行政院國家科學委員會專題研究計畫 成果報告

女生科學學習的觀念雛形、認知歷程及社會影響的動態歷程研究--科學自我概念與科學評價對兩性科學學習之影響
研究成果報告(精簡版)

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行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告
□期中進度報告

女生科學學習的觀念雛形、認知歷程及社會影響的動態歷程研究--科學自我概念與科學評價對兩性科學學習之影響

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摘要

本研究以 TIMSS 1999 和 2003 的資料探討科學成就、科學自我概念以及科學評價的性別差異。研究樣本為台灣八年級學生，1999 年和 2003 年的人數分別為 5772 和 5739 名。所有的統計數值顯示從 1999 到 2003 性別的差異縮小。然而，低成就與高成就的性別差異值得持續關注。在低成就組女生表現優於男生而且有較小的分數變異。在高成就組男生表現優於女生，同時有較大的分數變異。儘管在不同成就水準，性別差異方向不同，但是在各成就水準，男生的數學自我概念與科學評價皆高於女生。雖然性別的科學成就差異趨近，但科學自我概念與科學評價的性別差異並未有相同的趨勢變化。科學自我概念與科學評價和科學成就的相關在高成就組較高。

關鍵字：TIMSS、價值期望理論、科學自我概念、科學評價

Abstract

This study investigates gender differences in science achievement, self-concept of science ability, and subjective science values, based on TIMSS 1999 and 2003 database. The sample in the analyses presented including 5772 (TIMSS 1999) and 5739 (TIMSS 2003) Taiwane se eighth graders. All statistics showed that gender differences became smaller. However, the gender differences in the upper and lower levels deserved continued investigation. At lower level, girls average performance were better than boys and had sma ller score variation. At upper level, boys outperformed girls and had larger variance. No matter the direction of gender differences at each quarter, boys always had higher self-concept of ability and subjective science values. It evidenced that gender differences in self-concept and science values did not parallel diminishing differences in actual achievement. When students' achievement levels were controlled, science self-concept and values were more highly related to science achievement for high achievers.

Keywords: TIMSS, expectancy-value model, science self-concept, subjective science value s

Gender Differences in Science Achievement, Science Self-concept, and Science Values

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Abstract

This study investigates gender differences in science achievement, self-concept of science ability, and subjective science values, based on TIMSS 1999 and 2003 database. The sample in the analyses presented including 5772 (TIMSS 1999) and 5739 (TIMSS 2003) Taiwanese eighth graders. All statistics showed that gender differences became smaller. However, the gender differences in the upper and lower levels deserved continued investigation. At lower level, girls average performance were better than boys and had smaller score variation. At upper level, boys outperformed girls and had larger variance. In addition, boys outnumbered girls in the top 25% in science performance. Boys significantly outperformed girls, while at lower quarter, girls outperformed boys. No matter the direction of gender differences at each quarter, boys always had higher self-concept of ability and subjective science values. It evidenced that gender differences in self-concept and science values did not parallel diminishing differences in actual achievement. When students' achievement levels were controlled, science self-concept and values were more highly related to science achievement for high achievers.

Keywords: TIMSS, expectancy-value model, science self-concept, subjective science values

Introduction

Gender differences in science have long been discussed among educators and researchers. For Taiwanese eighth graders, there was a significant difference of 17 scale-score points favoring boys in TIMSS 1999 science performance, while the difference reduced to 1 point in TIMSS 2003 (Martin, Mullis, Gonzalez,& Chrostowski, 2004; Martin et al., 2000). This finding was consistent with previous research results. Research has demonstrated a decline in gender differences in science performance; however, female representation in science-related field is still low (Jacobs, 2005).

People will be most likely to choose a major that they think they can master. Therefore, high-achieving students will be more likely entering science-related professions. The nature of differences in science performance can be masked or distorted by just comparing average score. In the study, gender differences at different achievement levels,

especially at the highest-scoring 25 percent students, will be examined. In addition to mean differences, differences in spread of scores are important because they help to explain why male may outnumber females among the high-achieving students when gender differences in mean score are small (Feingold, 1992; Hedges & Nowell, 1995; Nowell & Hedges, 1998; Willingham & Cole, 1997; Strand, Deary, & Smith, 2006). Hedges and Nowell (1995) used the variance ratio (VR), the ratio of the male variance to the female variance to investigate this question and found VR values of 1.05-1.25 for mathematics performance. In this study, ratios of the female standard deviation to the male deviation (SDR) are computed to examine sex differences in score variability (Willingham & Cole, 1997). Previous research suggests that the combination of a small average difference favoring boys and a larger variance for boys may lead to more males than females at the high end of ability distribution (Humphreys, 1988; Hyde, Fennema & Lamon, 1990). Therefore, ratios of the female numbers to the male numbers (F/M) are computed to investigate the proportion of gender at each quarter. Are the percentages and average achievement of girls and boys at each quartile equal? Is the change in gender difference over period similar at different achievement levels?

In addition to difference in science performance, motivation factors might underlie gender differences in educational and vocational choices. Eccles et al. Expectancy Value Model suggests that people's choices are strongly determined by their values and self-concepts of ability (Eccles et al., 1983; Jacobs and others, 2002). Previous research indicates that even the males and females score equally well on standardized tests of math ability, the males hold higher self-concept of science ability and science value than females do, and males select more difficult math course than the female do (Simpkins, Davis-Kean, & Eccles, 2006). Thus, gender differences in attitudes toward science need to be closely examined. Can parallel changes in gender difference be found in self-concept of science ability and subjective value? Does gender shape the relations among achievement, self-concept of science ability, and subjective value?

Method

Data source and sample

The study was based on the TIMSS 1999 and 2003 database (IEA. 2001, 2005). The sample in the analyses presented including 5772 (TIMSS 1999) and 5739 (TIMSS 2003) Taiwanese eighth-grade students (the sample size varies slightly across measures because of small variations in missing data). All students in the sample completed self-concept of science ability items and science values items.

Measures

Based on theoretical considerations and derived variables related to TIMSS students' attitudes, scales for the self-concept of science ability, science interest, and science instrumental value constructs were developed.

Self-concept of science ability. Four questions regarding 'natural science' using a four point Likert scale were asked to assess students' self–concept of science ability. TIMSS derived variable 'index of students' self-concept in science' is also make up of the four items. Responses to each question were recoded if necessary, then added to form scale scores. The higher scale scores indicated higher self-concept of science. The four items in year 2003 are different from those in year 1999. Internal consistency reliabilities for the self-concept of science ability were .77 and .79 respectively.

Subjective science values. For subjective task value, separate scales for interest and for utility were created in year 1999 based on theoretical consideration and factor analysis. Scale for science interest consists of 5 items included in the index of students' positive attitudes towards general science. The utility value scale consists of 4 items from student background questionnaires in TIMSS 1999. The reliabilities for science interest and utility value scales were reasonable (.83 and.79). There was only one scale for science value in year 2003 with internal consistency .89. The scale contains 7 items included in the index of students valuing science. Some items were recoded to keep all items in the same direction. Higher score means students attached higher value to science.

Science Achievement. Because matrix-sampling approach was adopted by TIMSS, each student's achievement was estimated by imputation technique. TIMSS draws five 'plausible values' for each student on science scale. That is, each student has five estimates of achievement on the TIMSS science scale. SPSS and IDB analyzer were used to combine the results from the five plausible values and to compute various statistics and their standard errors.

Finding and Discussion

Students were assigned to 4 groups based on their first plausible science scale score. Students whose scores were less than 25 percentile were assigned to the first group (the lower quarter). For students whose scores fell between 25 percentile and 50 percentile were assigned to the second group. The fourth group consisted of students whose scores were higher than 75 percentile. Percentages and average achievement of girls and boys at each quartile were compared. Analyses were conducted using house weights to obtained

unbiased estimates.

Gender Difference in Science Achievement

[Take in Table 1 about here]

Table 1 presents average achievement and percentage separately for girls and bo ys for each group. Compared to 1999, on average, girls showed a ten-point improvement, while boys showed a six-point decline. However, achievement differences between TIMSS 2003 and 1999 for girls and boys were not significant. In both years, there were significant gender differences at upper quarter. Gender difference at lower quarter was also significant in 2003. At upper quarter, boys significantly outperformed girls, while at lower quarter, girls outperformed boys. It was important to note that achievement gender difference at upper quarter decreased from 14-point to 7-point score. At lower quarter, gender difference increased and became statistically significant. It seems that gender difference in score mean becomes smaller. There was no significant difference at median levels in both years.

All SDRs but one less than 1 indicated that there was greater variability in boys' scores. The phenomenon was more evident in the upper and lower end of distribution. The greater male variability merits further investigated.

There were 50 percent each of girls and boys in the sample in year 1999. For year 2003 the ratio of girls and boys was 0.94. For equitable performance, the percentages of girls and boys in each quartile should be the same as sample percentages. In 1999, there were more girls than boys whose achievement below average. In 2003, percentages of girls at each level were closer to sample percentages. Specifically, the percentage of girls below overall average decreases over period. In both years, gender difference is more apparent among high-performing students. At the upper quarter level, the percentages of girls were forty and forty-five in year 1999 and 2003 respectively.

All statistics showed that gender differences became smaller. However, the gender differences in the upper and lower levels deserved continued investigation. At lower level, girls average performance were better than boys and had smaller score variation. At upper level, boys outperformed girls and had larger variance. In addition, boys outnumbered girls in the top 25% in science performance. It is a worthy goal to increase the percentage and performance of girls in the highest range.

Gender differences in science self-concept and science values

Gender differences in science self-concept and science values were tested with t test. The results are presented in Table 2. As can be seen by looking at the table, overall, boys had higher self-concept and values than girls in both years. When students' science

achievement levels were taken into account, in 2003, boys had higher science self-concept of ability and science values at all achievement levels, although only boys in highest range had higher performance than girls. It evidenced that gender differences in self-concept and science values did not parallel diminishing differences in actual achievement.

In 2003, the effect sizes for science self-concept were around 0.4-0.5 and for science values were around 0.2-0.3. As in earlier studies, girls had similar performance in science, but their self-concepts and science values were lower than those of boys. In 1999, boys had higher science interest at all achievement levels. The effect sizes range from .16 to .43. At all achievement levels, boys had higher self-concepts than girls, though differences only became significant at achievement levels above average. The effect sizes were 0.29 for group 3 and 0.27 for the top 25% students. Boys had higher instrumental values for science for groups 2 and 4, however, the effect sizes were small (.12 and .13). The findings were different from earlier studies. Previous research suggested that boys and girls had similar overall values of science. When belief about importance is examined separately, results indicated that boys attach greater importance to do well in math than girls (Simpkins, Davis-Kean, & Eccles, 2006). In this study, in 1999, science interest and utility values were measured separately, while in 2003, overall value was measured. In contrast to earlier study, when overall value was measured, boys had higher science value. When interest and instrumental value were measured separately, findings showed that boys had higher interest but had similar instrumental value of science. It is important to note that changes in science beliefs from year to year could be due to different measures of science beliefs. It is desirable to investigate whether science values should be measured as a whole or each component measured separately.

[Take in Table 2 about here]

Relations Between Beliefs and Achievement

[Take in Table 3 about here]

Bivariate correlations computed to examine relations between science achievement and beliefs were presented in Table 3. For both genders, students' science self-concept and value were positively associated with their science performance. In 1999, the correlations between science achievement and beliefs were slightly different for boys and girls. In general, boys' performance was more strongly associated with their science self-concept and values than girls' performance. In 2003, the correlations were similar for boys and girls. The latter findings confirm previous work ((Simpkins, Davis-Kean, & Eccles, 2006). The differential strength of relations across years could be due to different measures used. Science self-concept was more strongly associated with achievement than science values

across year and across gender.

When students' achievement levels were considered, science self-concept and values were more highly related to science achievement for high achievers. It is expected that the correlations within achievement level are smaller than those estimated on the entire gender group due to range restriction. With this limitation, science self-concept and values were still statistically significant correlated with achievement for both genders. In contrast, there were zero correlations between achievement and beliefs about science for low achievers. Research evidenced that students who valued science, were interested in science or had higher ability self-concept were more likely to take more science courses or pursue a science-related career (Farmer, Wardrop, & Rotella, 1999; Simpkins et al., 2006). Simpkins et al. (2006) found that students' self-concepts had stronger influence on their course choices than their grades. In addition, beliefs about science positively related to future science course grade and choices. Building students' self-concept in science is probably a key to diminish gender difference in the pursuit of science-related careers.

Conclusion and Implications

Findings from this study are noteworthy in that they (1) were based on national, representative data sets, (2) addressed gender differences in mean levels and relations between beliefs and achievement, and (3) examined gender differences at different achievement levels.

Looking at average performance, the gender gap in science in Taiwan has closed or almost closed. However, at the top 25% of distribution, gender differences in score mean, ratio of the female numbers to the male numbers and SDR have changed little. To encourage more female students to go into science fields, making sure that girls are equally science ability is still a worthy goal. Educators have to make some efforts to increase female numbers of high-achieving students.

Despite gender differences in science performance have narrowed, clearly there are some important differences in self-concept of ability and values in science. Since research suggests that domain-specific values and competence beliefs may mediate gender differences in achievement behaviors and course choices (Eccles, Wigfield, et al., 1993; Simpkins, Davis-Kean, & Eccles, 2006), the trend toward increasing differences between boys' and girls' science self-concept and values should not be disregarded. It is worthy of noting that effect sizes for self-concept were medium in 2003. Educators should devote time and effort to not just improve female students' science performance but also to developing their beliefs.

Although the relations among task values, self-concept, and performance have been highlighted in research, other studies have not investigated the strength of relations at different achievement levels. The study found that science self-concept and value were more highly related to science achievement for high achievers. Therefore, for high-achieving students, the influence of raising self-concept and values on their science achievement would be stronger.

In this study, achievement, self-concept and science values were measured at the same time point. As a result, causal relations among those variable can not be claimed. Future study should examine the longitudinal relations among students' science achievement, their perception of competence and values, and their career choices from middle childhood through adult.

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Table 1 Gender differences in mean achievement, score variability, and percentage

		1999						2003					
group		mean	t value	standard deviation	SDR	percentage (s.e.)	F/M	mean	t value	standard deviation	SDR	percentage (s.e.)	F/M
1	female	469.13	1.8	64.39	.94	52.84 (1.89)	1.12	477.92	3.26**	48.23	.89	47.52 (1.8)	.91
	male	462.18		68.65		47.16 (1.89)		467.50		54.30		52.48 (1.8)	
2	female	548.52)	-0.73	41.78	.95	56.58 (1.52)	1.30	551.80	-0.05	33.07	1.01	50.72 (1.3)	1.03
	male	550.63		43.81		43.42 (1.52)		551.89		32.60		49.28 (1.3)	
3	female	596.91	-1.52	41.56	.96	51.06 (1.59)	1.04	603.25	1.25	30.58	.96	50.49 (1.6)	1.02
	male	604.56		43.49		48.94 (1.59)		601.79		31.90		49.51 (1.6)	
4	female	651.77	-4.29***	47.31	.89	40.33 (2.09)	0.68	653.95	-3.24**	36.67	.91	44.57 (2.03)	0.84
	male	666.27		52.94		59.67 (2.09)		660.44		40.22		55.43 (2.03)	
total	female	560.66	-3.99***	82.80	.88	50.2（1.13）	1.01	570.63	-0.29	74.49	.89	48.33 (1.04)	0.94
	male	577.56		93.91		49.8（1.13）		571.52		83.31		51.61 (1.04)	

*p<.05. **p<.01. ***p<.001.

Table 2 means of science self-concept, science values by gender and achievement level

		1999						2003			
		self-concept		interest		instrument		self-concept		value	
group	sex	mean（sd）	t value	mean （sd）	t value	mean （sd）	t value	mean（sd）	t value	mean（sd）	t value
1	female	9.44 (1.73)	-0.54	12.69 (2.63)	-3.87***	12.06 (2.46)	-0.41	8.39 (2.19)	-5.30***	15.47 (4.24)	-3.29**
	male	9.51 (2.18)		13.43 (2.85)		12.13 (2.74)		9.09 (2.30)		16.44 (5.15)	
2	female	9.97 (1.79)	-1.68	13.30 (2.62)	-4.18***	12.07 (2.40)	-2.02*	8.68 (2.32)	-4.60***	15.69 (4.26)	-4.85***
	male	10.11 (1.91)		13.92 (2.68)		12.35 (2.34)		9.37 (2.64)		17.08 (4.76)	
3	female	10.27 (1.82)	-5.95***	13.74 (2.59)	-8.32***	12.57 (2.24)	-0.25	9.71 (2.50)	-5.56***	17.08 (4.06)	-7.45***
	male	10.84 (1.93)		14.97 (2.79)		12.58 (2.34)		10.53 (2.90)		18.71 (4.62)	
4	female	10.95 (1.82)	-4.82***	14.69 (2.67)	-8.09***	12.51 (2.14)	-2.28*	11.0 (2.65)	-5.51***	18.83 (4.47)	-4.87***
	male	11.48 (1.72)		15.85 (2.69)		12.83 (2.25)		11.86 (2.78)		20.17 (4.61)	
total	female	10.11(1.86)	-7.78***	13.54 (2.74)	-13.79***	12.28 (2.34)	-3.29**	9.41 (2.62)	-11.90***	16.73 (4.45)	-9.91***
	male	10.57(2.07)		14.65 (2.91)		12.50 (2.42)		10.25 (2.89)		18.15 (5.01)	

*p<.05. **p<.01. ***p<.001.

Table 3 Correlations between science achievement and beliefs

	1999			2003		
group		female	male		female	male
1	self-concept	.02	.08	self-concept	.02	-.04
	interest value	-.03	.11	science values	-.01	-.02
	instrumental value	-.01	.08			
2	self-concept	.11*	.18*	self-concept	.08	.08
	interest value	.11	.16*	science values	.12**	.08
	instrumental value	.09	.11			
3	self-concept	.08	.14**	self-concept	.16***	.17**
	interest value	.13*	.12	science values	.12	.12*
	instrumental value	.08	.07			
4	self-concept	.16**	.22***	self-concept	.17***	.22***
	interest value	.19***	.18***	science values	.21***	.21***
	instrumental value	.07	.08			
total	self-concept	.26***	.37***	self-concept	.36***	.36***
	interest value	.24***	.34***	science values	.28***	.29***
	instrumental value	.10**	.14**			

*p<.05. **p<.01. ***p<.001

(六)計畫成果自評

本研究依原計畫達成預期研究目標，研究成果已發表於 IRC 2008 的國際研討會。將於近期內改寫投稿到學術期刊上。