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FACTORS CONTRIBUTING TO FUTURE TEACHERS' MATHEMATICS PEDAGOGICAL CONTENT KNOWLEDGE: EVIDENCE FROM TEDS-M2008

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The study was to examine the effect of the contents taught in teacher preparation programs on MPCK. 923 future primary teachers of Taiwan participated in the TEDS-M2008 study. The opportunity to learn and knowledge for teaching included in a questionnaire were conducted in the TEDS-M2008 study. The result shows that Taiwan and Singapore have superior performance of MPCK to other countries. The results also indicate that some topics of university-level mathematics, mathematics education, and education were contributing factors to future teachers' MPCK, but all topics of school-level mathematics were significant factors.

INTRODCUATION

The superior achievement of students from East Asia including Japan, Hong Kong, Singapore, and Taiwan in international comparative studies such as TIMSS (Mullits et al., 2004; 2008) and PISA (OECD, 2007) has attracted attention to explore the related factors (Leung & Li, 2010).Two most important and obvious factors are the kind of mathematics student learn and the quality of the teachers who teach the mathematics (Leung & Li, 2010). The quality of teachers in turn relies much on the quality of the teacher preparation offered by educational systems. However, the teacher education in the East Asian countries is still less known to the international community, until IEA launches the study of Teacher Education and Development Study in Mathematics (TEDS-M2008) which includes a component studying the characteristics of teacher education programs at primary and lower secondary levels (Tatto, et al., 2009). Of the East Asian systems, only Singapore and Taiwan are participating in TEDS-M2008.

One debating issue of teacher preparation (TP) curriculum is to balance between the courses of mathematics and pedagogy (Leung & Li, 2010; Monk, 1994; Wu, 2006). Mathematics educators claim that teachers need robust mathematics content knowledge (MCK) since interpreting students' mathematical thinking require strong MCK (Hill, et al., 2008), while general educators debate that teachers need more knowledge of pedagogy for dealing with students' diversity and classroom management. Consequently, it causes a segregation of the two areas in TP programs (Leung & Li, 2010). Furthermore, the discontinuity between the mathematics learned in university and that which will be taught in school is another debate. Mathematicians state that mathematics for TP should be taught at university level, while mathematics educators argue that the mathematics should be continuous with which will be taught in school. These debating issues are related to what the contents should be taught in TP programs. TEDS-M2008 surveyed the various contents taught in TP programs for FTs at primary level as one of the opportunities to learn (OTL) to understand the similarity and the difference across countries.

CONCEPTUAL FRAMEWORK

The high achievement of students in East Asia countries has been explained in terms of important differences in the quality of teachers (Leung, & Li, 2010). There are many factors which determine the quality of teachers, but without doubt, the preparation they undergo is a major factor that affects their instructional practices. However, the common criticism remains among mathematics educators on what knowledge is important for teachers to acquire and how much knowledge is efficient for equipping mathematics teaching in TP systems (Tatto, et al., 2009).

The distinct achievement of students in different countries has been explained with respect to important differences in the mathematics students learn (Leung, & Li, 2010; Tatto, et al., 2009). FTs are same as students as learners, so that we assume that the heterogeneous achievement of FTs in different countries might be caused from the contents studied in the TP programs in different teacher education systems. Monk (1994) suggests that the number of mathematics courses taken by a FT during TP has a positive relationship with students' achievement. Some studies define teachers' knowledge as the number of university-level mathematics course successfully completed (Eisenberg, 1977). Cooney & Wiegel, (2003) emphasize on the importance of school mathematics for teaching teachers mathematics. They suggest that FTs should explicitly study and reflect on school mathematics. FTs should not only understand school mathematics, but understand how students think about that mathematics. Therefore, the kind of contents and the number of courses that allow FTs to attain the knowledge they need to teach mathematics are the factors the mathematics educators concerned. However, no attempt is made to measure the relationship of the contents taught in the TP programs with FTs' knowledge. The current study will examine the effect of the contents taught in the TP programs on the FTs' matheatmics pedagogical content knowledge (MPCK). Here the MPCK includes planning and using the mathematics curriculum and interpreting students' mathematical thinking. For instance, analyzing students' mathematics solutions and predicting typical students' responses and misconceptions, (Tatto, et al., 2009).

METHOD

The 923 FTs attended the practicum in TP institutes identified by the TEDS-M2008 consortium. 22.4% of the samples had mathematics and science background, while 77.6% of the FTs had social study background.
The OTL and mathematics for teaching included in a questionnaire were conducted in the TEDS-M2008 study (Tatto, et al., 2009). The items of university level mathematics, school level mathematics, mathematics education, and general education were included in OTL part. Mathematics for teaching contains two constructs: MCK and MPCK. MCK contains four content domains (number, geometry, algebra, and data)

and three cognitive domains (knowing, applying, and reasoning). MPCK includes two domains: knowledge of mathematical curricula and planning for mathematics teaching (MPCK1) and knowledge of enacting mathematics for teaching and learning (MPCK2). (Tatto, et al., 2009). Only the MPCK items are reported in the current analysis.

TEDS-M 2008 used a rotated block design for increasing the scope of the mathematics measurements without increasing administration time. 5 booklets were tested for the primary level. Each FT was conducted only with one booklet within 90 minutes. Three question formats were used for assessing mathematics for teaching: multiple choice (MC), complex multiple choice (CMC), and open constructed response (CR). CMC response items consist of one stem followed by a list of choices, each of which is scored correct or incorrect (Tatto, et al., 2009).

Participants' responses to the items of mathematics for teaching were coded based on the coding guide and scoring rubrics developed by the TEDS-M2008 consortium. The data of OTL at various levels mathematics were first examined by using descriptive statistics to provide an overall picture of how much of the opportunity the FTs were given. To examine the factors contributing to MPCK, either the ANOVA or the Welch was used to test the significance. Once the assumption of homogeneity of variance of population is true, the ANOVA was used to test and followed by Scheffe test for pairwise comparisons. If the homogeneity of variance of population is not true, then the Welch is used to test. In this case, the Games-Howell test was for post-hoc test.

RESULT

Comparing to the international average score 500, the FTs from Singapore and Taiwan performed on the items of the MPCK were significantly superior to other countries, while there was no significant difference between Singapore with a score of 593 and Taiwan with a score of 592.

Contributing Factors to MPCK

University –level mathematics

According to the summary table of ANOVA displayed in Table 1, $F_{2,3591}$=1.23 was not a significant value, The result indicates that the number of the topics in probability & statistics FTs of Taiwan studied in the TP instructions was not a crucial factor contributing to MPCK.

Source	SS	df	MS	F
Between	11499.24	2	5749.62	1.23
Within	1.680 E+07	3591	4679.60	--
Total	1.682E+07	3593	--	

Table 1: ANOVA for the number of probability & statistics topics at university level contributing to MPCK

The data indicated in Table 2, the more topics in geometric, discrete structure & logic, and continuity & function the FTs studied in the TP intuitions, the higher scores of MPCK they performed. The result indicates that more topics of geometry, discrete structure & logic, and continuity & function at university level significantly contributed to MPCK.

Topics	Statistic	df1	df2	Sig.
Geometry	13.09	4	1410.94	***
Discrete structure & Logic	11.88	6	641.00	***
Continuity & Function	41.44	5	529.47	***

*** p<.005

Table 2: Welch for the number of geometry, discrete structure & logic, continuity & function topics at university level studied in the TP institutions contributing to MPCK

In geometry, 34.7% of the FTs studying 2 topics was the most percentage, while 12.7% of the FTs did not learn university-level geometry. 11.5 % of the FTs studying 4 geometric topics had highest scores of MPCK, seen as Table 3. The number of FTs without studying the topics in the TP programs from high to low was 25.4% in continuity & function, 12.7 in geometry, and 3.9 in discrete structure &logic.

In discrete structure &logic area, 43.1% of the FTs studying 4 topics were the greatest n. In continuity & function area, 48.5% of the FTs studying 1 topic were the greatest percentage. According to Games-Howell post hoc test, the mean score of FTs who studied the most number of topics in each area was extremely significantly higher than that of those who studied less than 3 topics, P<.005, as displayed in Table 3.

# of topics	Geometry			Discrete structure &logic			Continuity & Function		
	% N	Mean	Test	% N	Mean	Test	% N	Mean	Test
0	12.7	589.0	4-0***	3.9	588.8	6-0***	25.4	574.8	5-0***
1	17.0	579.1	4-1***	5.6	566.9	6-1***	48.5	594.6	5-1***
2	34.7	596.1	4-2***	11.7	584.2	6-2***	13.0	583.3	5-2***
3	15.7	591.4	4-3***	19.4	587.2	6-3***	5.7	626.5	4-0***
4	11.5	605.8	3-1***	43.1	593.8	5-1***	4.7	624.3	4-1***
5	--	--	2-1***	13.5	605.9	4-1***	2.7	629.3	3-0***
6	--	--		2.9	625.6	3-1***	--		1-0***
Total	100	592.3		100	592.3		100	592.3	

Table 3: Games-Howell post hoc test for the means of topics at university level.

School –level mathematics

Table 4 shows that the more topics of school-level mathematics the FTs studied, the higher scores of MPCK they performed. The result indicates that more mathematics topics at school level FTs studied significantly factors contributed to MPCK.

Topics	Statistic	df1	df2	Sig.
Geometry & number & measurement	7.76	3	370.48	***
Function & probability &Calculus	21.14	4	1484.82	***

*** p<.005

Table 4: Welch for the number of mathematics at school level affecting MPCK

The most popular of the school-level mathematics that 65.2% of the FTs studied was geometry, number, and measurement. These topics the FTs studied contributed to higher scores of MPCK. The FTs who studied 3 topics extremely significantly performed better than those who studied less than 3 topics, p<.005. Likewise, function & probability were popular topics of school-level mathematics. The greatest percentage with 31.3% of the FTs studied 3 topics of function & probability, seen as Table 5.

Number of topics	geometry & number & measurement			Function &probability &Calculus		
	% N	Mean	Test	% N	Mean	Test
0	3.3	579.9	3-0***	14.0	580.8	4-0***
1	4.8	577.6	3-1***	21.8	590.2	4-1***
2	26.8	589.1	3-2***	31.3	584.1	4-2***
3	65.2	595.3	2-1***	20.3	600.7	4-3***
4	--	--		12.6	615.3	3-0***

*** p<.005

Table 5: Games-Howell post hoc test for the means of the topics at school level

Mathematics Education

The topics of mathematics education consisted of foundation and instruction.

Source	SS	df	MS	F
Between	287851.28	5	57570.26	12.50***
Within	1.653 E+07	3588	4606.49	--
Total	1.682E+07	3593	--	

*** p<.005

Table 6: ANOVA for the number of topics of MEd-Instruction contributing to MPCK

The test of Welch Statistic=1.56, df1=3, df2=888.45, P=0.0198, is not significant. The result shows that more foundation topics of mathematics education that FTs studied did not contribute to the score of MPCK. However, the more courses related to mathematics education instruction that FTs studied highly contributed to the score of MPCK, $F_{5,3588}$=12.50, P<.005, seen as Table 6.

Table 7 shows that the FTs studying mathematics education courses were more relating to the topics of instruction than the foundations. 72.7% of the FTs studied at most 1 topic of foundation, while 93.2% of the FTs studied at least 1 topic on instruction. Moreover, at least 80% of the FTs have been taken 3 topics of Math Ed-instruction, while only 5.7% of the FTs have been studied 3 topics of Math Ed-foundation. The result indicates that the TP programs of Taiwan offered the FTs with more opportunities to learn about the mathematics instruction (e.g., developing teaching plan, mathematics curriculum) than the foundation of mathematics education (e.g. history of mathematics, philosophy of mathematics education). The 2% of the FTs who have never been studied the topics of mathematics instruction had the lowest score of MPCK. Moreover, the score was significantly lower than others'.

Number of topics	Math Ed-foundation		Math Ed-instruction		
	% N	Mean	% N	Mean	Scheffe test
0	34.3	589.0	2.0	558.9	2-0***

1	38.4	594.5	4.8	579.9	2-1*** 3-0*** 4-0*** 5-0***
2	21.6	592.9	10.0	602.1	
3	5.7	594.2	17.5	588.5	
4	--	--	34.6	594.7	
5	--	--	28.0	596.0	

*** p<.005

Table 7: Scheffe test for the means of the topics of Math Ed-instruction

Education

The topics of general education contained social science and application.

Source	SS	df	MS	F
Between	15407.94	3	5135.98	1.10
Within	1.680 E+07	3583	4688.88	--
Total	1.682E+07	3586	--	

Table 8: ANOVA for the number of topics of social science contributing to MPCK

The topics of social science are sociology, philosophy, and history of education, and the topics of application include educational psychology, methods of educational research, knowledge of teaching, and assessment. The result displayed in Table 8 shows that the number of topics of social science in education FTs studied did not contribute to the score of MPCK, $F_{3,3583}$=1.10.

In terms of the topics of application in education, the standard deviation of one of the six groups is 0, so that it is not necessary to have robust test for equality of means, so that pairwise comparison was made directly. The data indicated in Table 9 shows that the FTs had more opportunities to learn the topics related to educational application than the topics related to social science in education. More than 90% of the FTs studied at least 3 topics of educational application, while 33% of the FTs studied 3 topics of social science in education.

Number of topics	Ed-social science		Ed-application		
	% N	Mean	% N	Mean	Games-Howell test
0	13.9	595.6	0.1	585.8	1-0*** 2-0*** 4-0*** 5-0*** 5-3*** 3-2***
1	27.5	592.0	1.5	596.8	
2	25.6	594.0	8.3	597.1	
3	33.0	589.8	23.4	584.7	
4	--	--	31.2	591.0	
5	--	--	35.5	597.1	

*** p<.005

Table 9: Post-hoc test for the number of topics of MEd-instruction affecting MPCK

CONCLUSIONS AND IMPLICATIONS

Like other international comparative studies TIMSS and PISA, the FTs from Taiwan and Singapore in East Asia education systems again had superior achievement to counterparts in TEDS-M2008 study. The superior performance of MPCK was resulted from some of the contents taught in the TP programs that allow the FTs to attain the knowledge they need to teach mathematics. The contents included the topics at university level including geometry, discrete structure & logic, continuity & function, the topics at school level including number, geometry, measurement, probability, and statistics, the topics of instruction in mathematics education, and the topics of application in education. However, the topics of probability at university level, the topics of foundation in mathematics education, and the topics of social science in education were not significant factors affecting FTs' MPCK.

The results implicate to Taiwan policy-makers reflect on the curricular framework of teacher preparation programs. After entering 40-credit courses required in a TP program, each FT merely requires to take a 2-credit school-level mathematics course and a 2-credict mathematics method course. Other 36 credits are related to the courses in general education (Lin, 2010). However, the results of the study show that the philosophy and sociology, and the history of education studied in the TP programs did not enhance FTs' knowledge for teaching mathematics.

The results also implicate to the TP programs of Taiwan that the attempt to equip FTs' with efficient knowledge for mathematics teaching, requiring FTs take more credits in school mathematics and mathematics education, but reducing the credits in educations could be an intelligent policy. The result of the study supports the importance of school mathematics addressed by Cooney & Wiegel (2003). It could have more factors from TEDS-M2008 study, such as FTs' classroom participation contributing to their MPCK or MCK, providing further suggestions to teacher preparation programs of Taiwan. It needs further exploration in further study.

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