justified and involves a set of ideas and assumptions about the nature of knowledge that students have, has become a popular research topic in educational psychology [1, 2]. Educators also believed that students' epistemological beliefs play a fundamental role in their cognitive and learning processes and emphasized the importance of helping students obtain a better understanding of the epistemological beliefs for particular learning domains, such as mathematics and science [3, 4]. Contemporary science educators often emphasize the tentative and creative nature of science [5, 6]. From this view, the creative activities are always included in the science inquiry, and the status of science knowledge is always tentative. Mathematics educators [4, 7–10] also clearly highlight the role of students' beliefs about mathematics and how it is learned at school. For example, scholars assume that students' beliefs in their ability to solve time-consuming mathematics problems, in the importance of increasing their mathematics ability and in the usefulness of mathematics in everyday life, are all related to their motivation to learn to solve mathematical problems [11, 12].

Recent research has also suggested that students' epistemological beliefs, to some degree, are domain specific [6, 13, 14]. These beliefs are specifically related to students' problem solving, conceptual change, learning strategies, reasoning modes, and decisions when encountering a new situation [1, 13, 15, 16]. Mathematics and science education studies in particular have reported a variety of epistemological beliefs related to mathematics and science that may influence the learning processes that students choose to engage in [17, 18]. For example, Barnard et al. [17] indicated that self-regulation learning skills in the online learning environment may function as a mediator in the relationship between epistemological beliefs and academic achievement. Mason [19] examined relationships between students' epistemological beliefs in mathematics and academic achievement. The results found that epistemological beliefs could predict

Table 1: Examples of items from each scale in REQ, REQ-M, and REQ-S.

Factors	Sample items		
	REQ	REQ-M	REQ-S
Quick learning	Successful students learn things quickly.	Successful students learn *math* quickly.	Successful students learn *science* quickly.
Certain knowledge	Truth is unchanging.	Truth in *math* is unchanging.	Truth in *science* is unchanging.
Simple knowledge	Working on a problem with no clear solution is a waste of time.	Working on a *math* problem with no clear solution is a waste of time.	Working on a *science* problem with no clear solution is a waste of time.
Innate ability	An expert is someone who has a special gift in some area.	An expert in *math* is someone who has a special gift in math.	An expert in *science* is someone who has a special gift in science.

students' mathematics achievement. H. K. Wu and C. L. Wu [18] also showed that students who held a more sophisticated epistemology tended to develop better inquiry skills than those with naïve beliefs.

In junior high school, mathematics and science are two important, but different learning domains. Both disciplines appeal to logic to assess the validity of knowledge claims, but science must also refer to the empirical observation, while mathematics does not [20]. Because students' epistemological beliefs about knowledge are probably domain specific, scholars hypothesize that students may have different epistemological beliefs in these two domains, which may affect their learning in each. Based on the differences between students' mathematics and science epistemological beliefs, the integration of science and mathematics curricula can be designed well [21]. This may provide useful suggestions for preservice mathematics and science teachers in their professional development. Although previous studies have investigated students' epistemological beliefs toward mathematics and science separately [4, 22], few have compared students' epistemological beliefs toward mathematics with those toward science. Therefore, one of the purposes of this study is to examine the differences between students' epistemological beliefs in math and those in science.

1.2. Epistemological Beliefs and Gender Differences. Gender issues have been discussed extensively in mathematics and science education research. Males generally consider themselves as relatively more advantaged than females in learning mathematics and science [23–25]. Frenzel et al. [26] reported that even though girls and boys received similar grades in mathematics, the girls reported significantly more anxiety, hopelessness, and shame and less enjoyment and pride in mathematics than the boys. Similarly, female high school students have often displayed lower motivation and negative attitudes toward learning science [27, 28]. Furthermore, Lee and Yuan [25] found that motivation, enjoyment, and importance of mathematics were more prominent than freedom from fear of mathematics in predicting male adolescents' perceptions toward virtual manipulatives while freedom from fear and importance of mathematics were more prominent than enjoyment and motivation of mathematics in predicting female adolescents' perceptions toward virtual manipulatives. Some educators even claim that normal educational practice in mathematics and science is conductive to ignore females' epistemological beliefs [29, 30]. Based on the above descriptions, female students may have more inappropriate epistemological beliefs toward learning mathematics and science. This study also explored possible gender differences in junior high school students' epistemological beliefs toward mathematics and science.

1.3. The Aims of This Study. In short, the purposes of this study were to investigate

(1) the differences (if any) between students' epistemological beliefs toward mathematics and those toward science;

(2) the gender differences (if any) of students' epistemological beliefs toward mathematics and science.

2. Method

2.1. Sample. The sample in this study included 495 ninth graders (around 15 years old). These students came from nine junior high schools, three schools from the North, and two each from the Middle, South, and East regions of Taiwan. Among these respondents, 255 were female and 240 were male. The students were across different demographic and academic backgrounds, and, to a certain extent, represent the population of Taiwanese junior high school adolescents. Because all students were ninth graders, they had completed at least a one-year course in science and at least a two-year course in mathematics at the junior high school level and had an adequate background to develop epistemological beliefs regarding the nature of mathematics and science. The participants completed two questionnaires; one explored their epistemological beliefs in mathematics, and the other one investigated their epistemological beliefs in science.

2.2. Instruments. To assess students' views about the nature of mathematics and science, two questionnaires (see Table 1), called the Revised Epistemological Questionnaire in Math (REQ-M) and the Revised Epistemological Questionnaire in Science (REQ-S), were modified from the Revised Epistemological Questionnaire (REQ) developed by Yang and Chang

Table 2: Summary of male and female group means of participants' math and science scores on quick learning scale.

Gender/Discipline	Math	Science	Total
Male	2.299 (0.356)	2.257 (0.473)	2.278 (0.415)
Female	2.205 (0.340)	2.274 (0.452)	2.240 (0.396)
Total	2.2517 (0.351)	2.2656 (0.462)	

[31]. The REQ was reduced and adapted from the 63-item Schommer's Epistemological Questionnaire (SEQ) for high-school students [32]. The original SEQ was not used in this study because pilot tests showed that some SEQ items were unclear for Taiwanese students, and some factors had rather low reliabilities. To obtain REQ, the SEQ was tested with over 370 10th graders in Taiwan. Yang and Chang [31] conducted factor analysis to abstract four scales: (a) quick learning (learning occurs in a quick or not-at-all fashion) with eighteen items, (b) certain knowledge (absolute knowledge exists and will eventually be known) with six items, (c) simple knowledge (knowledge consists of discrete facts) with seven items, and (d) innate ability (the ability to acquire knowledge is fixed) with seven items. The reliability coefficients (Cronbach's α) were 0.87, 0.65, 0.59, and 0.65, respectively, for the four scales. The overall alpha for REQ was equal to 0.87.

Each item in both REQ-M and REQ-S used a five-point Likert scale with categories ranging from strongly agree (5 points) to strongly disagree (1 point), while items stated in a reverse manner were scored accordingly. The reliability coefficients of REQ-M were 0.60, 0.63, 0.73, and 0.61, respectively, for the four scales, indicating satisfactory reliability in assessing students' epistemological beliefs in mathematics. The overall alpha for REQ-M was equal to 0.73. Similarly, the reliability coefficients of REQ-S were 0.80, 0.61, 0.63, and 0.69, respectively, for the four scales, indicating satisfactory reliability in assessing students' epistemological beliefs in science. The overall alpha for REQ-S was equal to 0.80. For each scale, an average score was calculated to represent each individual's agreement with the scale statements, ranging for 1 to 5. For example, a higher average score on the certain knowledge scale in REQ-M indicates stronger agreement with the belief that mathematics knowledge is unchanging. To discuss conveniently and efficiently in the later sections, QL, CK, SK, and IA are abbreviated from the four scales: quick learning, certain knowledge, simple knowledge, and innate ability, respectively, in both REQ-M and REQ-S.

3. Results

3.1. Discipline and Gender Differences on the Scales. 2×2 (discipline by gender) mixed design ANOVAs were conducted to examine the discipline and gender differences on the four scales of students' epistemological beliefs. The ANOVA results indicated a significant interaction effect between discipline and gender on QL scale ($F = 6.336$, $P = 0.012$, partial $\eta^2 = 0.013$). Consequently, simple main effects of discipline and gender factors on QL scale were examined as shown in Table 3. For female students, they had higher scores on QL scales in science than in mathematics ($t = -2.421$, $P = 0.016$), whereas for male students, the scores on QL scale in math and science are not significantly different. Furthermore, male students had significantly higher scores on QL scale in math than did females ($t = 2.452$, $P = 0.015$), whereas male and female students had statistically equal scores on QL scale in science (see Table 2). In other words, female students express the stronger belief that science learning occurs in a quick fashion as compared with the view that mathematics learning occurs in a quick fashion. Male students express the stronger belief that mathematics knowledge is acquired quickly than female students do.

Table 3: Simple main effects of gender and discipline factors on quick learning scale.

	t	P	Comparison	Effect size (Cohen's d)
Discipline				
Male	1.242	0.216		
Female	−2.421	0.016	Science > Math	0.173
Gender				
Math	2.452	0.015	male > female	0.270
Science	0.424	0.672		

Table 4: Summary of male and female group means of participants' math and science scores on certain knowledge scale.

Gender/Discipline	Math	Science	Total
Male	3.521 (0.468)	3.458 (0.574)	3.490 (0.521)
Female	3.083 (0.730)	2.990 (0.598)	3.036 (0.664)
Total	3.302 (0.651)	3.224 (0.631)	

In regard to CK scale, the ANOVA results indicated no significant interaction effect between discipline and gender ($F = 0.423$, $P = 0.516$), a significant main effect for discipline factor ($F = 10.579$, $P = 0.001$, partial $\eta^2 = 0.022$), and a significant main effect for gender factor ($F = 84.774$, $P = 0.000$, partial $\eta^2 = 0.151$). Consequently, both male and female students had significantly higher scores on CK scale in mathematics (Mean = 3.302, SD = 0.651) than those on the same scale in science (Mean = 3.224, SD = 0.631). Male students (Mean = 3.490, SD = 0.521) also had higher scores on CK scale in both mathematics and science than female (mean = 3.036, SD = 0.664) students did (see Table 4). In other words, both male and female students express the stronger belief that mathematics knowledge is certain as compared with the view that science knowledge is certain. Male students express the stronger belief that knowledge is acquired quickly for both mathematics and science than female students do.

With regard to SK scale, the ANOVA results indicated a significant interaction effect between discipline and gender ($F = 4.844$, $P = 0.028$, partial $\eta^2 = 0.010$). Consequently, simple main effects of discipline and gender factors on SK scale were examined as shown in Table 6. For male students, they had higher scores on SK scales in science than in mathematics ($t = -2.236$, $P = 0.026$), whereas for female students,

Table 5: Summary of male and female group means of participants' math and science scores on simple knowledge scale.

Gender/Discipline	Math	Science	Total
Male	3.071 (0.511)	3.170 (0.491)	3.121 (0.501)
Female	2.750 (0.733)	2.696 (0.420)	2.723 (0.576)
Total	2.911 (0.651)	2.933 (0.514)	

Table 6: Simple main effects of gender and discipline factors on simple knowledge scale.

	t	P	Comparison	Effect size (Cohen's d)
Discipline				
Male	−2.236	0.026	Science > Math	0.198
Female	1.008	0.315		
Gender				
Math	6.403	0.000	Male > Female	0.508
Science	8.385	0.000	Male > Female	1.037

Table 7: Summary of male and female group means of participants' math and science scores on innate ability scale.

Gender/Discipline	Math	Science	Total
Male	2.464 (0.641)	2.750 (0.806)	2.607 (0.724)
Female	2.018 (0.485)	2.045 (0.581)	2.031 (0.533)
Total	2.241 (0.610)	2.397 (0.786)	

the scores on SK scale in math and science are statistically equal. Furthermore, male students had significantly higher scores on SK scale in math ($t = 6.043$, $P = 0.000$) and science ($t = 8.385$, $P = 0.000$), respectively, than did females (see Table 5). In other words, male students express the stronger belief that science knowledge is simple as compared with the view that mathematics knowledge is simple. Male students express the stronger belief that knowledge is simple for both mathematics and science than female students do.

Concerning the IA scale, the ANOVA results indicated a significant interaction effect between discipline and gender ($F = 15.743$, $P = 0.000$, partial $\eta^2 = 0.032$). Consequently, simple main effects of discipline and gender factors on IA scale were examined as shown in Table 8. For male students, they had higher scores on IA scales in science than in mathematics ($t = -5.024$, $P = 0.000$), whereas for female students, the scores on IA scale in math and science are not significantly different. Furthermore, male students had significantly higher scores on IA scale in math ($t = 9.226$, $P = 0.000$) and science ($t = 10.897$, $P = 0.000$), respectively, than did females (see Table 7). In other words, male students express the stronger belief that the ability to learn science is fixed as compared with the view that the ability to learn mathematics is fixed. Male students express the stronger belief that the ability to learn both mathematics and science is fixed than female students do.

3.2. Correlation Analysis . A series of mixed design ANOVAs for mean scores on the scales showed several differences between epistemological beliefs in mathematics and those in

Table 8: Simple main effects of gender and discipline factors on innate ability scale.

	t	P	Comparison	Effect size (Cohen's d)
Discipline				
Male	−5.024	0.000	Science > Math	0.393
Female	−0.836	0.404		
Gender				
Math	9.226	0.000	Male > Female	0.785
Science	10.897	0.000	Male > Female	1.003

science (shown in Tables 2, 4, 5, and 7). However, Table 9 reveals that all four corresponding scales in mathematics were positively correlated with their related scales in science. For example, students' views of certain knowledge of mathematics significantly correlated with their views of science ($r = .664$, $P < .001$). This is in line with the findings of Buehl et al. [33] that students hold, to a certain extent, both domain-specific and domain-general epistemological beliefs. Interestingly, the smallest correlation between domains was that of belief in simple knowledge, making it reasonable to suppose that there may be stronger beliefs in simple knowledge in science compared with mathematics. But this assumption did not reach the significant difference in statistic (see Table 9).

4. Discussion

By means of surveying a group of Taiwanese junior high school students, this study reveals that female students express the stronger belief that science learning occurs in a quick fashion as compared with the view that mathematics learning occurs in a quick fashion. Girls may consider that mathematics learning relies on more logic reasoning than science learning and mathematics learning is more difficult than science learning for female students. Hence, females tended to show the stronger view on quick science learning than quick mathematics learning. Furthermore, both male and female students express the stronger belief that mathematics knowledge is certain as compared with the view that science knowledge is certain. This may have come from recent innovative developments in science and technology, which may shape a relatively dynamic perspective on science knowledge. On the other hand, they may regard mathematics as a more stable discipline. Finally, male students express the stronger belief that science knowledge is simple and the ability to learn science is fixed as compared with the view that mathematics knowledge is simple and the ability to learn mathematics is fixed. One possible explanation is that male students consider that learning science relies on more memorization than mathematics. Therefore, they perceive that science knowledge is simpler than mathematics knowledge. In addition, male students may still find ways to improve their science learning and perceive that the ability to learn science is more fixed than that to learn mathematics [6].

Female students were less likely than male students to believe in certain knowledge, simple knowledge, and innate

Table 9: The correlations among epistemological beliefs toward mathematics and science ($n = 495$).

	Quick learning (Math)	Certain knowledge (Math)	Simple knowledge (Math)	Innate ability (Math)
Quick learning (science)	**0.310*****	0.004 (n.s.)	−0.255***	−0.169***
Certain knowledge (science)	0.126**	**0.664*****	0.259***	0.580***
Simple knowledge (science)	0.359***	0.243***	**0.169*****	0.487***
Innate ability (science)	0.530***	0.363***	0.288***	**0.482*****

$^{**}P < .01$; $^{***}P < .001$; n.s.: not significant.

ability for mathematics and science as well as certain quick learning for mathematics. One possible reason for the results may be that male students have more favorable attitudes toward mathematics and science [23, 25, 34], due to more male confidence in mathematics and science than females. Therefore, boys may have stronger views than girls that mathematics knowledge is acquired quickly, mathematics knowledge is certain, mathematics knowledge is simple, the ability to learn mathematics is fixed, science knowledge is certain, science knowledge is simple, and the ability to learn science is fixed. Students shared statistically similar views about quick learning for science, indicating that both boys and girls believed that science knowledge is acquired gradually over time. However, the topics such as geometry reasoning and proof are included in the second year in junior high school mathematics curriculum, so girls may have more difficulty in doing mathematics requiring more formal reasoning skills. Thus, females had a weaker view on quick learning in mathematics than did males.

5. Implications and Conclusion

This study revealed that students expressed a stronger view on the certain knowledge of mathematics than that of science. The use and existence of mathematics proofs support this notion, and students believe the goal in mathematics problem solving is to find the answer [35]. Schoenfeld [36] argued that formal mathematics has little to do with discovery or invention, correlated with the primary goal of instruction. Therefore, mathematics teachers may, based on this finding, develop more open-ended discovery activities to help students probe the variety and uncertainty of the mathematics world. On the other hand, science teachers may need to be more concerned with showing the tentative or changing nature of science knowledge. From the findings of previous research [37, 38], these students may have a more meaningful and integrated awareness of science knowledge. Science instruction combining more inquiry-oriented activities and the history of science may be beneficial for attaining this goal [39, 40].

This study found that male students had a stronger view on the simple knowledge and innate ability of science than those of mathematics. Female students had a stronger view on the quick learning of science than that of mathematics. Science teachers may communicate expectations in their interactions with male students during classroom instruction, through their comments on male students' papers, when assigning students to instructional groups, through the presence or absence of consistent support for students who are striving for high levels of attainment, and in their contacts with significant adults in a student's life. These actions could provide male students opportunities to learn and may influence male students' beliefs about their own abilities to succeed in science. They may have a chance to understand that science knowledge is organized as highly interrelated concepts. Furthermore, science teachers may provide females students with complex problem solving in authentic contexts which focus on engaging them in collaboration to construct science knowledge and offer enough time for female students to learn. Consequently, these problem-solving activities may have some impact on female students' view on the quick learning of science. On the other hand, mathematics teachers may need to focus on accommodating differences to help students learn mathematics. Technology could help achieve this end in the classroom. For example, technology tools and environments could give students opportunities to explore complex problems and mathematical ideas and could also furnish structured tutorials to students needing additional instruction and practice on skills, or link students in rural communities to instructional opportunities or intellectual resources not readily available in their locales [41]. Technology could also be effective in attracting students who disengage from nontechnological approaches to mathematics. Every student should have opportunities to use technology in appropriate ways so that they have access to interesting and important mathematical ideas [42–44].

This study also found that male students expressed higher agreement with quick learning, certain knowledge, simple knowledge, and innate ability of mathematics, as well as certain knowledge, simple knowledge, and innate ability of science than did female students. In other words, junior high school boys had relatively more unsophisticated epistemological beliefs in mathematics and science than did girls. Mathematics and science teachers may develop learner-centered activities to help male students gain insight into their beliefs about mathematics and science. For example, explicit reflections on these beliefs, writing reflective journals, small group

discussions and sharing [45], confronting students with the incompatibility of their current beliefs [41], and asking them to consciously consider the consequence of their naïve epistemological beliefs [46] are possible methods to help students review their mathematics and science beliefs [47].

Furthermore, notwithstanding the mean differences between students' epistemological beliefs toward mathematics and science, their views of these two domains had the positive correlation. For example, the extent of agreement with certain knowledge of mathematics was statistically different from that of science (as shown in Table 4), but students' epistemological beliefs across the two domains were highly related ($r = 0.664$, $P < .001$ as shown in Table 9). This implies that developing a more sophisticated vision of one domain such as mathematics may cultivate the elaboration of a more sophisticated vision of another domain such as science. Therefore, teachers in different domains of mathematics and science may together contribute to a better comprehensive perspective of epistemological beliefs toward mathematics and science by providing proper instruction.

Although the interaction effects between discipline and gender are significant on QL, SK, and IA scales, the effect size is small. Future studies need to examine the interaction between discipline and gender more carefully with a big sample size. Because the results reported in this study were based upon students' self-reported surveys, combining qualitative assessment, including interviews and observations of actual teaching and learning, would be helpful to more deeply explore their views and provide a more holistic understanding of their epistemological beliefs. Researchers are encouraged to examine students' epistemological beliefs among different countries. Such cross-national studies could help educators understand how different cultures may guide the development of students' epistemological beliefs about specific knowledge domains. Finally, how students' epistemological beliefs are intertwined with cognitive and motivational variables is an important issue to discuss in the future. For example, how are students' beliefs about knowledge related to their perceived competencies and interests? Do these beliefs play a role in students' choice of academic major and future careers? Do students of different epistemological orientations benefit from varied forms of instruction and classroom activities? The answers to such questions would likely improve our understanding of the learning process and potentially allow educators to teach more effectively.

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