行政院國家科學委員會專題研究計畫 成果報告

發現女學生科學學習歷程之獨特性—「關懷的科學」研究工具暨教學活動之研發與實施
研究成果報告(精簡版)

計 畫 類 別 ： 個別型
計 畫 編 號 ： NSC 97-2629-S-004-001-
執 行 期 間 ： 97 年 08 月 01 日至 98 年 09 月 30 日
執 行 單 位 ： 國立政治大學教育學系

計畫主持人： 邱美秀

計畫參與人員： 此計畫無其他參與人員

報 告 附 件 ： 出席國際會議研究心得報告及發表論文

處 理 方 式 ： 本計畫可公開查詢

中 華 民 國 98 年 11 月 19 日

Effects of a Women-in-Sciences/Men-in-Humanities Intervention on Taiwanese Adolescents' Attitudes towards Learning Science

Mei-Shiu Chiu
National Chengchi University, Taiwan

摘要

本研究採用前後測控制組設計，探索「認識女性科學人與男性人文人，覺察學術性別刻板印象，發展獨特自我」教學介入對學生科學學習態度(含興趣、信心、價值)的影響。研究參與者為 247 位台灣一所國中 8 年級 8 個班級的學生(其中 123 位為女生)，隨機分派至實驗組和控制組。和過去大多數研究結果近似，就全體學生而言，女生較男生有較為負向的科學學習態度。然而，研究結果也發現顯著的實驗與性別間交互作用，特別是在科學習習的價值上，效果更為明顯：在此教學介入後，男女生在科學學習態度上的落差減少。此研究結果顯示：不論是女生或男生的科學態度形成過程，均部分受學術性別刻板印象所影響。

關鍵字：科學學習態度、性別差異、學科性別刻板印象

Abstract

A pretest-posttest control group design was used to investigate effects of an intervention that focused on acknowledge of women in sciences and men in humanities, awareness of academic gender stereotypes, and development of unique selves on student attitudes (interest, confidence, and value) towards learning science. The research participants were 247 Grade-8 students (123 girls) from eight classes (randomly assigned to experimental and control conditions) in a junior high school in Taiwan. Similar to the result of most past studies, girls had more negative attitudes towards learning science than boys for all the students as a whole. However, there was an effect of interaction between experiment and gender, which showed that gender gaps in attitudes towards learning science, especially value of learning science, diminished after the intervention. The findings suggest that academic gender stereotypes at least partly intervene in the process of the formation of attitudes towards learning science for both girls and boys.

Keywords*:* science learning attitudes; gender differences; academic gender stereotypes

An ideal society should give full support to the development of a gender-equal society, in which individuals can develop their capacities and careers based on their unique characteristics, e.g., learning attitudes, rather than driven by academic gender stereotypes, e.g., the conception that women are humanities-goers and men are sciences-goers. There are, however, long-lasting and prevalent phenomena that women have more negative attitudes towards learning science and lower participation in science learning activities and careers than men (Dawson, 2000), which contradict the image of the gender-equal society. Further, as the phenomenon is so prevalent, strong, and consistent worldwide, we or our adolescents are very likely to attribute the phenomenon to gender differences by nature (Bornholt, Goodnow, & Cooney, 1994) rather than gender stereotypes by nurture. Research has indicated that gender gaps in mathematics diminish in gender-equal societies (Guiso, Monte, Sapienza, & Zingales, 2008), which implies that nurture at least may partly explain gender gaps favoring males in diverse aspects of science learning.

To think the reasons for gender gaps in science learning in a reverse way: Will our learning attitudes change if there are more women in sciences and more men in humanities in our world? If we can not make a real world with more women in sciences and more men in humanities at the moment, perhaps we can create a mini-world where women in sciences and men in humanities are highly valued and the misconception of academic gender stereotypes in our real society is emphasized.

The purpose of the present study therefore is to create this mini-world by conducting an experimental intervention in real educational settings and to see whether adolescents' attitudes towards learning science will change. If attitudes towards learning science can be changed by an intervention focusing on women in sciences, men in humanities, awareness of academic gender stereotypes, and development of unique selves, then we are likely to infer that academic gender stereotypes at least partly intervene in the process of the formation of attitudes towards learning science. In addition, raising female students' attitudes towards learning is an important issue in real educational settings and for a gender-equal society as there is a much stronger relationship between attitudes towards learning science and both science achievement and participation in science studies and careers for females than that for males (Gillibrand, 1999; Glynn, Taasoobshirazi, & Brickman, 2007; Zeldin & Pajares, 2000). Further, it is attitudes in relation to science that determine participation in science-related studies or careers rather than achievements, abilities and ambitions in science for females (Frome, Corinne, Eccles, & Barber, 2006). Researchers therefore appeal for interventions focusing on learning attitudes and experiences for females because females' performance is much more vulnerable to beliefs, attitudes, and experiences than males' (Quaiser-Pohl & Lehmann, 2002).

Adolescents are suitable participants for this intervention. Gender bias in favor of masculine jobs has gradually developed since childhood (Liben, Bigler, & Krogh, 2001). Gender differences in attitudes towards gender-stereotypic domains become much salient in adolescence (Cole et al., 2001; Jackson, Hodge, & Ingram, 1994). On the other hand, adolescence is likely to be a critical period for reversing the trend towards gender gaps favoring boys in attitudes towards learning science. Adolescents in the 7th or 8th grades temporarily have flexibly stereotypic beliefs in relation to psychological aspects of both genders and after Grades 7-8 their gender stereotypic flexibility may decrease (Alfieri, Ruble, & Higgins, 1996). Adolescents in the 8th grade have had sufficient knowledge of academic domain classification because learning periods in school are organized based on academic domains and most major sub-domains of science, e.g., biology, chemistry, and physics, have been formally introduced into the national curriculum in Taiwan by Grade 8. Adolescents are also likely to have experienced their parents' endorsement of academic gender stereotypes at least since their childhood (Tiedemann, 2000).

Numbers of Women in Sciences and Men in Humanities in Taiwan and the world

Women in sciences and men in humanities are minorities in Taiwan, which is also a prevalent phenomenon in the world. In 2006, there were only 38.89% female science majors and 13.18 % female engineering majors in Taiwan and 38.02% female science majors and 24.16% engineering majors for the countries of the Organization for Economic Co-operation and Development (OECD), as indicated by an official report made by Ministry of Education in Taiwan (2009a) (Table 1). On the other hands, there were 73.98% of females studying humanities and 63.96% studying social sciences in Taiwan and 64.52% studying humanities and 57.71% studying social sciences for the OECD countries. The gender gaps appear to be larger in Taiwan than those in the OECD countries in 2006. Further, compared with the results in 2006, Taiwan had much fewer female students studying sciences (35.28%), engineering (13.02%), humanities (70.48%), and social sciences (59.81%) in 2008 (Ministry of Education in Taiwan, 2009b). The trend reveals that gender gaps become larger in the traditional masculine fields, e.g., sciences and engineering, and those in traditional feminine fields, e.g., humanities and social sciences, become smaller in Taiwan.

Gender Differences in Attitudes towards Learning Science in Taiwan and the World

Among diverse attitudes towards learning science, interest, confidence (self-concept), and value are three constructs included in most surveys in relation to learning science, e.g., the student questionnaire used in the Program for International Student Assessment (PISA) of 2006 conducted by the OECD (2007), the student questionnaire used in the Trends in International Mathematics and Science Study (TIMSS) conducted by the International Association for the Evaluation of Educational Achievement (IEA) (Olson, Martin, & Mullis, 2008), and student questionnaires developed and used by Dalgety, Coll, and Jones (2003), Siegel and Ranney (2003), and Tuan, Chin, and Shieh (2005).

The results of the PISA 2006 study revealed that boys indicated higher interest, confidence, and value in relation to learning science than girls, with effect sizes of -.02, -.27, and -.13 for interest, confidence, and value, respectively, on average for the OECD countries. The gender gaps favoring boys appeared to be much stronger in Taiwan, with effects sizes of -.29, -.53, and -.16 for interest, confidence and value, respectively (Table 3.21 in the Volume 2 of the OECD (2007), pp. 90-91). The results of the TIMSS 2007 study revealed that the percentages of girls showing high, medium, and low confidence in learning science were 47%, 38%, and 15% and those of boys were 50%, 39%, and 11%, respectively, on international average (Martin, Mullis, & Foy, 2008, p. 193). There were significantly more boys than girls in the group of high confidence and more girls than boys in that of low confidence. The trend of gender gaps favoring boys in confidence appeared to be much larger in Taiwan, with the percentages of girls showing high, medium, and low confidence being 16%, 32%, and 51% and those of boys being 30%, 39%, and 31%, respectively. Boys had significantly larger percentages than girls in high and medium confidence and boys had a significantly smaller percentage than girls in low confidence.

Results of small-scale studies also indicate significant gender gaps in attitudes towards learning science. Girls have less confidence, interest, and future-orientation towards learning science than boys, except that girls show more interests in health sciences and biology, as indicated by studies researching students from diverse cultures, e.g., Greek, Japan, Taiwan, and the US (Christidou, 2006; DeBacker &

Nelson, 2000; Evans, Schweingruber, & Stevenson, 2002; Jones, Howe, & Rua, 2000; Meece, Glienke, & Burg, 2006; Miller, Slawinski Blessing, & Schwartz, 2006; Trusty, Robinson, Plata, & Ng, 2000). Gender gaps in attitudes towards learning science may become larger for college students (Lips, 2004).

Interventions in Relation to Academic Gender Stereotypes

Women better at or studying sciences and men better at or studying humanities are likely to experience more threats of academic gender stereotypes than women better at or studying humanities and men better at or studying sciences. Psychologists generally use laboratory experiments to investigate immediate effects of primed stereotypic threats on research participants' responses, e.g., performances on specific tasks and self-report emotional reactions. The results of Thoman, White, Yamawaki, and Koishi's (2008) study revealed that female college students experiencing an ability component of gender-mathematics stereotypes had lower mathematics achievements than those experiencing an effort stereotype. In addition, there was a positive relationship between confidence and achievement for females experiencing an ability stereotype but there was not for those experiencing an effort stereotype. Ambady, Shih, Kim, & Pittinsky's (2001) study shows that activation of gender identity will increase boys' performance in quantity but reduce girls'. Increasing opportunities to see female leaders in the society can decrease female students' gender stereotypic attitudes (Dasgupta & Asgari, 2004).

Educators use field experiments in an attempt to reduce academic gender stereotypes and to raise desirable learning outcomes. Häussler and Hoffmann (2002) and Hoffman (2002) succeeded in diminishing Grade-7 students' gender gaps in interest, self-concept, and achievements in physics by interventions in real physics classrooms focusing on making physics interesting for girls, training teachers to effectively deal with gender-stereotypic behavior in classrooms, and to conduct half single-sex teaching. Effective educational experiments for raising female students' mathematics achievements included interventions that focused on the perspective of malleable intelligence, the attribution of learning difficulties to external environments, and the nullification of gender stereotypes (Good, Aronson, & Harder, 2008; Good, Aronson, & Inzlicht, 2003). Engaging students in structured free recall activities could reduce gender biases of students who tended to evaluate female professors as less accurate and less desirable (Bauer & Baltes, 2002). After an extracurricular intervention focusing on the use of cooperative learning and hands-on activities to teach science, girls increased their involvement in learning and in asking questions but boys still had greater sexist attitudes than girls (Hong, Lin, & Veach, 2008).

The Present Study

The aim of the present study was to investigate the effects of an experimental intervention that focused on acknowledge of women in sciences and men in humanities, awareness of gender stereotype, and development of uniqueness on students' attitudes towards learning science, which included interest in learning science, confidence (self-concept) in learning science, and value of learning science. The intervention was based on the assumption that women were stereotyped as humanities-goers and that men were stereotyped as sciences-goers by our society. The intervention was developed and conducted for Grade-8 students in Taiwan. A pretest-posttest control group design was used to answer the following three research questions.

1. What is the difference in attitudes towards learning science between students who experience the intervention (the experimental group) and those who do not experience the intervention (the control group)?

2. What is the gender difference in attitudes towards learning science?
3. What is the differential effect of the intervention on attitudes towards learning science between girls and boys?

Research Question 1 explored the major effect of experiment, Research Question 2 the major effect of gender, and Research Question 3 the interactive effect of experiment and gender. For Research Question 1, it was predicted that there would be no significant effect of experiment on attitudes towards learning science because while girls were likely to increase their attitudes towards learning science, boys were likely to reduce because the intervention focused on women in sciences and men in humanities. For Research Question 2, it was predicted that there were gender differences in students' attitudes towards learning science. In addition, boys had more positive attitudes towards learning science than girls, a result replicating that of past related studies, partly because of academic gender stereotypes. For Research Question 3, it was predicted that gender gaps in attitudes towards learning science would diminish after the intervention.

Method

Participants

The research participants were 247 Grade-8 students from eight classes in a junior high school in Taiwan. Each class was randomly assigned to either experimental or control conditions, which resulted in four classes as the experimental group and the other four classes as the control group. There were 27-34 students in each class and around half were girls within each class. There were 122 students (61 girls) in the experimental group and 125 students (62 girls) in the control group. Tables 2-4 show a detailed description of the numbers of the participants in each condition.

Procedure

A pretest-posttest control group design was used in the present study. Both the experimental and control groups experienced a pretest, a posttest, and a teaching program on career development, except that the experimental group experienced an intervention focusing on acknowledge of women in sciences and men in humanities, awareness of academic gender stereotypes, and development of unique selves. The same test content was administered one week before and after the teaching program, respectively, as the pretest and posttest. The teaching program lasted for five weeks. The lessons were scheduled within regular class periods as career development is part of the national curriculum in Taiwan, in which gender issues were encouraged to be included in the teaching of each subject. Each class was taught once for one sub-topic per week. Each lesson took 45 minutes. Table 1 shows the research design.

<Insert Table 1 around here.>

The contents of the intervention were developed by a research team, which included a college teacher, a school teacher (who taught all the lessons for the eight classes of the experimental and control groups), and five research assistants, who were all education majors. The content of the intervention and the research design were reviewed by four experts in education and necessary revisions were made according to their suggestions.

Intervention

The intervention included five experimental lessons. Each lesson had a distinct sub-topic: gender and academic/vocational interest, gender and academic/vocational self-concept, gender and academic/vocational aspiration, gender and academic/vocational value for individuals, and gender and academic/vocational value for the society. The categories of academic subjects were school subjects, including Chinese, English, mathematics, sciences, social sciences, arts, and physical education.

The categories of vocations used in the intervention (the experimental lessons) were based on Holland's theory (Feldman, Smart, & Ethington, 2008), which was one of the major theories used in most lessons on career development in Taiwan secondary education and also used in the lessons for the control group. The procedure for each lesson of the intervention included three phases, each focusing on one kind of activities. The following description of the three phases mainly used the sub-topic of 'interest' as an example.

The preparation activity (around 5 minutes). The teacher introduced the topic, provided some examples (real role models in Taiwan and the world) of the interests of women in sciences and men in humanities, partially with some other minorities (e.g., women in sports), and raised the issue of academic gender stereotypes.

The development activity (around 35 minutes): Students engaged in activities initiated by the teacher. The activities included: (A) Students completed questionnaires concerning their own interests and their awareness of gender stereotypes in relation to interests. (B) Students engaged in cooperative games in which students identified daily language uses, pictures, or practices in relation to academic gender stereotypes. (C) Students made comparisons in interests between males and females. (D) Students discussed in groups the differences between their own interests and gender-stereotypic interests. (E) Students discussed the questions posed by the teacher that challenged students' academic gender stereotypes. (F) Students presented to the class and participated in whole-class discussion based on their findings obtained from group discussion. During the activities, students also engaged in completing their worksheets that organized the activities and provided spaces for students to record their performances. At last, the teacher summarized the findings obtained from student presentation and class discussion, provided students with additional examples of women in sciences, men in humanities, and other minorities, and encouraged students to develop themselves based on their unique characteristics rather than gender stereotypes.

The synthesis activity (around 5 minutes). Students wrote down their views on interests in learning science and their wishes for the changes the world might make for them to learn science better, if nay, on worksheets. The teacher summarized all the activities and major findings from the lesson and collected the worksheets completed in the lesson. At last, if necessary, the teacher prepared students for the next lesson. For instance, students interviewed their parents for their views on the value of their present jobs, their dreams in relation to jobs at the students' age (Grade 8 or around 14 years old), and the reasons for choosing their present jobs.

As revealed by the content of the intervention, the issue of academic gender stereotypes was addressed by social cognitive approaches. If academic gender stereotypes are built through learning by social messages, then the new concept of developing selves based on personal uniqueness rather than gender stereotypes needs to be rebuilt by vicarious learning, verbal persuasion, affective arousal, and active action (Bandura, 1977; Hampton & Mason, 2003). Multiple teaching strategies were used to motivate students and the strategies included lectures, cooperative games (Street, Hoppe, Kingsbury, & Ma, 2004), cooperative learning (Cheung & Slavin, 2005; Slavin & Lake, 2009), and hands-on activities. Teaching materials, e.g., the vignettes of the examples of women in sciences and men in humanities, were delivered by lectures, worksheets, and PowerPoint.

Measures

Students filled in the same three measures in relation to their attitudes towards learning science for the pretest and posttest. The items of the three measures were obtained from the student questionnaire in the PISA of 2006 (OECD, 2007). Students were asked to rate for each of the items of the measures on a four-point Likert-type scale, ranging from 1 = *strongly agree* to 4 = *strongly disagree*. Student responses were reverse coded in the present study so that a larger number represented a more positive response on the three measures.

Interest in learning science. The measure investigated student general interest in learning science and included five items. (a) I generally have fun when I am learning science topics. (b) I like reading about science. (c) I am happy doing science problems. (d) I enjoy acquiring new knowledge in science. (e) I am interested in learning about science (PISA variables st16q01-05).

Confidence (or self-concept) in learning science. The measure examined students' perceptions of their capacities to learn science well. There were six items on this measure. (a) Learning advanced science topics would be easy for me. (b) I can usually give good answers to test questions on science topics. (c) I learn science topics quickly. (d) Science topics are easy for me. (e) When I am being taught science, I can understand the concepts very well. (f) I can easily understand new ideas in science (PISA variables st37q01-06).

Value of learning science. The measure included five items, asking students whether learning science was of beneficial to their personal lives. (a) Some concepts in science help me see how I relate to other people. (b) I will use science in many ways when I am an adult. (c) Science is very relevant to me. (d) I find that science helps me to understand the things around me. (e) When I leave school there will be many opportunities for me to use science (PISA variables st18q03, 05, 07, 08, and 10).

Results

Tables 2-4 present the descriptive statistics of 2 tests (pretest and posttest) × 2 groups (control and experimental groups) × 2 genders (girls and boys) for the three measures of attitudes towards learning science, i.e., interest, confidence, and value, respectively. Data were analyzed based on a doubly multivariate repeated measures model, in which experiment and gender were the between-subject effects and test was the within-subject effect (or the repeated measure). The same three measures of attitudes towards learning science were administered in the pretest and posttest and so the posttest scores on the three measures could be analyzed by controlling for the pretest scores on the three measures, respectively.

<Insert Tables 2-4 around here.>

The results of multivariate tests provided initial answers to the three research questions. For the between-subject effects, the results showed that (1) there was no significant difference in attitudes towards learning science between students who experienced the intervention (the experimental group) and those who did not (the control group) (Wilks' Lambda = 1.00; $F_{(3, 241)} = .37$, $p > .05$, $\eta^2 = .00$); (2) there was a significant and large gender difference in attitudes towards learning science (Wilks' Lambda = .78; $F_{(3, 241)} = 22.13$, $p < .001$, $\eta^2 = .22$); and (3) there were significantly differential effects of the intervention on girls' and boys' attitudes towards learning science (Wilks' Lambda = .96; $F_{(3, 241)} = 3.33$, $p < .05$, $\eta^2 = .04$). For the within-subject effect, the results showed that the interactive effects between test (pretest and posttest) and (1) experiment, (2) gender and (3) experiment by gender, respectively, were not significant (Table 5).

<Insert Table 5 around here.>

The focus of the present study was on between-subject effects (i.e., the answers to the three research questions) as the above shows. We may also be interested to know the results in relation to each of the three measures of attitudes towards learning science as below shows.

Differences in Attitudes towards Learning Science between Students who Experienced the Intervention and Those who did not (Research Question 1)

A comparison was made between the students in the experimental group and those in the control group in the mean posttest scores on the three measures of attitudes towards learning science (interest, confidence, and value), controlling for pretest scores. As predicted, there were no significant differences in the three measures between the experimental and control groups. (Please find the test results presented in Lines 2-4 of Table 6 for the effect of experiment. The values of mean and standard deviation of the three measures for the control and experimental groups are presented in Tables 2-4.)

The predictions were based on four rationales. (1) The experimental intervention focused on women in sciences and men in humanities. (2) The three measures were all related to science learning. (3) After the experimental intervention, girls in the experimental group were likely to increase their interest, confidence, and value towards learning science while boys in the experimental group would decrease their interest, confidence, and value towards learning science. (4) The developmental trajectories in relation to attitudes towards learning science for girls and boys in the control group would remain relatively unchanged since they experienced a teaching program focusing on career development only, without paying attention to academic gender stereotypes. As a result, the major effect of experiment was not significant between all the participants (girls and boys combined) in the experimental group and those in the control group.

Gender Differences in Attitudes towards Learning Science (Research Question 2)

There were significant gender differences in interest, confidence, and value towards learning science for all the participating students as a whole. In addition, all the gender gaps favored boys. (The first 5-7 lines of Table 6 show the test results and the last 2-3 lines of Tables 2-4 show the means and standard deviations of the three measures for girls and boys in total.)

Differential effects of the Intervention on girls' and boys' Attitudes towards Learning Science (Research Question 3)

There was a significantly interactive effect of experiment and gender on value of learning science (Line 10 of Table 6). Table 5 shows the means and standard deviations of test × group × gender for the measure of value. On the other hand, the interactive effects of experiment and gender on interest and confidence in learning science, respectively, were not significant (Tables 2-3 for descriptive statistics and Table 6 for test results).

Despite the two non-significant results for interest and confidence, there were similar trends in the interactive effect of experiment and gender among the three measures of attitudes towards learning science. The trend was that there was a smaller gender gap for the students in the experimental group and a larger gender gap for those in the control group in the three measures of attitudes towards learning science in the posttest (Interest: Mean Difference (girl-boy) for the experimental group (MDE) = -.39 > Mean Difference (girl-boy) for the control group (MDC) = -.59. Confidence: MDE = -.42 > MDC = -.76. Value: MDE = .07 > MDC = -.40. Tables 2-4). Compared with the situation in the pretest, the gender gaps in interest and confidence scores were much similar between the students in the experimental group and those in the control group (Interest: MDE = -.54, MDC = -.51. Confidence: MDE = -.55, MDC = -.65). The most dramatic change happened in value of learning science, in which the gender gap favored boys in the pretest phase for both the experimental and control groups (MDE = -.17, MDC = -.42), while the gender gap favored girls in the posttest phase for the experimental group (MDE = .07) but not for the control group (MDC = -.40), which made the interactive effect of experiment and gender significant (Table 6). Figure 1 shows the differential patterns of changes from pretest to posttest in mean scores on the three measures for the control and experimental groups.

<Insert Figure 1 around here.>

To state in terms of changes from pretest to posttest, the gender gaps from the pretest to posttest phases for students in the control group revealed a disappointing trend: with interest from -.51 to -.59 (increased gender gap favoring boys), confidence from -.65 to -.76 (increased gender gap favoring boys), and value from -.42 to -.40 (slightly decreased gender gap but still favoring boys). On the other hand, the gender gaps from the pretest to posttest phases for students in the experimental group showed a desirable trend, with interest from -.54 to -.39 (decreased gender gap favoring boys), confidence from -.55 to -.42 (decreased gender gap favoring boys), and value from -.17 to .07 (decreased gender gap and a change from favoring boys to favoring girls). Figure 2 shows the gender gaps in the three measures during the pretest and posttest for the control and experimental groups

<Insert Figure 2 around here.>

Discussion

The aim of the present study was to examine the changes in attitudes towards learning science made by both girls and boys after an intervention that emphasized acknowledge of women in science and men in humanities, awareness of academic gender stereotypes, and development of unique selves. Women in sciences and men in humanities are minorities in our society, who are likely to be relatively ignored or under-valued by our society and which might become part of the causes of academic gender stereotypes. Another reason for emphasizing both women in sciences and men in humanities was that the intervention was conducted in co-educational classes in real educational settings and it appeared to be a better and ethical choice to place balanced emphases on the minorities of both women and men. As the dependent variables were three measures (interest, confidence, and value) all in relation to attitudes towards learning science, it was predicted that girls' attitudes towards learning science would increase after the intervention. In addition, a byproduct of the intervention is likely to be slightly decreased attitudes towards learning science for boys after the intervention. In other words, both girls and boys are influenced by gender stereotypes.

These predictions generally reflected in the present results as answers to the three research questions: (1) non-significant effects of experiment, (2) significant effects of gender, and (3) significant effects of interactions between experiment and gender on student attitudes towards learning science. The major focus of the present study is on the interactive effect of experiment and gender, i.e., differential effects of the intervention on attitudes between girls and boys, which implies the effectiveness of the intervention. The non-significant effect of experiment is a byproduct of the interactive effect. The significant gender differences replicate most past research results and imply a strong effect of academic gender stereotypes and further action is needed to be taken.

Academic Gender Stereotypes Intervening in the Formation of Attitudes towards Learning Science

The primary intention of the present intervention is to increase girls' positive attitudes towards learning science by valuing women in sciences. The present results showing an upward trend in female attitudes towards learning science fits to the intention of the intervention. The most salient effect occurs in value of learning science. The result suggests that girls are well-prepared to link science to their daily life, which echoes Zohar and Sela's (2003) finding that girls need deep understanding or connected knowledge in learning physics. The gains of the experimental effect on interest and confidence were also positive but not so salient. Large gender gaps favoring boys in interest and confidence is likely to be one of the major reasons.

On the other hand, the emphasis of men in humanities is a reasonable operation in the intervention because the present study was conducted in real co-education settings and a gender-equal intervention is an ethical practice of teaching. In other words, valuing men in humanities is a reasonable intervention for male minorities in terms of academic aptitudes although the initial intention of the intervention was not to reduce boys' positive attitudes towards learning science. The present finding, however, shows that compared with boys in the control group, boys in the experimental group relatively reduced their attitudes towards learning science. Perhaps we should begin to face the facts that there are elements of both genders and both drives towards sciences and humanities within each females and males (Gilbert & Calvert, 2003). It is an acceptable phenomenon that boys can have more negative attitudes towards learning science than girls. Or, ideally, boys and girls should have similar attitudes towards learning science for a gender-equal society.

Based on the above findings regarding the increasing trend of attitudes toward learning science for girls and the decreasing trend for boys, we may infer that academic gender stereotypes at least partly intervene in the process of the formation of attitudes towards learning science for both girls and boys. In other words, academic gender stereotypes by nurture are likely to be part of the reasons for gender gaps in attitudes towards learning science. We may begin to suspect the phenomenon that boys have more positive attitudes towards learning science than girls or that girls have more negative attitudes towards learning science than boys is influenced by academic gender stereotypes. The high relationship between attitudes towards learning science and achievement in science suggests an illusive cycle, in which we create a world that we expect (e.g., women are humanities goers and men are sciences goers) and then that we have now (e.g., there are more women in humanities and men in sciences).

Breaking the illusive cycle in relation to academic gender stereotypes is an important issue for educational practice. We have girls going to humanities and boys going to sciences not because of their unique characteristics but because of academic gender stereotypes. A gender-equal society or education needs to raise their students' and teachers' awareness of academic gender stereotypes, to encourage development based on personal uniqueness, to value minorities in our society, e.g., women in sciences and men in humanities, and to celebrate the diversity of our society.

Strong Gender Gaps Favoring Boys in Attitudes towards Learning Science

Girls have more negative attitudes towards learning science than boys, a present finding that replicates most past research results. The finding is undesirable as the gender gaps favoring boys, although the gender gap in the value of learning science non-significantly favors girls after the intervention. Research has indicated that there are significant relationships between attitudes towards learning science and achievement in science (Chang & Cheng, 2008) and the relationships are much stronger for girls than those for boys (Weinbergh, 1995). Girls experience more negative learning attitudes and psychological distress than boys, despite their academic achievements (Marsh & Yeung, 1998; Pomerantz, Altermatt, & Saxon, 2002). Diminishing gender gaps in attitudes towards learning science is of paramount importance for educators in science.

This undesirable finding suggests a strong effect of academic gender stereotypes in our society. The fact that there are more men in sciences and women in humanities may increase this gender stereotypes. The finding also reveals a limitation of the present study. The intervention lasted for only five weeks, once a week, and more time, e.g., 12 weeks, may be needed to validate the effectiveness of teaching programs (Slavin & Lake, 2009). The limited time of the present intervention is mainly due to the educational situation in Taiwan, where academic achievement is highly emphasized in secondary education by parents and by school teachers and administers, who have much stress from parents.

It is suggested that preservice and inservice teacher education programs need to include the topic of academic gender stereotypes. Teachers are encouraged to include this issue in their daily practices in teaching any school subjects, e.g., science, mathematics, and language, given the desirable effect of the intervention on diminished gender gaps and limited time allocated for formal inclusion of the issue of academic gender stereotypes in real educational settings. Teachers need to be reminded not to increase academic gender stereotypes in their teaching. Teachers also need to provide more support for students who are minorities in terms of academic gender stereotypes, e.g., girls who are interested in sciences and boys who are interested in humanities. The minorities who do not fit to academic gender stereotypes are very likely to experience stereotype threats, to adapt themselves to academic gender stereotypes, and to go for a field or career that fails to satisfy their own uniqueness.

Implication for Future Research

A quasi-experimental design can adapt interventions into real educational settings and increase ecological validity but a laboratory experiment can better validate a cause-and-effect relationship. The intervention focused on three major sub-interventions: providing examples of women in sciences and men in humanities, raising awareness of academic gender stereotypes, and encouraging development of unique selves. The intervention including three sub-interventions was designed to fit to real educational settings and the effect obtained from the intervention need to be viewed as a combined effect from the three sub-interventions as a whole. Further research can conduct laboratory experiments to validate the separate effects of the three sub-interventions. The present study was conducted for a sample of students from a specific culture. Further research can examine the effect of similar interventions for research participants from different cultures.

References

Alfieri, T., Ruble, D. N., & Higgins, E. T. (1996). Gender stereotypes during adolescence: Developmental changes and the transition to junior high school. *Developmental Psychology, 32*, 1129-1137.

Ambady, N., Shih, M., Kim, A., & Pittinsky, T. L. (2001). Stereotype susceptibility in children: Effects of identity activation on quantitative performance. *Psychological Science, 12*, 385-390.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*, 191-215.

Bauer, C. C., & Baltes, B. B. (2002). Reducing the effects of gender stereotypes on performance evaluations. *Sex Roles, 47*, 465-476.

Bornholt, L. J., Goodnow, J. J., & Cooney, G. H. (1994). Influences of gender stereotypes on adolescents' perceptions of their own achievement. *American Educational Research Journal, 31*, 675-692.

Chang, C.-Y., & Cheng, W.-Y. (2008). Science achievement and students' self-confidence and interest in science: A Taiwanese representative sample study. *International Journal of Science Education, 30*, 1183-1200.

Cheung, A., & Slavin, R. E. (2005). Effective reading programs for English language learners and other language-minority students. *Bilingual Research Journal, 29*, 241-267.

Christidou, V. (2006). Greek students' science-related interests and experiences: Gender differences and correlations. *International Journal of Science Education, 28*, 1181-1199.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum.

Cole, D. A., Maxwell, S. E., Martin, J. M., Peeke, L. G., Seroczynski, A. D., Tram, K. B. H., Ruiz, M. D., Jacquez, F., & Maschman, T. (2001). The development of multiple domains of child and adolescent self-concept: A cohort sequential longitudinal design. *Child Development, 72*, 1723-1746.

Dalgety, J. D., Coll, R. K., & Jones, A. (2003). Development of chemistry attitudes and experiences questionnaire (CAEQ). *Journal of Research in Science Teaching, 40*, 649-668.

Dasgupta, N., & Asgari, S. (2004). Seeing is believing: Exposure to counterstereotypic women leaders and its effect on the malleability of automatic gender stereotyping. *Journal of Experimental Social Psychology, 40*, 642-658.

Dawson, C. (2000). Upper primary boys' and girls' interests in science: Have they changed since 1980? *International Journal of Science Education, 22*, 557-570.

DeBacker, T. K., & Nelson, R. M. (2000). Motivation to learn science: Differences related to gender, class type, and ability. *The Journal of Educational Research, 93*, 245-254.

Evans, M., Schweingruber, H., & Stevenson, H. W. (2002). Gender differences in interest and knowledge acquisition: The United States, Taiwan, and Japan. *Sex Roles, 47*, 153-167.

Feldman, K. A., Smart, J. C., & Ethington, C. A. (2008). Using Holland's theory to study patterns of college student success: The impact of major fields on students. In J. C. Smart (Ed.), *Higher Education: Handbook of Theory and Research* (pp. 329-380). Netherlands: Springer.

Frome, P., Corinne, A., Eccles, J., & Barber, B. (2006). Why don't they want a male-dominated job? An investigation of young women who changed their occupational aspirations. *Educational Research and Evaluation, 12*, 359-372.

Gilbert, J., & Calvert, S. (2003). Challenging accepted wisdom: Looking at the gender and science education question through a different lens. *International Journal of Science Education, 25*, 861-878.

Gillibrand, E. (1999). Girls' participation in physics in single sex classes in mixed schools in relation to confidence and achievement. *International Journal of Science Education, 21*, 349-362.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. *Journal of Research in Science Teaching, 44*, 1088-1107.

Good, C., Aronson, J., & Harder, J. A. (2008). Problems in the pipeline: Stereotype threat and women's achievement in high-level mathematics courses. *Journal of Applied Developmental Psychology, 29*, 17-28.

Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat.

Applied *Developmental Psychology, 24*, 645-662.
Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, gender, and mathematics. *Science, 320*, 1164-1165.
Hampton, N. Z., & Mason, E. (2003). Learning disabilities, gender, sources of efficacy, self-efficacy beliefs, and academic achievement in high school students. *Journal of School Psychology, 41*, 101-112.
Häussler, P., & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self-concept, and achievement in physics classes. *Journal of Research in Science Teaching, 39*, 870-888.
Hoffmann, L. (2002). Promoting girls' interest and achievement in physics classes for beginners. *Learning and Instruction, 12*, 447-465.
Hong, Z.-R., Lin, H.-S., & Veach, P. M. (2008). Effects of an extracurricular science intervention on science performance, self-worth, social skills, and sexist attitudes of Taiwanese adolescents from single-parent families. *Sex Roles, 59*, 555-567.
Jackson, L. A., Hodge, C. N., & Ingram, J. M. (1994). Gender and self-concept: A reexamination of stereotypic differences and the role of gender attitudes. *Sex Roles, 30*, 615-630.
Tiedemann, J. (2000). Parents' gender stereotypes and teachers' beliefs as predictors of children's concept of their mathematical ability in elementary school. *Journal of Educational Psychology, 92*, 144-151.
Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education, 84*,180-192.
Liben, L. S., Bigler, R. S., & Krogh, H. R. (2001). Pink and blue collar jobs: Children's judgments of job status and job aspirations in relation to sex of worker. *Journal of Experimental Child Psychology, 79*, 346-363.
Lips, H. M. (2004). The gender gap in possible selves: Divergence of academic self-views among high school and university students. *Sex Role, 50*, 357-371.
Marsh, H. W., & Yeung, A. S. (1998). Longitudinal structural equation models of academic self-concept and achievement: Gender differences in the development of mathematics and English constructs. *American Educational Research Journal, 35*, 705-738.
Martin, M. O., Mullis, I. V. S., & Foy, P. (2008). *TIMSS 2007 international science report*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center.
Meece, J. L., Glienke, B. B., & Burg, S. (2006). Gender and motivation. *Journal of School Psychology, 44*, 351-373.
Miller, P., Slawinski Blessing, J., & Schwartz, S. (2006). Gender differences in high-school students' views about science. *International Journal of Science Education, 28*, 363-381.
Ministry of Education in Taiwan (2009a). *Analysis of gender differences in fields of study in higher education: A comparison between Taiwan and OECD countries* (in Chinese). Retrieved November 2009 from http://www.edu.tw/statistics/content.aspx?site_content_sn=7857.
Ministry of Education in Taiwan (2009b). *Percentages of students in higher education by nine fields of study and two genders* (in Chinese). Retrieved November 2009 from http://www.edu.tw/statistics/content.aspx?site_content_sn=8168.
Olson, J. F., Martin, M. O., & Mullis, I. V. S. (Eds.) (2008). *TIMSS 2007 technical report.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center.
Organization for Economic Co-operation and Development. (2007). *PISA 2006: Science competencies for tomorrow's world executive summary*. Paris, France:

Author.
Pomerantz, E. M., Altermatt, E. R., & Saxon, J. L. (2002). Making the grade but feeling distressed: Gender differences in academic performance and internal distress. *Journal of Educational Psychology, 94*, 396-404.
Quaiser-Pohl, C., & Lehmann, W. (2002). Girls' spatial abilities: Charting the contributions of experiences and attitudes in different academic groups. *British Journal of Educational Psychology, 72*, 245-260.
Siegel, M. A., & Ranney, M. A. (2003). Developing the changes in attitude about the relevance of science (CARS) questionnaire and assessing two high school science classes. *Journal of Research in Science Teaching, 40*, 757-775.
Slavin, R. E., & Lake, C. (2009). Effective programs in middle and high school mathematics: A best-evidence synthesis. *Review of Educational Research, 79*, 839-911.
Street, H., Hoppe, D., Kingsbury, D., & Ma, T. (2004). The game factory: Using cooperative games to promote pro-social behavior among children. *Australian Journal of Educational & Developmental Psychology, 4*, 97-109.
Thoman, D. B., White, P. H., Yamawaki, N., & Koishi, H. (2008). Variations of gender-mathematics stereotype content affect women's vulnerability to stereotype threat. *Sex Roles, 58*, 702-712.
Trusty, J., Robinson, C. R., Plata, M., & Ng, K.-M. (2000). Effects of gender, socioeconomic status, and early academic performance on postsecondary educational choice. *Journal of Counseling & Development, 78*, 463-472.
Tuan, H. L., Chin, C. C., & Shieh, S. H. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education, 27*, 639-654.
Tuan, H.-L., Chin, C.-C., & Shieh, S.-H. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education, 27*, 639-654.
Weinbergh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*, 387-398.
Zeldin, A. L., & Pajares, F. (2000). Against the odds: Self-efficacy beliefs of women in mathematical, scientific, and technological careers. *American Educational Research Journal, 37*, 215-246.
Zohar, A. (2003). Her physics, his physics: Gender issues in Israeli advanced placement physics classes. *International Journal of Science Education, 25*, 245-268.

Acknowledgements

The author wishes to express her gratitude to Prof. Huann-Shyang Lin for his provision with the Chinese-version items of the student questionnaire used in Taiwan for the PISA 2006 study. This research was supported by National Science Council, Taiwan (NSC 97-2629-S-004 -001).

Table 1

The research design

	Pretest	Teaching (5 Lessons/Weeks)	Posttest
Control group	X [a]	Y1[b]	X
Experimental group	X	Y2[c]	X

[a] The same measures are used during the pretest and posttest for the control and experimental groups.

[b] The teaching for the students in the control group focuses on career development.

[c] The teaching for the students in the experimental group focuses on gender and career development.

Table 2

Descriptive statistics of test × group × gender for the measure of interest in learning science

Test	Group	Gender	Mean	Standard Deviation	Number	Mean Difference (Girl – Boy)
Pre-test	Control	Girl	2.48	.60	62	-.51
		Boy	2.99	.64	63	
		Total	2.74	.67	125	
	Experimental	Girl	2.41	.59	61	-.54
		Boy	2.94	.74	61	
		Total	2.67	.72	122	
	Total	Girl	2.44	.60	123	-.52
		Boy	2.97	.69	124	
		Total	2.71	.69	247	
Post-test	Control	Girl	2.37	.62	62	-.59
		Boy	2.97	.71	63	
		Total	2.67	.73	125	
	Experimental	Girl	2.47	.60	61	-.39
		Boy	2.86	.82	61	
		Total	2.67	.74	122	
	Total	Girl	2.42	.61	123	-.49
		Boy	2.91	.77	124	
		Total	2.67	.73	247	

Table 3

Descriptive statistics of test × group × gender for the measure of confidence in learning science

Test	Group	Gender	Mean	Standard Deviation	Number	Mean Difference (Girl – Boy)
Pre-test	Control	Girl	2.12	.55	62	-.65
		Boy	2.77	.61	63	
		Total	2.45	.67	125	
	Experimental	Girl	2.11	.56	61	-.55
		Boy	2.66	.74	61	
		Total	2.38	.71	122	
	Total	Girl	2.11	.56	123	-.60
		Boy	2.72	.68	124	
		Total	2.41	.69	247	
Post-test	Control	Girl	2.07	.58	62	-.76
		Boy	2.84	.76	63	
		Total	2.46	.77	125	
	Experimental	Girl	2.17	.62	61	-.42
		Boy	2.59	.84	61	
		Total	2.38	.76	122	
	Total	Girl	2.12	.60	123	-.59
		Boy	2.72	.81	124	
		Total	2.42	.77	247	

Table 4

Descriptive statistics of test × group × gender for the measure of value of learning science

Test	Group	Gender	Mean	Standard Deviation	Number	Mean Difference (Girl – Boy)
Pre-test	Control	Girl	2.57	.61	62	-.42
		Boy	2.99	.54	63	
		Total	2.78	.61	125	
	Experimental	Girl	2.70	.68	61	-.17
		Boy	2.87	.67	61	
		Total	2.78	.68	122	
	Total	Girl	2.64	.65	123	-.30
		Boy	2.93	.61	124	
		Total	2.78	.65	247	
Post-test	Control	Girl	2.71	.53	62	-.40
		Boy	3.11	.60	63	
		Total	2.91	.60	125	
	Experimental	Girl	2.94	.57	61	.07
		Boy	2.87	.77	61	
		Total	2.90	.67	122	
	Total	Girl	2.82	.56	123	-.17
		Boy	2.99	.69	124	
		Total	2.91	.63	247	

Table 5
Results for multivariate tests

Effect		Wilks' Lambda	Hypothesis df	Error df	*F*	*p*	η^2
Between Subjects	Experiment	1.00	3	241	.37	.77	.00
	Gender	.78	3	241	22.13	.00	.22
	Experiment × Gender	.96	3	241	3.33	.02	.04
Within Subjects	Test × Experiment	.99	3	241	.55	.65	.01
	Test × Gender	.99	3	241	1.08	.36	.01
	Test × Experiment × Gender	.98	3	241	1.92	.13	.02

Note: df = degree of freedom. Small effect size: $.01 < \eta^2$ (partial eta squared) $< .06$; medium effect size: $.06 < \eta^2 < .14$; large effect size: $\eta^2 > .14$ (Cohen, 1988, p. 283).

Table 6
Results for tests of between-subjects effects

Effect	Variable	Sum of Squares	df	Mean Square	*F*	*p*	η^2
Experiment	Interest	.12	1	.12	.15	.70	.00
	Confidence	.54	1	.54	.71	.40	.00
	Value	.00	1	.00	.00	.96	.00
Gender	Interest	31.81	1	31.81	40.98	.00	.14
	Confidence	43.89	1	43.89	57.69	.00	.19
	Value	6.60	1	6.60	10.44	.00	.04
Experiment × Gender	Interest	.25	1	.25	.32	.57	.00
	Confidence	1.57	1	1.57	2.06	.15	.01
	Value	4.11	1	4.11	6.50	.01	.03
Error	Interest	188.61	243	.78			
	Confidence	184.89	243	.76			
	Value	153.58	243	.63			

Note: df = degree of freedom. Small effect size: $.01 < \eta^2$ (partial eta squared) $< .06$; medium effect size: $.06 < \eta^2 < .14$; large effect size: $\eta^2 > .14$ (Cohen, 1988, p. 283).

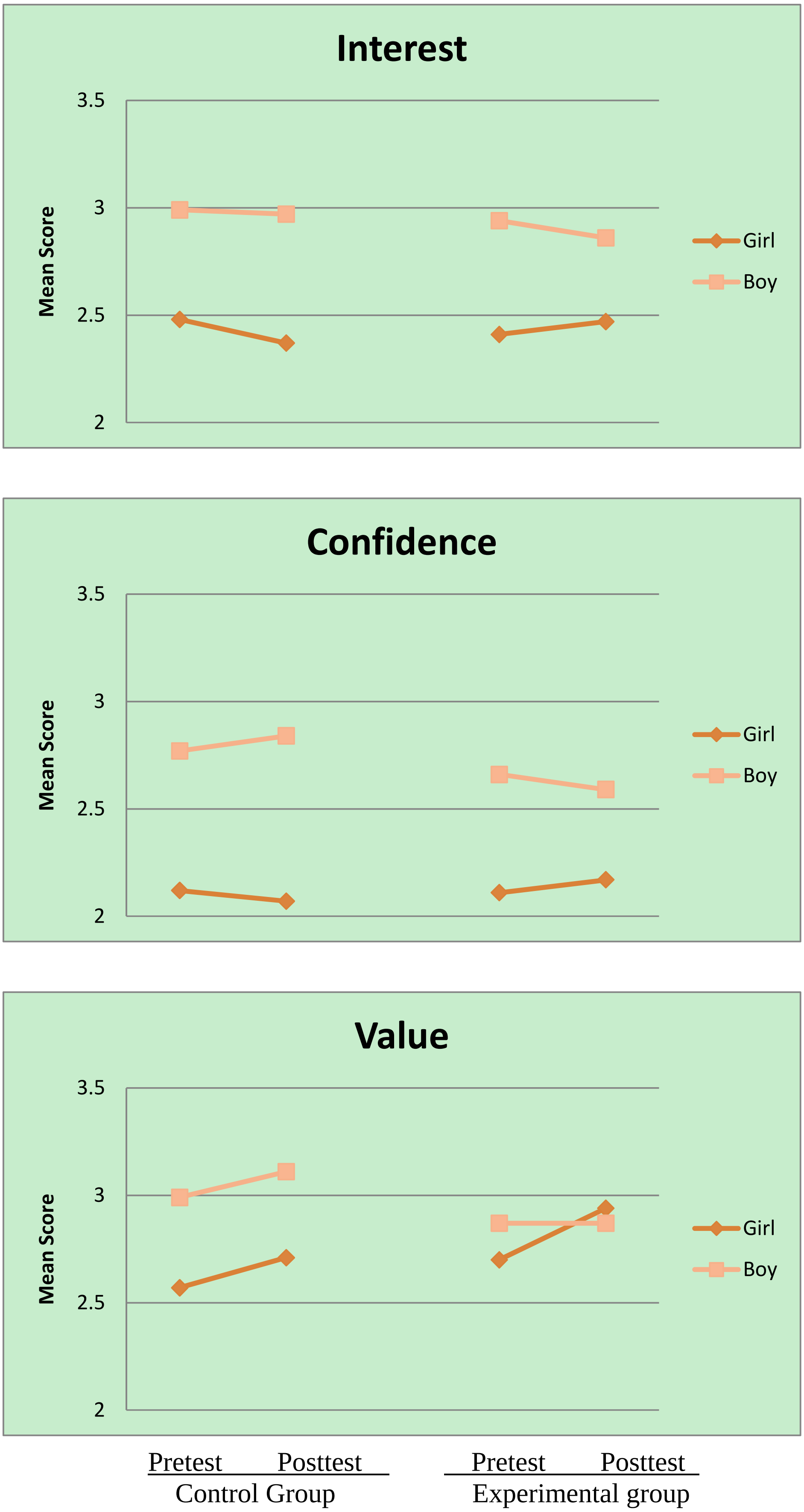

Figure 1. Changes in mean scores from pretest to posttest for the control and experimental groups.

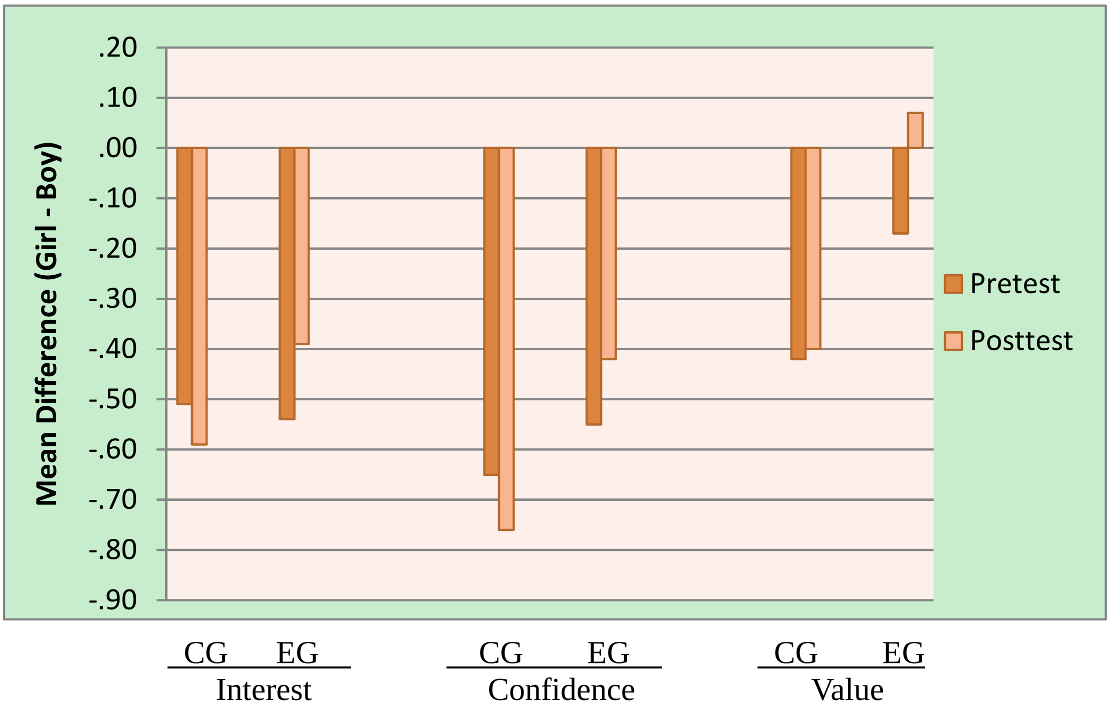

Figure 2. Gender differences in the mean scores of interest, confidence, and value, respectively, by test (pretest and posttest) and experiment (the control and experimental groups). CG = the control group; EG = the experimental group.

附件：出席國際學術會議心得報告及發表之論文各一份

一、心得報告

報告人姓名	邱美秀	服務機構及職稱	國立政治大學教育學系 副教授
時間 會議地點	2009 年 7 月 19-24 日 希臘塞薩羅尼基(Thessaloniki, Greece)	本會核定補助文號	NSC 97-2629-S-004-001
會議名稱	(中文)第 33 屆國際數學教育心理學年會 (英文) The 33rd Conference of the International Group for the Psychology of Mathematics Education, PME33		
發表論文題目	(中文)減少測量與代數成就表現上性別差距的情意、認知與社會因素 (英文)Affective, cognitive, and social factors in reducing gender differences in measurement and algebra achievements. (全文請見此表之後)		

報告內容

一、參加會議經過

19 日註冊與開幕

20 日主持一論文發表會、參與各場次學術活動

21 日發表論文、參與各場次學術活動

22-24 日參與各場次學術活動

二、與會心得

1、台灣取得主辦 PME 年會，令人高興。感謝相關學者的辛勞！

2、此學術研討會歷史悠久，與會學者包含知名資深、新生代、與研究生約千人，並且包括許多國家的學者。台灣有不少學者(含教授與研究生)參與並發表論文，這是很好的將台灣研究放置國際舞台的機會。

3、活動內容豐富、論文水準高、熱心的學者們提供建設性的意見以促進此領域之學術研究。

4、此團體主要由一群國際委員們規畫，學術活動規畫周詳、豐富，社群活動的規畫亦很貼心。

5、整體而言，這是一個高水準的國際學術研究團體與研討會。

三、考察參觀活動

除了學術活動外，主辦單位安排了很多元的文化參訪活動，介紹希臘文化。

四、建議

1、繼續擴大台灣學者與研究生參與此研討會的機會。

2、會中認識了二位在美國的華人，他們新近主辦一個數學教育的期刊，為的是幫助華人把研究放在國際的舞台上(結合美國學者的資源)，邀請大家參與審稿或投稿。近年來，台灣或東方越來越多學者以英文發表，如東方國家的一些教育期刊已進 SSCI。數學教育界目前只有一個 SSCI 期刊，而該期刊又是極偏特定文化。平心而論，SSCI 或 SCI 期刊，常只是「時間」的問題；此外，SCI 有時 2-3 頁即可，SSCI 期刊既少，頁數又多，文化的因素更是一大洪溝，很難相提並論。近年來不少國家或大學推出新的數學教育或教育期刊，同時接受英文與本國語言或數種語言的學術論文，即為彌補這個現況。台灣學界宜多出版一些學術期刊，讓更多台灣的、東方的學術作品得以展現在世界上，而不為特定的強勢文化所掌控，這是台灣文化、華人文化對人類與世界文明貢獻的開端。我們真的不需要再追求單一的強權文化，而是讓更多台灣、華人的文化與智慧得以展現出對人類文明的影響力。故建議：辦更多的學術期刊，包括中文和英文。

五、攜回資料名稱及內容

Proceedings of 33rd Conference of the International Group for the Psychology of Mathematics Education 共五冊。

二、發表論文：Chiu, M.-S. (2009). Affective, cognitive, and social factors in reducing gender differences in measurement and algebra achievements. In Tzekaki, M., Kaldrimidou, M. & Sakonidis, C. (Eds.). *Proceedings of the 33rd Conference of the International Group for the Psychology of Mathematics Education*, *2*, 321-328. Thessaloniki, Greece: PME.

AFFECTIVE, COGNITIVE, AND SOCIAL FACTORS IN REDUCING GENDER DIFFERENCES IN MEASUREMENT AND ALGEBRA ACHIEVEMENTS

Mei-Shiu Chiu[*]

National Chengchi University, Taiwan

The results of the TIMSS 2003 study indicated that boys had higher measurement achievements than girls and girls had higher algebra achievements than boys. It was predicted in this present study that affective, cognitive, and social factors could reduce these gender differences. The results of a series of regression analyses showed that gender differences in measurement achievements could be reduced by the sub-factors of inductive affect, social backgrounds, and cognitively closed learning experiences, while those in algebra achievements by the sub-factors of deductive affect, cognitively open learning experiences, and social resources, in a descending sequence.

INTRODUCTION

Gender differences in math achievements have long been an issue in math education as there should be equal opportunity, treatment, and outcomes for both boys and girls (Fennema, 1990). There appears a trend that gender differences in math achievements have gradually diminished and remain only in the band of high achievers at the school stage, but more males still enroll in advanced math courses than females (Askew &

[*]This research is supported by the National Science Council, Taiwan (NSC 97-2629-S-004 -001). 2009. In Tzekaki, M., Kaldrimidou, M. & Sakonidis, C. (Eds.). *Proceedings of the 33rd Conference of the International Group for the Psychology of Mathematics Education*, Vol. 2, pp. 321-328. Thessaloniki, Greece: PME.

Wiliam, 1995; Köller, Baumert, & Schnabel, 2001). In addition, qualitative differences between genders in math achievement still remain, as indicated by the result of the Trends in International Math and Science Study (TIMSS) of 2003 that boys were better at measurement than girls and girls were better at algebra than boys (Mullis, Martin, Gonzalez, & Chrostowski, 2004). Similar findings were obtained by Guiso, Monte, Sapienza, & Zingales (2008) using the data from the Program for International Student Assessment (PISA) of 2003. The identification of likely factors in reducing these gender differences can not only aid in creating an equal environment for both boys and girls to learn math but also foster an understanding of the qualitative differences in the relationships between gender and content domains in math.

Affective, cognitive, and social factors have all been found to be related to math achievement (Chiu, 2006, 2007). It is also likely that these factors are effective in reducing gender differences in math achievement. However, it is still necessary to ascertain the specific sub-factors to explain why there are differential gender differences in specific content domains in math.

Two affective sub-factors

There are two kinds of affective sub-factors which are likely to be effective in reducing gender differences in math achievement: inductive and deductive affects. Inductive affects are developed based on a long-term interaction with the world or an accumulation of a large amount of data from the world. The most significant affect in an inductive manner is confidence, two major sources of which are external or social comparisons with others' achievements and internal or intra-personal comparisons in achievements between different domains of knowledge (Chiu, 2008). Deductive affects are developed largely from drives or wills, which will help channel resources, focus attention, and overcome obstacles in order to search for some specific goals. One of the most significant affects in a deductive manner is academic aspiration.

Two cognitive sub-factors

Boaler (1998) compared math teaching strategies between two schools in England. In the school taking a content-based approach, students worked alone on a booklet and collected another one when finishing. There was no whole-class teaching and teachers interacted with individual students. On the other hand, students in a school focusing on a process-based approach were given open-ended problems and encouraged to develop ideas, extend problems, and relate math to daily lives. In addition, students discussed the meaning of their math work with peers and negotiated possible solutions. It was found that students in the content-based school had difficulty in solving real-life problems, while students in the process-based school had a deep approach to learning and using math. There were no significant gender differences in math achievement in the process-based school but boys had a higher achievement than girls in the content-based school.

Two social sub-factors

The sub-factors of social support may include (1) social backgrounds or the distal sub-factors, e.g., social and economic status (SES), and (2) social resources or opportunities, e.g., extra tutoring that is not part of regular school courses. It was found that social support was related to math achievements (Byrnes, & Miller, 2007). Guiso et al. (2008) found that gender differences in math achievements diminished in more gender-equal nations, which emphasized education, well-being, and political and economic status for females, but gender differences in geometry and arithmetic still remained in such nations. There appears to be a lack of evidence for the effect of social backgrounds and resources on gender equality in specific content domains in math.

The above three kinds of sub-factors in the affective, cognitive, and social aspects are likely to be related to gender differences in measurement and algebra achievements. The above claim is based on the following rationales. Girls are sensitive to external, social, and contextual messages and are likely to be highly influenced by inductive affects and social backgrounds. In addition, girls' tendency toward active reactions to social messages may imply that girls need cognitively closed learning experiences to concentrate on the pattern of measurement problems, which need cognitively focused thinking. On the other hand, boys' insensitivity towards social messages may decrease their ability to solve algebra problems, which requires dealing with complex messages and relationships. As such, open learning experiences may help foster boys' ability to deal with complex messages and relationships. In addition, boys' focus on one specific goal and adult investment by figures such as parents in channeling their efforts toward that goal is likely to compensate for their weakness in algebra, which requires practice and effort to achieve familiarity with and concentration in dealing with complex messages and relationships. Based on the above rationales, three hypotheses, also as depicted by Figure 1, are posited as follows.

1. Affective, cognitive, and social factors can reduce gender differences in measurement and algebra achievement.
2. Gender differences in measurement achievements can be reduced by the sub-factors of inductive affects (e.g., confidence), cognitively closed learning experiences (e.g., working on problems alone and reviewing homework in class), and social backgrounds (e.g., parental education levels).
3. Gender differences in algebra achievements can be reduced by the sub-factors of deductive affect (e.g., academic aspiration), cognitively open learning experiences (e.g., working in groups and relating math to lives), and social resources (e.g., receiving extra math tutoring).

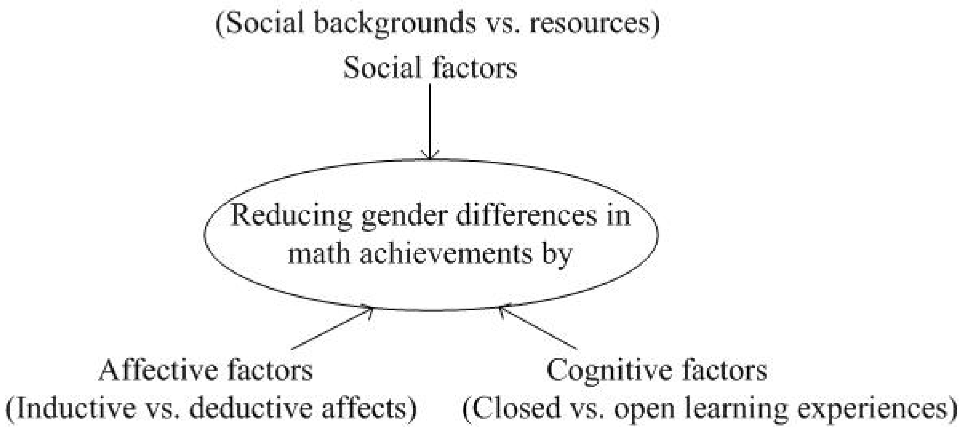

Figure 1: A model of affective, cognitive, and social factors in reducing gender differences in math achievements

METHOD

Participants

The participants were 230,229 Grade-8 students (50.3% girls, 49.2% boys, and 5% missing) from 47 countries participating in the TIMSS study of 2003.

Indicators

Five kinds of indicators (including 11 items) were taken from the database.

(1) Math achievements included students achievement results for *measurement* and *algebra* (TIMSS-variables bsmmea01 and bsmalg01).

(2) *Gender* (girls = 0; boys =1; TIMSS-variable itsex).

(3) Affective factors included students' *confidence* in learning math, e.g., 'I usually do well in math' (TIMSS derived-variable bsdmscl) and students' academic *aspiration* as to how far in school they expect to go (TIMSS-variable bsbghfsg).

(4) Cognitive factors referred to closed and open teaching strategies or learning experiences. Closed learning experiences included *working on problems on their own* and *reviewing their homework* in class (TIMSS-variable bsbmhwpo and bsbmhroh). Open learning experiences consisted of *working in small groups* and *relating math to daily lives* in class (TIMSS-variable bsbmhwsg and bsbmhmdl).

(5) Social factors comprised *parents' highest education levels* (TIMSS derived-variable bsdgedup) and *extra lessons or tutoring in math* that is not part of regular class (TIMSS-variable bsbmexto).

The achievement scores were obtained based on students' answers to a set of math problems in the content domains of measurement and algebra. The scores on the other indicators were derived from students' self-reports on a questionnaire. A higher score on all the indicators, except for gender, represented a higher achievement, degree, or frequency in the present study.

Statistical analysis

The major analysis method used here is linear regression. As suggested by the TIMSS 2003 user guide, student weights had to be used in all analyses in order to generate results representing the populations and SENWGT was used in the present study as it treated each country equally by setting a sample size of 500 for each country. Missing data were dealt with by pairwise exclusion in regression analyses.

RESULTS

Correlations between factors

The results of correlation analyses revealed that there were low correlations between all the items (below .331), except for a high correlation between measurement and algebra achievements (.873) (Table 1). The low correlations indicate a low degree of the problem of multicollinearity in regression analyses. No regression analysis was performed between the measurement and algebra achievements.

Factors in reducing gender differences in measurement achievements

The relation between gender and measurement achievements, or the regression coefficient for the effect of gender on measurement achievements, was small but significant (.022), as can be seen in Table 1 and in Model 1 (M01) in Table 2. The results mean that the .048% variance in measurement achievements could be explained by gender differences and that the positive value could indicate that boys are favored in solving measurement problems.

	M	A	1	2	3	4	5	6	7	8
Measurement achievement (M)										
Algebra achievement (A)	.873									
1. Gender	.022	-.045								
2. Confidence in math	.198	.201	.066							
3. Academic aspiration	.226	.265	-.069	.207						
4. Working on problems alone	.144	.139	.020	.133	.094					
5. Reviewing homework	-.069	-.045	-.029	.075	.050	.140				
6. Working in groups	-.260	-.255	.042	.029	-.026	.048	.117			
7. Relating math to daily lives	-.160	-.153	.051	.126	.031	.095	.201	.280		
8. Parental education levels	.330	.327	.017	.106	.240	.130	.005	-.146	-.071	
9. Extra math tutoring	-.169	-.138	.054	-.003	-.018	-.016	.050	.168	.114	-.073

Table 1: Pearson correlations between the 11 indicators. The correlations underlined are not significant at the .05 level.

The sub-factors that could reduce the regression coefficients for the effect of gender on measurement achievements included confidence (.022 in M01 → .009 in M02), working on problems alone (.022 → .019 in M04), reviewing homework (.022 → .020 in M05), and parental education levels (.022 → .017 in M08). The other sub-factors showed an increase in gender differences in measurement (M03, M06, M07, and M09). In addition, confidence alone could successfully reduce gender differences from significant (M01) to non-significant (M02). The two most effective sub-factors were confidence and parental education levels, which together could reduce the effect of gender differences from .022 to .006 (non-significant) (M10), and the three most effective sub-factors (i.e., confidence, parental education levels, and reviewing homework) all together could reduce gender differences from .022 to .005 (non-significant).

Factors in reducing gender differences in algebra achievements

The regression coefficient for the effect of gender on algebra achievement was -.045, which meant that .203% of the variance in algebra achievements could be explained by gender differences and the negative value revealed that girls were favored in solving algebra problems (M12 in Table 3). The effect of gender differences on algebra achievements was around four times (4.23 = .203% / .048%) larger than that on measurement achievements.

The sub-factors that could reduce the regression coefficient for the effect of gender on algebra achievements were academic aspiration (-.045 in M12 → -.023 in M14), working in groups (-.045 → -.030 in M17), relating math to daily lives (-.045 → -.033 in M18), and extra math tutoring (-.045 → -.033 in M20). None of these sub-factors could successfully reduce the significant gender effect to a non-significant one, perhaps partly because of the large effect of gender on algebra achievements. The two strongest sub-factors (i.e., aspiration and working in groups) together could reduce the regression coefficient for the effect of gender on algebra from -.045 to -.017 (M21), which, however, was still statistically significant. The two strongest sub-factors (i.e., aspiration and working in groups) with extra math tutoring all together could reduce the regression effect of gender on algebra from -.045 to -.013 (M22), which was non-significant. A point to note is that the two open learning experiences, working in groups and relating math to daily lives, and extra math tutoring were negatively related to algebra achievements but that these interventions and investments could effectively reduce gender differences.

Factors \ Models	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11
1. Gender	.022	.009	.038	.019	.020	.033	.030	.017	.031	.006	.005
Affective factors											
2. Confidence in math		.197								.164	.154
3. Academic aspiration			.229								
Cognitive factors (Math in class)											
4. Working on problems alone				.144							.048
5. Reviewing homework					-.068						
6. Working in groups						-.261					
7. Relating math to daily lives							-.162				
Social factors											
8. Parental education levels								.329		.312	.302
9. Extra math tutoring									-.170		

Table 2: Beta estimates obtained by regression analyses for the sub-factors in predicting measurement achievements. The estimates underlined are not significant at the .05 level.

Factors \ Models	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22
1. Gender	-.045	-.054	-.023	-.048	-.047	-.030	-.033	-.046	-.033	-.017	-.013
Affective factors											
2. Confidence in math		.201									
3. Academic aspiration			.261							.257	.256
Cognitive factors (Math in class)											
4. Working on problems alone				.140							
5. Reviewing homework					-.047						
6. Working in groups						-.253				-.247	-.232
7. Relating math to daily lives							-.150				
Social factors											
8. Parental education levels								.329			
9. Extra math tutoring									-.138		-.094

Table 3: Beta estimates obtained by regression analyses for the sub-factors in predicting algebra achievements. The estimates underlined are not significant at the .05 level.

DISCUSSION

The above findings indicate that affective, cognitive, and social factors can be effective in reducing gender differences in math achievements, but that there exist qualitative differences between the sub-factors in reducing gender differences in measurement and those in reducing gender differences in algebra. Gender differences in measurement achievements can be reduced by sub-factors such as confidence (inductive affects), parental education levels (social backgrounds), working on problems alone, and reviewing homework in class (cognitively closed learning experiences), in a descending sequence. On the other hand, gender differences in algebra achievements can be reduced by sub-factors such as academic aspiration (deductive affects), working in groups, relating math to lives (cognitively open learning experiences), and receiving extra math tutoring (social resources), also in a descending sequence. In addition, affective factors are the strongest factors in reducing both the weakness of girls in measurement and weakness of boys in algebra. The second strongest factor, however, is social factors for girls and cognitive factors for boys. This qualitative difference is further depicted in Figure 2.

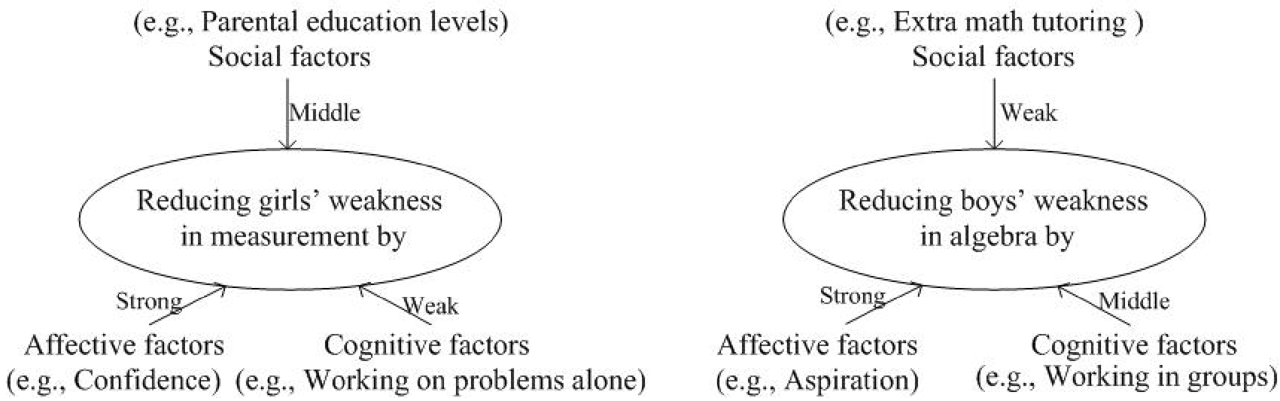

Figure 2: Differential affective, cognitive, and social sub-factors in reducing gender differences in measurement and algebra

The findings are consistent with the results of related studies that indicate that girls' weakness in math problem-solving is at least partly related to their weakness in affective factors, especially girls' low confidence in math (Gallagher & de Lisi, 1994). Academic aspiration is likely to be an important affective factor for boys. Closed and open teaching strategies or learning experiences were found to be related to gender differences in achievements in different math content domains. Past research on social factors in education typically focuses on SES. The recognition of the effect of social resources, which are provided to students in an active way, is a manifestation of the benefit that social investment can bring in improving students' math achievements.

The researcher took an integrated, domain-specific, and context-dependent approach to researching multiple factors in the relationships between gender and math achievements. In other words, it is argued that there is an integrated relationship between gender, math content domains, and cultural tools. Future research can further identify other effective sub-factors in affective, cognitive, and social aspects that may reduce gender differences in math achievements. For example, the frequent use of computers in learning math may be of benefit to boys and an interest-induced teaching program of benefit to girls.

References

Askew, M., & Wiliam, D. (1995). *Recent research in mathematics education 5-16*. London: Stationery Office.

Boaler, J. (1998). Open and closed mathematics: Student experiences and understanding. *Journal for Research in Mathematics Education, 29,* 41-62.

Byrnes, J. P., & Miller, D. C. (2007). The relative importance of predictors of math and science achievement: An opportunity-propensity analysis. *Contemporary Educational Psychology, 32*, 599-629.

Chiu, M. S. (2006). Routine and novel mathematical solutions: Central-cognitive or peripheral-affective participation in mathematics learning. In J. Novotna, H. Moraova, M. Kratka, & N. Stehlikova (Eds.), *Proceedings of the 30th Conference of the International Group for the Psychology of Mathematics Education, 2,* 313-320. Prague, Czech Republic: PME.

Chiu, M. S. (2007). Mathematics as mother/basis of science in affect: Analysis of TIMSS 2003 data. In J. H. Woo, H. C. Lew, K. S. Park, & D. Y. Seo (Eds.), *Proceedings of the 31st Conference of the International Group for the Psychology of Mathematics Education, 2,* 145-152. Seoul: PME.

Chiu, M. S. (2008). Achievements and self-concepts in a comparison of math and science: Exploring the internal/external frame of reference model across 28 countries. *Educational Research and Evaluation, 14,* 235-254.

Fennema, E. (1990). Justice, equity, and mathematics education. In E. Fennema & G. C. Leder (Eds.), *Mathematics and gender* (pp. 1-9). New York: Columbia University, Teachers College.

Gallagher, A. M., & de Lisi, R. (1994). Gender differences in scholastic aptitude tests: Mathematics problem solving among high-ability students. *Journal of Educational Psychology, 86,* 204-211.

Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, gender, and math. *Science, 320,* 1164-1165.

Köller, O., Baumert, J., & Schnabel, K. (2001). Does interest matter? The relationship between academic interest and achievement in mathematics. *Journal for Research in Mathematics Education, 32,* 448-470.

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., & Chrostowski, S. J. (2004). *TIMSS 2003 International Mathematics Report.* Chestnut Hill, MA: TIMSS & PIRLS International Study Center.