行政院國家科學委員會專題研究計畫　期中進度報告

學生在 TIMSS 不同數學題型上的成就及其與性別、數學學習情意、學習情境的交互作用(1/2)

計畫類別：個別型計畫
計畫編號：NSC94-2522-S-004-001-
執行期間：94 年 08 月 01 日至 95 年 07 月 31 日
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此精簡報告主要包含三篇已發表或已被接受之論文：

Chiu, M. (2005). *Predictors of Mathematical Achievement and Deep Approaches: A Comparison Between TIMSS Results of Taiwan, Japan, and England.* Paper presented at the Japan-Taiwan Bilateral Symposium, The First International Conference on Asia Comparative Education, National Taiwan Normal University, Taiwan, 8th-12th November 2005. (Supported by NSC 94-2522-S-004 –001)

Chiu, M. (2006, accepted). Routine and novel mathematical solutions: central-cognitive or peripheral-affective participation in mathematics learning. *Proc. 30th Conf. of the Int. Group for the Psychology of Mathematics Education*. Prague, Czech Republic: PME. (Supported by NSC 94-2522-S-004 –001)

Chiu, M. (2006, accepted). *A situated self-regulated learning system: Evidence from Taiwanese children's constructs of mathematical problems*. Paper presented at the 2nd International Biennial Conference of the Metacognition Special Interest Group (SIG 16) of the European Association of Research in Learning and Instruction (EARLI), The University of Cambridge Faculty of Education, UK, 19 – 21 July 2006. (Supported by NSC 94-2522-S-004 –001)

後二篇將於今年 7 月發表於國外的學術研討會，故「出席國際學術會議心得報告」將於參加研討會後繳交。

Chiu, M. (2005). *Predictors of Mathematical Achievement and Deep Approaches: A Comparison Between TIMSS Results of Taiwan, Japan, and England.* Paper presented at the Japan-Taiwan Bilateral Symposium, The First International Conference on Asia Comparative Education, National Taiwan Normal University, Taiwan, 8th-12th November 2005.

Predictors of Mathematical Achievement and Deep Approaches:

A Comparison Between TIMSS Results of Taiwan, Japan, and England

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Using 13-year-old students' background and mathematics achievement data from the Trends in Mathematics and Science Study (TIMSS, 2003), the study aimed to identify significant predictors of mathematics achievement and deep approaches to mathematics; comparisons were also made between Taiwan, Japan and England. One-way ANOVAs were conducted to compare the students of the three cultures over the achievement indicators and 16 background variables. Stepwise regressions were performed to identify best variables predictive of mathematics achievements and deep approaches. There were different pictures of learning and teaching practices between the three cultures. Predictors of mathematics achievement were found to be quite different from those of deep approaches to mathematics.

Achievement has long been the focus for many educational studies; however, deep approaches, including intrinsic motivations and willingness to take or do more mathematics, are another important indicator of learning outcomes or teaching quality (Kember, Charlesworth, Davies, McKay, & Stott, 1997). The present study focused on educational issues that would be likely to contribute the two major outcomes of teaching and learning.

Byrnes (2003) proposed a 3C Model of Skill Acquisition and argued that students' achievement was determined by the following three conditions: (1) the exposure condition, where genuine opportunities were provided to promote their skills/achievements; (2) the motivational condition, where students were willing to

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make use of these opportunities; (3) the skill level condition, where students were able to make use of these opportunities. In other words, teachable, manageable or changeable variables would be worth finding in order to improve educational practices and promote students' learning outcomes. In the present study, these variables included variables related to affective contexts and teaching contexts. The only demographic variable explored in the present study was gender, as gender differences on mathematics achievements have long been the study focus of research on mathematics education.

Affective contexts and achievement

Research, in general, reveals that there is a significant relationship between self-efficacy and attainment. Past attainment was the best predictor of present attainment (McCaffery et al., 2001). Apart from cognitive variables, self-efficacy or confidence tended to be the best affective predictor of attainment (Pietsch, Walker, & Chapman, 2003). High achievers tended to have a high confidence and low achievers low confidence (Meyer & Koehler, 1990; Meece, Wigfield, & Eccles, 1990; Seegers & Boekaerts, 1996, 1993). Confidence even appeared to be a better predictor of students' participation in mathematics than mathematics attainment (Meyer & Koehler, 1990). Zimmerman (1995) summarized several studies and claims that self-efficacy was a critical factor in predicting mathematics attainment and mathematics anxiety, while anxiety made no direct impact on attainment. Efficacy explained 13% of the variance in attainment even when mathematics ability was controlled.

Learning approaches were viewed as a significant predictor of achievement, as revealed by Diseth & Martinsen (2003) and Saljo (1981), in which the participants were students at the stage of higher education, studying diverse subjects. Deep approaches normally positively relate to achievement, such as Saljo (1981) and Zeegers (2001). There are, however, some exceptions; for instance, Diseth & Martinsen's study showed that the deep approach was not a predictor of achievement. They attributed the missing relationship between the deep approach and achievement to the 'fixed curriculum' and 'examination procedure'. Another example is reported in Newble and Hejka (1991), in which the deep approach was not a significant predictor of attainment, for students from either traditional or problem-based medical schools. Newble and Hejka attributed this result to 'examination systems which drive the students toward a surface or strategic approach' (p. 339).

Relatively, fewer studies were focused on the role of students' perceptions of value of mathematics in achievements. Usefulness/value of mathematics is the best predictor of participation in mathematics (Meyer & Koehler, 1990). In Whitebread &

Chiu’s (2004) and Chiu’s (2004) study, children with a rebellion or negative ambivalence toward mathematics tended to view mathematics in an instrumental way, not perceiving teachers as worth following, with little self-efficacy, not obeying existing rules to solve problems, not investing much time in learning mathematics, and not perceiving mathematics as interesting.

Research has revealed that positive possible selves (e.g. educational aspirations) would increase the possibility of development of plans, strategies and positive emotions; this in turn would trigger active actions and create positive achievement (Markus & Cross, 1994).

Teaching contexts and achievement

Askew, Brown, Rhodes, Johnson, & Wiliam (1997) identify three orientations of teaching: connectionist, transmission and discovery for English teachers. In terms of ‘numeracy subject knowledge’ (Askew et al., p. 49), connectionist teachers tend to introduce and elaborate links between different mathematical concepts; transmission teachers generates superficial and few links; discovery teachers work on problems as deep as the connectionist teachers but have difficulty elaborating the links. In addition, there is a moderately positive relationship between children’s attainment and teachers’ working on mathematical problems in depth, by using links ‘explained in conceptual terms rather than being only procedural (rule-based)’ (p. 52) without apparent rationales. Strongly transmission oriented teachers have lower depth than strongly connectionist and discovery teachers. The connectionist orientation was found to foster greater pupil achievement than discovery and transmission orientations. The characteristics of ‘connectionist’ teachers described by Askew et al. is also consistent with those of an ideal teacher suggested by Manouchehri & Goodman’s (2000) study.

McCaffery et al. (2001) compared two kinds of teaching practice in high schools in the US. Students’ achievement scores were obtained for open-ended and multiple-choice problems respectively. The teaching materials based on new curriculum reform in the US are called ‘integrated mathematics’, while there are still some schools who use ‘traditional sequence’ mathematics textbooks. There are two significant results of the two different teaching methods. Firstly, for the students receiving integrated mathematics, the more their teachers tended to be integrated-mathematics oriented, the higher achievement the students obtained for both the open-ended and multiple-choice problems. Secondly, for students receiving traditional mathematics, there was no relationship between the teaching method and students’ achievement for either kind of problem. The results imply that, according to

McCaffery et al. (2001), teachers have to put the principles of the curriculum reform into practice, in order to effectively implement the reform.

A common conclusion which Askew et al. (1997) and McCaffery et al. (2001) made was that strongly connectionist or integrated-oriented teaching tends to have positive impact on students' attainment.

Gender and achievement

According to Fennema (1990), the equality of gender in mathematics should include 'equal opportunity to learn mathematics', 'equal educational treatment' and 'equal educational outcomes'. However, males enrolled on the advanced mathematics courses more than females in the UK, Australia (Leder, 1990) and Germany (Koller, Baumert, & Schnabel, 2001). In terms of cognitive outcomes, by the end of secondary education, males tended to learn more mathematics than females (Fennema, 1990). Some studies have shown that the difference between attainments of males and females were minimal and only in the top bands of 10% to 20% (Leder, 1990). In 1992, the pilot of national curriculum tests for UK 14-year-olds showed that girls had higher attainment than boys, though gender differences still remained in the band of high achievers, in which there was a ratio of two girls to three boys obtaining grade 'A' at the age of 16 in the GCSE (Askew & Wiliam, 1995).

In order to delve into the deep meaning of what TIMSS data could possibly reveal, the present study would draw on raw data of TIMSS 2003 to conduct diverse kinds of statistical analyses, as have widely used in research of educational psychology. As a result, the study results should be interpreted under the condition of samples used in these analyses. Detailed procedures would be described about how the raw data were processed and analyzed.

Method

Participants

The participants were 1089 13-year-old students in Taiwan, Japan and England, who filled in the student questionnaires and took the Booklet 3 mathematics tests in the TIMSS 2003. They were 445 Taiwanese students (222 girls, 223 boys), 403 Japanese students (206 girls, 197 boys), and 241 English students (119 girls, 122 boys).

Taiwanese samples were chosen, as the study of the sample would provide implications for improvement on teaching and learning contexts for children of the researcher's major concerns. The implications could be further enriched by comparison with Japan, which shares some common eastern cultures with Taiwan, and has prestige of high-quality achievements. English samples were selected, since it was one of the western cultures which play significant roles in the world, and shared a common character with Taiwan and Japan: Their country land is composed of islands, which are near continents. This common geographical characteristic offers a ground for comparison, as some common characteristics might be shared by the people of these three cultures, such as outward looking because of their land limitation and ocean accessibility. The researcher has ever stayed in England for doctoral study during 2000-2004 and did field work there, which would facilitate the explanation of study results, especially where cultural comparisons were made.

Measures

There were two measures used in the present study: student self-report questionnaire and student mathematics achievement test of Booklet 3, in TIMSS 2003.

Student questionnaire. The TIMSS student background questionnaire contained a wide range of items which aimed to collect information about students' diverse learning contexts. There were two kinds of items in the questionnaire: demographic/factual items, and Likert-scale items. With the aim of the present study and according to literature and study focus, potential predictors of mathematics achievements were selected from the factors identified by factor analysis for the Liker-scale items, or derived from the demographic/factual items.

The factor analysis drew on the data from Taiwanese students who filled in the Student Questionnaire, TIMSS 2003. The participants included 4661 Grade 4 students and 5379 Grade 8 students. In order to facilitate comparisons between Grades 4 and 8 students for future research, only common items in the two questionnaires were selected for analysis. Factor analyses were performed to identify factors for Likert-scale items grouped together in the two questionnaires respectively. Factors identified based on the Grade 4 data were compared with those based on the Grade 8 data. A factor would be confirmed in the present study for later analysis, only if it met the following two criteria. First, two sets of questionnaire data both revealed same factors with same items. Second, factors were identified by one set of the data only, but the literature on mathematics education showed that the factors had been significant predictors of mathematics achievement.

The final 16 background variables selected were organized into 6 groups, as can be seen in Appendix A, with information of scoring methods, and internal reliability coefficients for the factors. Although the variable of constructivist teaching revealed low reliability, factor analysis on the items of mathematics teaching approaches for the 13,065 three-culture samples showed a clear three-factor structure, i.e. the Variables 5-7. In addition, the constructs of constructivist and transmission teaching are well documented in literature of mathematics education. Therefore, the variable of constructivist teaching was kept for the further analyses. The mean score of responses to items in a factor was obtained to work as the value of a factor in analysis.

Student achievement test. Students' responses to the mathematics test items of Blocks 3, 4 and 13 on Booklet 3 in TIMSS 2003 were used as the indicators of the students' mathematics achievement. There were 43 mathematics items in total, which included 28 multiple-choice items and 14 constructed-responses items, over the five mathematics content domains: algebra (11 items), data (3 items), geometry (6 items), measurement (8 items), and number (15 items). Any completely correct answer to an item was awarded one point; no point was awarded for other responses, including partially correct, incorrect, invalid and omitted ones. Mean scores of the 43 items were calculated and served as the indicators of mathematics achievement.

Items of Blocks 3, 4 and 13 on Booklet 3 were chosen as the achievement measures because they together made up the most quantity of released mathematics items, which could be obtained from a single booklet. In addition, none of these items was placed at the last sections of the test books, where some students might omit to solve the items because of their low speed in problem-solving, rather than their ability.

Data analysis

One-way ANOVA was conducted to compare the Taiwanese, Japanese and English students over the achievement indicators and 16 background variables. LSD post hoc multiple comparisons were made where there were significant ANOVA test results. Stepwise regressions were performed to identify best variables predictive of mathematics achievements and deep approaches for the Taiwanese, Japanese and English students respectively. Comparisons were also made for the results of regression analyses.

Results

Cultural differences on variables

Table 1 lists the means, standard deviations, and ANOVAs test results over the variables for the three cultures. As can be seen, there were cultural differences between the three cultures, except for gender and deep approaches. Similar numbers of boys and girls attended the tests for the three cultures respectively. Students of the three cultures showed similar and relative high interest in learning mathematics and taking more mathematics in school.

There were significant differences between the three cultures on the mathematics achievements, in descending order: Taiwan, Japan and England. The result was consistent with that reported in TIMSS 2003 International Mathematics Report (Page 34, Chinese Taipei: 585; Japan: 570; England: 498). This result also implied that the achievement measure used in the present study provided reasonable indicators of students' achievements.

Table 1

Means, standard deviations, and one-way ANOVAs test results comparison between three countries on variables

Variables	Taiwan M	Taiwan SD	Japan M	Japan SD	England M	England SD	F	LSD post hoc results
Math Achievement	.66	.24	.62	.20	.52	0.2	34.29**	T>E ,T>J, J>E
Learning affects								
1. Self-efficacy in math	2.46	.74	2.25	.64	2.97	.64	78.2**	T>J, E>T, E>J
2. Deep approach to math	2.25	.86	2.32	.75	2.24	.77	1.13	
3. Value of math	2.61	.67	2.51	.57	2.88	.61	24.8**	T>J, E>T, E>J
4. Educational aspiration	2.20	.73	1.52	.56	1.88	.85	83.19**	T>J, T>E, E>J
Math teaching approach								
5. Content-complexity	2.44	.70	2.68	.65	2.41	.57	18.24**	J>T, J>E
6. Constructivist teaching	2.02	.69	1.99	.71	2.46	.62	38.85**	E>T, E>J
7. Transmission teaching	3.02	.77	3.49	.68	3.16	.68	44.77**	J>T, J>E, E>T
Teaching strategy								
8. Math homework	1.85	.69	1.48	.60	1.55	.66	36.69**	T>J, T>E
9.Extra math lessons or tutoring	2.31	1.1	1.73	.89	1.27	.55	97.97**	T>J, T>E, J>E
10.Computer-use for learning	2.07	.84	1.5	.61	2.59	.87	144.76**	T>J, E>T, E>J
School quality								
11.Favorable school	3.01	.54	2.91	.57	2.9	.57	4.74**	T>J, T>E
12.Safe school	4.86	1.36	5.35	1.04	5.06	1.12	17.51**	J>T, J>E, E>T
Learning resources								
13.Computer availability	4.78	.67	4.22	.98	4.78	.60	62.25**	T>J, E>J
14.Books at home	2.92	1.25	3.05	1.22	3.21	1.29	4.05*	E>T
15.Test language use home	3.23	.78	3.94	.31	3.85	.49	176.88**	J>T, J>E, E>T
Others								
16.Gender	.50	.50	.49	.50	.51	.50	.11	

* Significant at the .05 level,

** Significant at the .01 level

In the aspect of *learning affects*, English students had more confidence about their mathematics ability and more regarded mathematics as a valuable pursuit for their present and future lives than Taiwanese and Japanese students respectively; Taiwanese students were higher on these two variables than Japanese students. On the other hand, Taiwanese students showed higher educational aspiration than English and Japanese students. To summarize the three results, English students appeared to have the most positive learning affects among the three, Taiwanese students the second, and Japanese students the third. This result showed an interesting contrast to that of achievement comparison. It implied that what students perceived and what they really gained were very likely to be different. A striking finding was that English students had high confidence in their mathematics ability (Mean= 2.97, above average=2.5), while Japanese and Taiwanese students have below average confidence, despite their high achievement on the international comparison tests.

In *mathematics teaching approaches*, Japanese teachers were perceived by their students as offering a wide variety of teaching contents in a single lesson, than their counterparts. English teachers were viewed by their students as offering more opportunities for them to work together in small groups and explain their answers. According to their students' viewpoints, Japanese teachers were the most transmission-oriented, English teachers the next, and Taiwanese teachers the least. The result revealed that teachers of the respective three cultures took quite different approaches to mathematics teaching.

In the aspects of *mathematics teaching strategies*, Taiwanese students had more amount of mathematics homework to do than Japanese or English students. Taiwanese students also received the most extra mathematics lessons or tutoring from their teachers, Japanese students the next, and English students the least. In other words, Taiwanese students spent the most significant amount of time doing mathematics besides scheduled mathematics lessons. English students had the most amount of experience using computers to write reports and looking up ideas and information for learning, Taiwanese students the next, and Japanese students the least.

Taiwanese students liked to go to school, viewing their peers as hard workers and having a high regard for their teachers' attentiveness and encouragement, more than Japanese and English students. However, Taiwanese students experienced the most number of unsafe events in school; Japanese schools were the safest, and English schools the next. The unsafe events mainly included stealing, bullying and ignoring by students.

In the aspect of *learning resources*, computers were more available for Taiwanese and English students than for Japanese students. A note to make was that, despite this difference, most students in the three cultures had computers at home and school (mean scores of the three cultures all above 4). English students had more books at home than Taiwanese students. Although most students in the three cultures spoke their respective test-use languages (Mandarin (Chinese), Japanese and English) (all high above average, 2.5), there were significant differences between the three cultures. The ratio of Japanese students who spoke Japanese at home was higher than that of their English and Taiwanese counterparts who spoke their official languages respectively. The ratio of English students who spoke English at home was higher than that of Taiwanese students who spoke Mandarin at home.

Regression analyses

Two dependent variables were used in the stepwise regression analyses; they were mathematics achievement and deep approaches to mathematics. For each dependent variable, the other 16 variables served as independent variables, as can be seen in Table 2. The results of analyses showed that, or Taiwanese students, the five predictors of mathematics achievement were, in descending order: educational aspiration, self-efficacy, transmission teaching, content-complexity teaching, and test language use at home. These predictors together predicted 53% of the variance of Taiwanese students' achievement, as revealed by the R^2 value in Table 2. Japanese students, the five predictors were educational aspiration, self-efficacy, transmission teaching, books at home and 'constructivist teaching' (at a reverse direction), which predicted 30% of the variance of Japanese students' achievement. For English students, the four predictors were self-efficacy, educational aspiration, transmission teaching, test language use at home, and computer availability. These four variables together predicted 25% of the variance of English students' achievement. The three regression models were all significant, as revealed by the F values in Table 2.

Table 2

Predictors of mathematics achievement and deep approaches to mathematics for Taiwan, Japan and England respectively

Dependent variables	Math achievement			Deep approaches to mathematics		
Independent Variables	Taiwan Beta(rank)	Japan Beta(rank)	England Beta(rank)	Taiwan Beta(rank)	Japan Beta(rank)	England Beta(rank)
Math Achievement						
Learning affects						
1. Self-efficacy in math	.30**(2)	.279**(2)	.27**(1)	.29**(2)	.18**(2)	.17*(3)
2. Deep approach to math						
3. Value of math				.41**(1)	.32**(1)	.33**(1)
4. Educational aspiration	.32**(1)	.280**(1)	.25**(2)			
Math teaching approach						
5. Content-complexity	.16**(4)					
6. Constructivist teaching		-.14**(5)				
7. Transmission teaching	.18**(3)	.23**(3)		.13**(3)	.12*(5)	.
Teaching strategy						
8.Math homework						
9.Extra math lessons or tutoring						
10.Computer-use for learning					.13*(4)	.31**(2)
School quality						
11.Favorable school				.11**(4)	.16**(3)	
12.Safe school						
Learning resources						
13.Computer availability			.165*(4)			
14.Books at home		.17**(4)	.166*(3)		.	
15.Test language use home	.15**(5)					
Others						
16.Gender						
R	.73	.56	.53	.69	.54	.62
R^2	.53	.31	.28	.47	.29	.38
Adjusted R^2	.53	.30	.25	.47	.28	.37
F	82.96**	26.27**	12.61**	82.15**	23.61**	27.11**

* Significant at the .05 level,

** Significant at the .01 level,

To summarize, educational aspiration and self-efficacy were best predictors of achievement for all the three cultures. Taiwanese and Japanese students' achievement were more related to teachers' teaching approaches; English students' achievements were more related to learning resources, though Japanese students' achievement also related to books at home and Taiwanese students' achievement related to test-languages use.

Deep approaches failed to be a significant predictor of achievement; achievement also failed to predict deep approaches for the three cultures, as revealed in the right half of Table 2. The four significant predictors of Taiwanese students' deep approaches to mathematics were, in descending order: value of mathematics, self-efficacy, transmission teaching and favorable schools. These four predictors together predicted 47% of the variance of Taiwanese students' deep approaches to mathematics. The five predictors of Japanese students' deep approaches were value of mathematics, self-efficacy, favorable schools, computer use for learning, and transmission teaching, which predicted 28% of the dependent variables' variance. There were only three significant predictors of English students' deep approaches; they were value of mathematics, computer use for learning, and self-efficacy.

The three cultures had two common predictors of students' deep approaches; they were value of mathematics and self-efficacy in mathematics. Taiwanese and Japanese students' interest and positive action towards mathematics were predicted by how much they liked their school and whether their teachers' teachings were transmission-oriented. Japanese and English students' deep approaches were influenced by the frequency of computer-use for learning purposes. No variables of learning resources served as significant predictors of student deep approaches.

A final note to make is that gender was neither a significant predictor of students' mathematics achievement nor that of their learning approaches to mathematics for the students in the three cultures respectively.

Discussion

Based on the results of comparison between the cultures on several issues in relation to mathematics learning and teaching, a theme or picture of mathematics teaching and learning was likely to be delineated for each culture.

Taiwan. Most students might have desirable mathematics achievements in 'international' terms, but, in 'personal' terms, students failed to have corresponding confidence in their mathematics ability. They had high ambition in pursuit of higher education; this motivation could promote their achievement. Perceptions of value of mathematics could increase their interest and action to learn more mathematics. Students worked on mathematics relatively quite often; they were given mathematics homework or extra lessons besides scheduled mathematics periods. Teachers used diverse approaches to mathematics teaching. Students' achievement relied on teachers' direct teaching and in-depth interpretation of connected mathematics concepts. Teaches' direct teaching could promote their interest in learning more mathematics. Students liked their schools and teachers, which increase their interest in learning mathematics; on the other hand, peer quality might be a small trouble for their school life, such as bullying and stealing. Most students had computers at home and school, though computer-use could not increase their interest in mathematics. There were not many books at home for most families. Though most students spoke official language at home, there were a significant number of students speaking some other local languages; this was likely to be a disadvantage for them in taking tests, or this might relate to their social or economical background and, in turn, influence their achievement.

Japan. Students had high achievement but low confidence in their mathematics ability, though confidence was a significant factor in predicting their achievement and interest in studying mathematics. Their aspiration to higher education could increase their achievement, while their perceptions of value of mathematics could really promote their interest and action to do more mathematics. Teachers were good at giving content-rich mathematical knowledge in a specific period of teaching. Most teachers were transmission-oriented, which could increase students' achievement and interest in doing more mathematics. Though there were few teachers focusing on a constructivist teaching approach, this approach had a negative influence on students' achievement. Japanese schools were safe places, where there were very few events of bullying and stealing. Computer-use for learning was well-managed by teachers and therefore could enhance students' interest in taking more mathematics. If students like their schools and teachers, they were also likely to have more interests and action to do more mathematics.

England. Students had relatively high regard for their ability in mathematics, despite the results of international comparison tests. Like Japan and Taiwan, students' confidence and aspiration to higher education can predict their achievement. Transmission was a normal teaching practice in English mathematics classroom, but constructivist approaches were also often taken by teachers. English school was quite safe. However, teaching and schooling failed to influence students' achievement and deep approaches to learning mathematics, except the experiences of computer-use for learning, which could increase students' interest and action to do more mathematics.

Most students had many books at home, and computers at home and school; these two factors could predict students' achievement. This implies that English students' achievement and learning approaches are more likely to be influenced by other factors outside of school, such as social and economic status, while Taiwanese and Japanese teachers and schooling did have more influence on their students' learning mathematics.

Neither culture had significant gender difference in mathematics achievement.

Implication for educational practice: What we can learn from other cultures?

Every culture offers an important mirror for others to more clearly look at themselves, and a lesson to learn from.

Japan provided their students very safe schools, very few events of bullying and stealing; English schools were safer than Taiwanese ones as well. Japanese teachers were good at giving students multiple, diverse and connected mathematical knowledge in a given period for students. This teaching has been identified by Askew et al. (1997) as a 'connectionist orientation', which was the most effective teaching approaches to prompting students' mathematics achievement. 'Content-complexity' teaching approach could predict Taiwanese students' achievement, but not in Japan. Further research is needed to explore this issue. In Japan and England, computer-use for learning had positive influence on students' achievement, but this could be not found in Taiwan. It implies that computer-assisted learning for mathematics was better managed in Japan and England than in Taiwan. Taiwanese families had fewer books at home than English families. Further international joint studies are needed for clarifying these issues in order to learn from other cultures.

English students had high confidence in their mathematics ability. Research has indicated that confidence or self-efficacy has been a significant predictor of participation in mathematics (Meyer & Koehler, 1990) and mathematics achievement (Zimmerman, 1995). Although Taiwanese students had a good result on the test, the low confidence might inhibit their will in pursuit of learning opportunities or occupations related to mathematics. Future research is needed to identify significant factors in developing students' confidence in mathematics and to develop appropriate teaching approaches which promote confidence and achievement at the same time.

Taiwanese teachers gave students a significant amount of homework and extra lessons and teaching for mathematics. These teaching strategies, however, failed to have positive influence on students' achievement, not only for the samples of Taiwan but also for those of Japan and England respectively. Therefore, further research is needed to assess the necessary amount of homework and teaching time.

Implications for theories

Learning approaches are viewed as a significant predictor of achievement, as revealed by Diseth & Martinsen (2003), Saljo (1981), and Zeegers (2001). There are, however, some exceptions; for instance, Diseth & Martinsen's study (2003) showed that deep approaches were not a predictor of achievement.

In the present study, achievement could not predict deep approaches; deep approaches failed to predict achievement. The predictors of them were also quite different, except for self-efficacy. Transmission teaching was found a significant predictor of achievement and deep approaches only in Taiwan and Japan. For achievement, apart from self-efficacy, educational aspiration was the best predictor; for deep approaches, value of mathematics was the best predictor. In addition, achievement appears to be more likely to be influenced by learning resources than by schooling and teaching strategies. Deep approaches were predicted more by computer-use for learning and favorable schooling, than by learning resources. High quality of schooling seems to be a necessity for students' deep approaches to mathematics.

Further research is needed to explore whether there were separate paths toward mathematics achievement and deep approaches to mathematics, as some research has indicated that deep approaches can be related to achievement. In addition, it is also necessary to identify which learning context and affective variables are needed to promote them respectively and explore the relationships between these variables.

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Appendix A Student background variables

1.Self-efficacy in mathematics (1= agree a lot to 4= disagree a lot) (reversed coding, r) (α(*T*aiwan) = .59; α(*J*apan) = .54; α(*E*ngland) = .55)
I usually do well in mathematics.
Mathematics is more difficult for me than for many of my classmates. (reverse meaning to the construct, so he original coding was remained)

2.Deep approaches to mathematics (1= agree a lot to 4= disagree a lot) (r) (α(*T*) = .78; α(*J*) = .74; α(*E*) = .69)
I would like to take more mathematics in school.
I enjoy learning mathematics.

3. Value of mathematics (1= agree a lot to 4= disagree a lot) (r) (α(*T*) = .81; α(*J*) = .71; α(*E*) = .76)
I think learning mathematics will help me in my daily life.
I need mathematics to learn other school subjects.
I need to do well in mathematics to get into the <university> of my choice.
I would like a job that involved using mathematics.
I need to do well in mathematics to get the job I want.

4. Educational aspiration (1=below first degree, 2=first degree, 3=beyond first degree)
How far in school do you expect to go?

Taiwan	Japan	England
1 = Senior high school, vocational school	1 = Upper secondary school	1 = GSCE Level / A Level
2 = Vocational high school	2 = Junior college (2 years)	2 = Access course for higher education
3 = College/junior college of technology	3 = Option not administered or data not available	3 = HNC or HND
4 = Bachelor`s degree	4 = University	4 = Bachelor`s degree
5 = Master's or PhD	5 = Graduate school	5 = Master`s degree or higher
6 = I do not know	6 = I do not know	6 = I do not know

5. Content-complexity (1=every or almost every lesson to 4=never) (r) (α(*T*) =.75 ; α(*J*) = .74; α(*E*) = .66)
We work on fractions and decimals
We interpret data in tables, charts, or graphs
We write equations and functions to represent relationships

6. Constructivist teaching (1=every or almost every lesson to 4=never) (r) (α(*T*) = .38; α(J) = .37; α(E) =.26)
We work together in small groups
We explain our answers

7. Transmission teaching (1=every or almost every lesson to 4=never) (r) (α(*T*) = .60; α(J) = .63; α(E) = .43)
We listen to the teacher give a lecture-style presentation
We work problems on our own

8.Math homework (1=high: at least 3-4 times, at least 31 minutes for each, to 3=Low: at most 1-2 times, at most 30 minutes for each) (r)
How often does your teacher give you homework in mathematics? (1= every day to 5=never)
When your teacher gives you mathematics homework, about how many minutes are you usually given? (1 = fewer than 15 minutes to 5=more than 90 minutes)

9.Extra math lessons or tutoring (1= every or almost every day to 4=never or almost never) (r)
During this school year, how often have you had extra lessons or tutoring in mathematics that is not part of your regular class?

10.Computer-use for learning (1= every or almost every day to 4=never or almost never) (r) ($\alpha(T) = .76$; $\alpha(J) = .71$; $\alpha(E) = .75$)
How often do you do these things with a computer?
I look up ideas and information for mathematics
I look up ideas and information for science
I write reports for school

11. Favorable school (1= agree a lot to 4= disagree a lot) (r) ($\alpha(T) = .68$; $\alpha(J) = .69$; $\alpha(E) = .73$)
I like being in school
I think that students in my school try to do their best
I think that teachers in my school care about the students
I think that teachers in my school want students to do their best

12.Safe school (1= Yes, 2=No, changed to 1=Yes, 0=No, counting the 'yes's and doing reversed coding, 6=no these unsafe things, to 1=5 unsafe things)
In school, did any of these things happen during the last month?
Something of mine was stolen
I was hit or hurt by other student(s) (e.g., shoving, hitting, kicking)
I was made to do things I didn't want to do by other students
I was made fun of or called names
I was left out of activities by other students

13.Computer availability (1=home & school; 2=home, not school; 3=school, not home; 4=use computer, but not school, not home; 5 no computer) (r)
Where do you use a computer? (1=yes, 2=no, for the following respectively)
At home; At school; At a library; At a friend's home; At an Internet café; Elsewhere

14.Books at home (1=None or very few (0-10 books) to 5=Enough to fill three or more bookcases (more than 200 books) (r)
About how many books are there in your home? (Do not count magazines, newspapers, or your school books.)

15.Test language use home (1=always to 4=never) (r)
How often do you speak <language of test> at home?
(Language of test: Taiwan=Mandarin (Chinese); Japan=Japanese; England=English)

16.Gender (0=girl, 1=boy)
Are you a girl or a boy?

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ROUTINE AND NOVEL MATHEMATICAL SOLUTIONS: CENTRAL-COGNITIVE OR PERIPHERAL-AFFECTIVE PARTICIPATION IN MATHEMATICS LEARNING

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The study aimed to identify influential variables that determined students' routine and novel responses to a creative mathematical problem in the TIMSS 2003 study. A special focus was placed on comparisons between the five Asian outperforming countries and the five English-speaking Western ones. The Western countries had more novel solutions than their Asian counterparts. Routine solutions were related to a centrally cognition-oriented context of mathematics learning; novel solutions came from a peripherally affect-oriented context. Asian novel solvers experienced a far more peripheral and negative affective participation in their mathematical learning communities than Western novel solvers.

INTRODUCTION

There has been a growing concern on affective issues in mathematics education (McLeod, 1994; Grootenboer, 2003). Most studies on the affective domain of mathematics education, however, aimed at students' attitudes toward mathematics as a whole (e.g. Di Martino & Zan, 2003; Hannula, 2002). There are relatively fewer studies focusing on the affective issue in relation to mathematical problem-solving, especially to performance on actual mathematical problem-solving tasks (e.g. Schoenfeld, 1989; Whitebread & Chiu, 2004; Chiu, 2004). The study

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reported in this paper was a further endeavor in the study of 'the intersection of the cognitive and affective domains' (Schoenfeld, 1989, p. 338) in mathematics education. Using student responses to TIMSS 2003 for five Asian performing and five English-speaking Western countries, the present study compared students' routine and novel solutions to a creative mathematical problem in relation to their affective issues and learning contexts. This 'integrated approach' will likely to broaden our understanding of affective issues in mathematics education by taking account of specific problem type, learning contexts and cultures at the same time.

LITERATURE REVIEW

Mathematical problem-solving is not only a cognitive issue but also an affective one. The affective moments in the process of mathematical problem-solving are 'feelings' and 'psychological states' (Mason et al., 1996, p. 130) hard to grasp but worth calmly observing, providing that we avoid negative thoughts, such as criticism, judgment and embroidery. With the trend toward constructivist mathematics in the US, McLeod (1994) indicated that students' affective responses to solving non-routine mathematical problems deserve researchers' attention. This is because, in order to solve non-routine problems, students need to invest a significant amount of time and intense feelings are likely to occur. Middleton & Spanias (1998) also indicate that realistic mathematical problems tend to 'provide more avenues for failure' (p. 68). This suggests differential affective responses to different types of mathematical problems.

Researchers have identified a variety of types of mathematical problems, such as word and calculation problems (Vermeer et al., 2000), routine and non-routine problems (e.g. McLeod, 1994), well-structured and ill-structured problems (Nitko, 1996), and creative/construction problems (e.g. Schoenfeld, 1989). Relating problem types to affective issues, Schoenfeld found that students tended to solve proof tasks with already-known procedures and to solve construction ones with a trial-and-error approach. Vermeer et al.'s study showed that children made a higher appraisal of computation problems than application problems; they also had higher motivation to solve computation than application problems. Boys tended to have more confidence than girls; girls tended to attribute their failure to ability and the difficulty of tasks. Boys had higher achievement than girls for application problems but there was no difference between boys and girls for computation problems. Boaler's (1998) research indicated that boys had more confidence, enjoyed more in mathematics and had higher achievement for close-ended problems than girls. However, in the process-based, mathematics-project teaching, this gender difference had been eliminated. Whitebread & Chiu's (2004) study identified four distinct patterns of students' affective response in relation to problem types, with involvement students preferring ill-structured/challenging problems, rebellion students preferring well-structured problems (with the degree of difficulty fitting to or slightly higher than their ability), conformity students preferring easy, diverse problems, and avoidance students preferring easy well-structured problems. The above literature suggests that there are complex interactions between students' diverse performances on complex mathematical problems and affective issues, in relation to learning contexts, such as gender, teaching, and learning resources, as was explored in the present study.

METHOD

Participants

The participants were 4,198 13-year-old students in five Asian outperforming countries and five English-speaking Western countries (Table 1 shows the student number of each country); they filled in the student questionnaires and took the Booklet 3 mathematics tests in the TIMSS study in 2003. As there were some missing data for the student variables, these cases were deleted and ended with 3,269 students for the analysis of influential variables (Table 2).

Indicators

Four kinds of indicators were taken from the TIMSS 2003 study. (1) *Country mathematics achievement*. The individual country's mathematics achievements were indicated by their average scale scores of each country, as provided by on Page 34 in the TIMSS 2003 International Mathematics Report. (2) *Student mathematics achievement*. One set of plausible values of student mathematical achievement provided by the TIMSS database were used as the indicators of individual students' overall mathematical achievements. These values were good estimates of parameters of student populations. (3) *Student responses to the focused problem*. The focused problem in the present study was 'Write a fraction that is less than 4/9'. This was the only 'creative' mathematical problem, in the TIMSS 2003 study, which had endless correct answers. In addition, these correct answers can be clearly classified as ‘routine correct solutions’(3/9, 1/3, 4/10, 2/5), ‘novel correct solutions’ (other correct solutions), and ‘incorrect solutions’. (4) *Student self-report results*. There were 16 other variables selected from the self-report TIMSS student questionnaire (Table 2). The variables based on the Likert-scale were derived from factor analysis on the sample of 4,198 students in the present study.

RESULTS

There were significant differences between the Asian and Western countries in the four kinds of mathematical achievements, as presented in Table 1. The Asian countries outperformed the Western counterparts in the aspects of the overall mathematical achievements (t (8)=14.67) and the percentages of routine responses to the focused problem (t (8)=6.49). As a reasonable result, the Asian countries had less incorrect responses than the Western countries (t (8)=-4.66). However, the Asian countries had fewer novel ‘correct’ responses than the Western ones (t (8)=-5.18). This result was a contrary to the above trend, as it is sensible to predict that different samples should have similar distribution patterns of ‘correct answers’ of many kinds. The result also implied that there are different meanings of ‘novel responses to mathematical problem-solving’ between the Asian and Western students.

Table 1: Achievements by countries, and test results

	Asian outperforming countries					Mean	English-speaking Western countries					Mean	T
	Hong Kong	Japan	Korea	Singapore	Taiwan	(N=5)	Australia	England	New Zealand	Scotland	United States	(N=5)	
Number of students1	413	403	439	499	445		403	241	323	297	735		
Country math achievement 2	586	570	589	605	585	587.0	505	498	494	498	504	499.8	14.67**
Routine responses 3 (%)	62.7	65.3	76.3	76.6	68.3	69.8	48.9	52.7	40.6	39.4	44.9	45.3	6.49**
Novel responses 4 (%)	15	14.9	4.3	5.4	9.0	9.7	24.8	19.5	21.7	22.9	22.7	22.3	-5.18**
Incorrect responses (%)	22.3	19.9	19.4	18	22.7	20.5	26.3	27.8	37.8	37.7	32.4	32.4	-4.66**

1For each country shows the number of students who solved the focused problem in Booklet 3, TIMSS 2003.
2Math achievements are the average scale scores as indicated in Exhibit 1.1, TIMSS 2003 International Mathematics Report, p. 34.
3Routine responses to the focused problem include 3/9, 1/3, 4/10, 2/5.
4Novel responses are the correct solutions to the focused problem, except the above routine responses.
** Significant at the .01 level

Discriminant function analyses were performed, in order to determine the influential student variables in defining the three kinds of responses. The analysis was conducted for the three samples of all the students, Asian students and Western students respectively, given the possibility that there were differential meanings of novel responses between the Asian and Western students. As can be seen in Table 2, Function 1s for the three samples can best distinguish routine responses from incorrect ones. This implies that Function 1s address issues of achievements. Function 2s, on the other hand, can distinguish novel responses from the other two types of responses, addressing issues of novelty.

Table 2. Discriminant analysis: Functions at Group means

Country group		%of Variance	Wilks' lambda	Routine responses	Novel responses	Incorrect responses	F(ANOVA test)	LSD test results
All students	Function 1	90 %	.78**	.386	-.279	-.773	399.04**	R>N,R>I, N>I
	Function 2	10 %	.97**	-.041	.387	-.137	45.42**	N>R, N>I, R>I
Asian students	Function 1	92 %	.83**	.252	-.170	-.828	163.47**	R>N,R>I, N>I
	Function 2	8 %	.99*	.030	-.394	.070	13.84**	R>N, I>N
Western students	Function 1	92 %	.80**	.424	.030	-.673	159.24**	R>N,R>I, N>I
	Function 2	8 %	.98*	-.082	.262	-.070	14.52**	N>R, N>I

* Significant at the .05 level
** Significant at the .01 level

Table 3 reveals that, for all the students, the most significant influential variables that distinguish routine responses from incorrect responses are mathematics achievements and aspiration to higher education. Novel solvers were distinguishable by their test-language use at home, computer-use for learning, computer availability, positive mathematical affect (self-efficacy and value), and low disposition toward schooling. In addition, most novel solvers were boys and had fewer extra mathematics lessons.

Both Asian and Western routine solvers were distinguishable by their high mathematical achievements, self-efficacy in mathematics, and aspiration to higher education (Tables 4-5). The two groups of students, however, were different in their perceptions of mathematical teaching. Transmission- and constructivist-oriented teaching approaches were both positive variables in influencing Asian students' achievements. Western high-achievers experienced fewer extra mathematical lessons or tutoring.

Compared with their Asian counterparts, most Asian novel solvers' parents were from other countries. They has low disposition toward schooling and negative mathematical affects (including self-efficacy, deep approaches, and value). Although Asian novel solvers had more learning resources (such as speaking test-use languages at home and having computers at home and school), they perceived few opportunities of computer-use for learning purposes. They also experienced ‘freer’ mathematical teaching approaches or strategies: few extra mathematics lessons or tutoring, few transmission-oriented teachings, and little mathematical homework.

Table 3. Affective/contextual variables by all solvers

	Routine responses N=1935		Novel responses N=486		Incorrect responses N=790		ANOVA test	LSD post hoc test	Discriminant analysis	
Student variables	M	SD	M	SD	M	SD	F	Results	Function1	Function2
Affects										
1. Self-efficacy in math	2.74	.80	2.77	.74	2.55	.83	18.52**	R>I,N>I	.18	.37 [a]
2. Deep approach to math	2.58	.88	2.48	.86	2.46	.88	6.31**	R >N, R >I	.12	-.07
3. Value of math	2.94	.63	3.04	.63	2.96	.64	4.76**	N> R,N>I	-.05	.29 [a]
4. Disposition to schooling	3.05	.56	2.97	.60	3.06	.60	4.26**	R >N	.02	-.30 [a]
5. Aspiration to higher education	2.08	.76	1.95	.80	1.86	.78	24.08**	R>N,R>I,N>I	.25[a]	.01
Math teaching approaches										
6. Content-complexity	2.57	.67	2.62	.69	2.55	.68	1.75		.02	.19
7. Constructivist teaching	2.56	.71	2.62	.70	2.56	.73	1.64		-.02	.18
8. Transmission teaching	3.06	.66	3.04	.65	2.99	.69	3.39*	R>I	.09	.06
Teaching strategies										
9. Math homework	1.93	.71	1.92	.69	1.93	.71	.047		-.00	-.03
10.Extra math lessons/tutoring	1.96	1.08	1.61	.88	1.81	1.01	23.45**	R>N,R>I,I>N	.17	-.51 [a]
11.Computer-use for learning	2.29	.84	2.41	.90	2.36	.94	4.83**	N>R	-.09	.21 [a]
Social & economic status										
12. Mother born in the country	.84	.36	.83	.38	.82	.39	1.78		.07	-.00
13. Father born in the country	.85	.35	.82	.39	.83	.38	2.70		.07	-.10
14. Test-language use at home	3.52	.77	3.71	.63	3.53	.79	12.88**	N>R,N>I	-.05	.52 [a]
15. Computer availability	4.67	.64	4.74	.60	4.53	.78	17.22**	R>I,N>I	.14	.46 [a]
Others										
16. Gender	.50	.50	.51	.50	.42	.49	7.62**	R>I,N>I	.12	.20 [a]
17. Math Achievement	582.08	78.67	532.08	72.02	494.28	78.71	381.29**	R>N,R>I,N>I	.97 [a]	.01

* Significant at the .05 level
** Significant at the .01 level

a Absolute correlation between the student variable and the Function 1 (or Function 2) equal to or larger than .20

Table 4. Student variables by responses for Asian students

	Routine responses N=1266		Novel responses N=160		Incorrect responses N=353		ANOVA test	LSD post hoc Test	Discriminant analysis	
Variables	M	SD	M	SD	M	SD	F	Results	Function 1	Function 2
Learning affects										
1. Self-efficacy in math	2.52	.76	2.28	.66	2.22	.73	26.29**	R>N,R>I	.39 [a]	.37 [a]
2. Deep approach to math	2.60	.86	2.40	.84	2.43	.82	8.74**	R>N,R>I	.21 [a]	.36 [a]
3. Value of math	2.83	.62	2.70	.62	2.74	.61	4.69**	R>N,R>I	.14	.31 [a]
4.Disposition toward schooling	3.06	.53	2.94	.54	3.03	.54	3.71**	R>N	.07	.46 [a]
5. Educational aspiration	2.08	.74	1.99	.74	1.85	.73	14.36**	R>I	.30 [a]	-.00
Math teaching approach										
6. Content-complexity	2.52	.67	2.49	.67	2.38	.66	5.66**	R>I	.18	-.08
7. Constructivist teaching	2.48	.70	2.39	.70	2.32	.68	7.54**	R>I	.21[a]	.10
8. Transmission teaching	3.02	.66	2.89	.69	2.86	.68	10.26**	R>N,R>I	.24 [a]	.25 [a]
Teaching strategy										
9. Math homework	1.92	.73	1.84	.75	1.91	.71	.77		.02	.23 [a]
10.Extra math lessons/tutoring	2.28	1.11	2.07	1.02	2.14	1.09	4.27**	R>N,R>I	.13	.32 [a]
11.Computer-use for learning	2.20	.85	2.08	.89	2.14	.91	1.64		.07	.26 [a]
Social & economic status										
12. Mother born in the country	.86	.35	.77	.42	.84	.37	5.06**	R>N,I>N	.09	.53 [a]
13. Father born in the country	.88	.33	.81	.40	.85	.36	3.97**	R>N	.10	.40 [a]
14. Test-language use at home	3.40	.81	3.49	.83	3.31	.89	2.96*	N>I	.08	-.36 [a]
15. Computer availability	4.64	.64	4.64	.70	4.49	.77	6.81**	R>I,N>I	.19	-.22 [a]
Others										
16.Gender	.51	.50	.49	.50	.43	.50	3.74**	R>I	.15	-.03
17. Math Achievement	604.87	72.58	574.85	67.56	531.00	72.89	148.68**	R>N,R>I, N>I	.95[a]	.04

* Significant at the .05 level,
** Significant at the .01 level
a Absolute correlation between the student variable and the Function 1 (or Function 2) equal to or larger than .20

Table 5: Student variables by responses for Western students

Variables	Routine responses N=680 M	SD	Novel responses N=334 M	SD	Incorrect responses N=450 M	SD	ANOVA Test F	LSD post hoc test Results	Discriminant analysis Function 1	Function 2
Learning affects										
1. Self-efficacy in math	3.15	.71	3.02	.65	2.81	.81	28.48**	R>N,R>I,N>I	.42 [a]	-.06
2. Deep approach to math	2.53	.88	2.52	.86	2.48	.92	.32		.04	.02
3. Value of math	3.15	.60	3.20	.58	3.14	.62	1.20		.02	.28 [a]
4.Disposition toward schooling	3.04	.61	2.99	.63	3.07	.64	1.85*	R>N,I>N	-.06	-.30 [a]
5. Educational aspiration	2.08	.81	1.94	.83	1.87	.82	8.93**	R>N,R>I	.23 [a]	-.22 [a]
Math teaching approach										
6. Content-complexity	2.66	.64	2.68	.69	2.67	.67	.07		-.02	.05
7. Constructivist teaching	2.71	.69	2.74	.68	2.76	.71	.62		-.06	.05
8. Transmission teaching	3.14	.65	3.12	.62	3.10	.67	.64		.06	-.05
Teaching strategy										
9. Math homework	1.94	.68	1.95	.66	1.94	.71	.05		-.01	.06
10.Extra math lessons/tutoring	1.35	.70	1.39	.71	1.54	.86	7.98**	I>R,I>N	-.22 [a]	-.10
11.Computer-use for learning	2.45	.81	2.57	.86	2.52	.94	2.61*	N>R	-.07	.35 [a]
Social & economic status										
12. Mother born in the country	.81	.39	.86	.35	.80	.40	2.24*	N>I	.03	.38 [a]
13. Father born in the country	.80	.40	.83	.38	.81	.39	.32		-.01	.15
14. Test-language use at home	3.77	.61	3.82	.46	3.7	.66	3.89**	N>I	.11	.38 [a]
15. Computer availability	4.74	.63	4.79	.54	4.57	.78	12.35**	R>I,N>I	.23 [a]	.50 [a]
Others										
16.Gender	.49	.50	.52	.50	.42	.49	4.20**	R>I,N>I	.13	.32 [a]
17. Math Achievement	538.97	72.38	511.10	64.54	464.63	70.36	148.91**	R>N,R>I,N>I	.97[a]	-.05

* Significant at the .05 level,
** Significant at the .01 level
a Absolute correlation between the student variable and the Function 1 (or Function 2) equal to or larger than .20

DISCUSSION

Although some Asian countries outperformed other countries on several international competition tests in mathematics and science, such as TIMSS and PISA, the present study highlighted their significant lack of novel problem-solutions in mathematics, even by analyzing responses to one ‘creative’ mathematical problem in TIMSS 2003 study. While routine solutions were related to their general mathematics achievements and aspiration to higher education, novel solutions was more related to positive affects about mathematics and plentiful learning resources. Novel solvers also appeared to have negative disposition toward schooling and did not rely on extra teaching. This result implies routine and novel mathematical solutions are cultivated by different contexts of mathematics learning, with ‘routine solutions’ determined by mathematical achievement and performance/ability goals, and ‘novel solutions’ determined by

Western novel solvers were distinguishable from their Asian counterparts by their abundant learning resources and high regard for mathematics. Most Western novel solvers were boys and their mothers were natives. They, however, had slightly low disposition toward schooling and low aspiration to higher education. A comparison between the three samples in the influential variables is presented in Table 6.

Table 6: Student groups by influential variables of routine and novel solving

Student group	Influential variables of ***routine*** solving	Influential variables of ***novel*** solving
All students	(+)Math achievement (+)Aspirational affect	(+) Learning resources (language, computer use/availability) (+) Math affect (self-efficacy, value) (-) Schooling affect (-) Teaching (extra math) (+) Boy
Asian students	(+)Math achievement (+)Math affect (self-efficacy) (+)Aspirational affect (+)Teaching (transmission, constructivist)	(-) Nationality (mother, father) (-) Schooling affect (-) Math affect (self-efficacy, deep approach, value) (+) Learning resources (language, computer availability) (-) computer use (-) Teaching (extra math, transmission, math homework)
Western students	(+)Math achievement (+)Math affect (self-efficacy) (+)Aspirational affect (-)Teaching (extra math)	(+) Learning resources (computer availability, language, computer use) (+) Math affect (value) (+) Nationality (mother) (+) Boy (-) Schooling affect (-) Aspirational affect

strong learning-resource supports, positive mathematical affects, and detached schooling/teaching experiences. In other words, routine solutions were developed by an achievement-centered learning context or centrally cognition-oriented context of mathematics learning; novel solutions came from a self-centered learning context or a peripherally affect-oriented contexts of mathematics learning. Mathematics has long been regarded by students as full of routine problems that can be solved by routine procedures (Schoenfeld, 1989). In order to become the 'formal member' of mathematics learning, i.e. becoming a high-achiever, providing routine solutions are likely to be the most significant means. Given the critical aim of high-achievement in mathematics learning, novel solvers are the 'peripheral' (Lave & Wenger, 1991, p. 29) members of mathematics 'classroom communities' (Hamm & Perry, 2002, p. 135).

The tension between central-cognitive and peripheral-affective participation tends to be stronger for the Asian students than for the Western students. Both Asian and Western routine solvers have high mathematics achievement, self-efficacy in mathematics and high aspiration to higher education. Asian routine solvers benefited from both transmission and constructivist approaches of mathematical teaching, while Western routine solvers experienced few extra mathematics lessons/tutoring in school. In other words, Asian routine solvers were at the very center of mathematical learning, in terms of both achievement orientation and participation in teaching activities; Western routine solvers were at the center of learning, in terms of achievement orientation, but less in terms of teaching.

Asian novel solvers experienced a far peripheral and negative affective participation in their mathematical learning communities. The only positive factor for Asian novel solutions was learning resources of test-language use and computer availability. Asian novel solvers' parents were not natives; they had various kinds of negative affective responses to schooling and mathematics; they experienced loose mathematical teaching. This picture is a mirror image of their Asian routine solvers', a rather positive one. On the other hand, except for low disposition toward schooling and low educational aspiration, Western novel solvers appeared to possess advantages of strong support for independent learning from abundant learning resources, high regard for mathematics, and native mothers. The narrowly achievement goals fail to be their focus, Western novel solvers had positive or no less social/economic and affective support. This might encourage them to create their own novel/unique solutions for the sake of their own and mathematics. The differential achievements between Western and Asian novel solutions on the international competition test, or later achievement of mathematics expertise, are likely to be explained by the differences between the positive learning contexts of Western novel solvers and the negative ones of the Asian solvers.

A final point to make is that although some studies have shown that the difference between mathematics achievements of boys and girls are minimal and only in the top bands of 10% to 20% (e.g. Askew & Wiliam, 1995), the present study revealed that boys tended to produce novel solutions more than girls, especially in Western countries. In comparison with Vermeer et al.'s (2000) study, which indicated that boys tended to be better at complex 'application' than girls, there appears a need to study in depth gender differences in mathematics achievements in relation to problem types and affective issues.

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A situated self-regulated learning system: Evidence from Taiwanese children's constructs of mathematical problems

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Abstract

This study examined 75 Taiwanese children's personal constructs of diverse mathematical problems by the repertory grid technique. These constructs were 'situated' in the contexts of their solving the diverse mathematical problems in the classroom, and regulated by the children as 'psychological tools' in order to successfully participate in their mathematical learning world. By coding, categorizing and formulating these constructs, there emerged a situated self-regulated learning system that comprised three cognitive components (situated-perceptions, -strategies, and -aims), and one affective component (situated-affect). The relatively differential emphases on these components for diverse problems also suggested a 'situated' characteristic of children's sensitively regulating their authentic learning.

Summary

There have been a number of researchers who proposed models of self-regulated learning or meta-cognition (e.g. Boekaerts, 1996; Zimmerman, 2000; Pintrich, 2000; de Corte et al., 2000; Whitebread et al., 2005). Most of the models were built upon the researchers' rationales, along with past theories, and evidenced or elaborated by further empirical studies (e.g. Zimmerman & Martinez-Pons, 1998; Fuchs et al., 2003). There are, however, a lack of agreement between the models on the components and the systems of self-regulated learning (SRL). Research based on a

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top-down design is theory-driven or hypothesis-verification, while research based on a bottom-up design is theory-finding or phenomenon-illumination. Aiming to identify significant components and formulate a system of SRL in relation to situated phenomena, this study drew on a bottom-up research procedure, the repertory grid technique (Kelly, 1955), by which children's personal constructs of mathematical problems in their learning contexts, were induced.

Method

There were 51 children individually interviewed for the four focused problems in the fractions topic (Problems 1-4) and 24 children for the two focused problems in the coordinates topic (Problems 5-6). Children were selected for interviews by balancing classes, gender and attainments. The six focused problems are as follows.

Problem 1: Please use calculation procedure, 7 ÷5 = 1 2/5 , to make a mathematical problem.

Problem 2: Mother made several pizzas and Betty got 3/4 pizza. By which ways could the pizzas be divided?

Problem 3: Thirty-six scenery postcards are packed in a box. Equally divide ten boxes of postcards between nine persons. How much of a box of scenery postcards will one person get?

Problem 4: Two ribbons (of equal length) are equally divided between six persons. How much ribbon will one person get?

Problem 5: Bombing headquarters--Game rules: (1) Two people in a group, each person decides his/her coordinates for the headquarters. (2) Two people in turn bomb the other's headquarters. The person who correctly hit the other's coordinates first wins the game.

Problem 6: In the following graph a silkworm is going to eat mulberry leaves. (1) What are the coordinates of the mulberry leaf? Mark it on the picture, and read it. (2) What is on the coordinates (5,4)? (3) The silkworm wants to eat the mulberry leaf. How many grids should it walk west? How many grids should it walk north? (4) After finishing the mulberry leaf, the silkworm walks east for three grids and south for five grids. Which position will it walk to? What are the coordinates of the position? Mark it on the picture and read it. (5) Try to describe what the coordinates of the baby silkworm are?

The interview began by asking children to solve the focused mathematical problems. Next, using the repertory grid technique, children's *personal constructs* in relation to the focused problems were established. For the fractions topic, children randomly chose three problems from the four focused problems and separated the three problems into 'two similar problems' and 'one different problem'. They were asked for their constructs of 'similarity' and 'difference' between the problems. The procedure was repeated until no further constructs could be formed. A similar procedure was used for the coordinates topic, but children were asked for the 'similarity' and 'difference' between the two problems directly.

The constructs obtained by the technique were coded and categorized by two coders, with the aim of forming meaningful components in mind. The components were formulated to develop a situated SRL system.

Results and discussion

A situated SRL system is formulated based on the quality and relationships among the components. The system comprises three cognitive components (situated perceptions, situated strategies, and situated aims) and one affective component (situated affects). Situated affects are embedded in between the three cognitive components, rather than as a significantly separate part, as revealed in most SRL models. The rationales for this formation is that affect was much less perceived by the children as a construct than cognition. However, once it was perceived, affect was normally found interwoven with either cognitive component. Affect also serves as a trigger of strong emotions, substantial concerns, and complex events.

The research result also suggests a ‘situated’ characteristic of SRL: relatively differential emphases on the four components for diverse mathematical problems. For example, affect was significantly induced for a game problem (Problem 5); strategies were emphasized for close-ended problem (Problems 3-4); aims were the major concerns for open-ended problems (Problems 1-2); children significantly invested on situated perceptions in order to clarify a wordy problems (Problem 6).