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MATHEMATICS TEACHER EDUCATION IN TAIWAN

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Introduction

Teachers enjoy a relatively high reputation in Taiwan because of the high prestige of teaching jobs and the significant regard for education in traditional Chinese culture. The historical background of political, economic, and social contexts has resulted in a generous and ensured salary and other benefits for current teachers. These incentives make a teaching career extremely attractive for people seeking stable lives. Therefore, becoming a teacher is a competitive task that requires rigorous evaluation and screening.

Mathematics is one of the core academic subjects and is required throughout grades 1-12 in Taiwan. Mathematics teacher competency is therefore one of the most important parameters of school quality. Teacher opportunity to learn becomes essential for producing high-quality teachers.

Teacher opportunity to learn is derived from pre-service academic work, practicum, and in-service professional development. Special in-service opportunities are offered to teachers because the Taiwanese government encourages teachers to pursue higher academic degrees, such as a master's degree in teaching, through in-service study (MOE, 2006a).

The first section of this paper briefly introduces the historical and cultural background that shapes the current teacher education system, which includes a description of the current mathematics pre-service teacher education system and practice. In the second section, we discuss the opportunity to learn (OTL) and its relationship to the knowledge of pre-service mathematics teachers at the secondary and primary levels in an international context. The third section describes the academic activities and research in mathematics teacher education and the OTL they offer. The concluding section offers a summary of the practice and challenges Taiwan faces and reflects on and envisions mathematics teacher education in Taiwan.

Section 1: Historical Development and Current System of Teacher education

1.1 Development and Transformation of Teacher Education

Teacher education in Taiwan is dramatically influenced by political, economic, and social contexts. The historical development and transformation of teacher education can be divided into three major periods (Hsieh, Lin, Chao, & Wang, 2009).

1.1.1 Initiation of Teacher Education

The first formal teacher-training program was offered in 1896 at the Kokugo Gakkou

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(Japanese Language School) during the Japanese colonial period. This program was to prepare Japanese people to become teacher educators, school principals, and teachers (Wu, 1983) to teach the Japanese language among others. In 1899, three "normal schools" were established to mark the first time Taiwanese people had the chance to be educated as primary level teachers to teach primary school arithmetic (Wu, 1983; p. 18). For most of the colonial period, Japanese and Taiwanese pre-service teachers were trained separately. The Japanese government also enacted the first official regulation of teacher education, the "Official Regulation of Taiwan Governor-General Normal School" in 1899 (Lee, 1995; Wu, 1983).

1.1.2 Rise and Decline of the Protectionist Teacher Education System

In 1946, the second year after the Japanese colonial period, the first institution to educate Taiwanese high school teachers– Provincial Taiwan Normal College (predecessor of National Taiwan Normal University)– was established by the Nationalist (KMT) government from mainland China. This marked the beginning of continuous efforts to teach Taiwanese to speak Mandarin and to regenerate Taiwanese culture by pushing primary graduates, who were taught Japanese and in whom the idea of "Japanization" was instilled, to go to junior high schools where the Chinese language and anti-communist ideas were exposed (Cheng, 1998). During this period, the government believed that teacher quality could influence the thinking and inner quality of people, which in turn could influence the development of politics, economy, and national defense (Cao & Liang, 2002). In 1955, President Chiang Kai-Shek used the motto, "Teachers First, Normal Education Foremost," to greatly improve teacher quality (Ministry of Education [MOE], 1976, p. 565).

The KMT government believed that after screening pre-service teachers for preparation in institutions, their preparation and benefits should be covered by the government to attract talented students to a teaching career and to avoid teacher shortage in schools to protect the stability of the teacher education system. Therefore, teachers were educated at the expense of the government and guaranteed job assignments, similar to civil servants. Their education was executed by normal institutions and dominated by the government. A student who could not enter normal institutions had hardly any chance of becoming a teacher. The primary features of the teacher education system in Taiwan during this period were protective, uniform, and closed.

From the 1960s to 1980s, the Taiwan economy improved rapidly, along with living standards. The late 1980s witnessed the shaping of multi-party politics, liberated thinking, and a stronger legislative system. The protectionist teacher-education system did not match the prevalent ideas of a free society and a free economy. Scholars, educational communities, and the opposition party voiced the necessity for more open access to teacher education. This tide finally crushed the decades-old protectionist teacher education system.

1.1.3 Rise of the Competitive Teacher Education System

In 1994, the government enacted the Teacher Education Act (TEA), which opened multiple means toward teacher education in that all four-year universities or colleges were allowed to run teacher education for grades k-12 teachers if they met the requirements for applying as a teacher education institution. The government was no longer responsible for free tuition and job assignments.

The retention policy for teachers remained unchanged; teachers still enjoyed favorable remuneration and benefits. For instance, although teachers were given a two-month summer vacation and a 21-day winter vacation, they were still paid a salary for the entire year and given an additional 1.5 month new-year-bonus and a one-month "merit-of-professional-performance" bonus each year. This new reform paved the way for teacher education but retained the liberal salary and benefits that made the teaching profession more accessible and attractive. Along with a lower demand for teachers resulting from fewer births, the competition to receive teacher education and obtain teaching jobs has been extremely high.

1.2 Reformation of Mathematics Teacher Education

Traditional approaches to teaching mathematics in schools have had a profound effect on mathematics teacher education in Taiwan. School education in Taiwan is focused heavily on helping students achieve high rankings in entrance examinations. Traditional mathematics teaching has been dominated by formal mathematical content and narrative teaching. Junior high and primary school mathematics textbooks prior to 2001 and 1996 were standardized in Taiwan.

In 1997, a new national standardized junior high school mathematics textbook was implemented. Textbook authors initiated open views, such as infusing cartoons and investigations into mathematics textbooks, from which the entrance examination questions formulated. These changes centered on students, the links between mathematics and life, cultivation of student creativity, thinking, and reasoning abilities, and on an active attitude toward learning and appreciating mathematics (Hsieh, 1997). The authors also raised the notion that textbook reform could create widespread teacher education amongst in-service teachers who were using the textbooks and pre-service teachers whose college instructors typically included these textbooks as their teaching materials.

Since 1996, primary mathematics textbooks were edited by private publishers and reviewed by the government. This was a time of constructivist thinking in Taiwan, and textbook writers, affected by such thinking, included many student methods in the textbooks. Although this constructivism movement was later criticized by society, in-service and pre-service mathematics teachers began to consider deeply how students think, shifting toward teacher-centered to student-oriented teaching. Beginning in the 1980s, Dr. Fou-Lai Lin initiated and promoted studies in mathematics education. These researchers – the educators of teachers in Taiwan – began to educate mathematics teachers by combining their practical experience with

the results of mathematics education studies, thus moving Taiwan mathematics teacher education toward a new realm.

1.3 Current Teacher Education System

1.3.1 Acts and Programs of Teacher Education

Taiwan teacher education is a strong, national policy-driven system. The current pre-service teacher education system is regulated mainly by the national Teacher Education Act (TEA) and the Teacher Education Act Enforcement Rules (TEAER), enacted in 1994, 1995, and last amended in 2005, 2011, respectively. These regulations established the targets, institutions, recruitment, curricula, and accreditation of the teacher education system. The teacher education institutes include (1) normal universities/universities of education, (2) universities with TE affiliated departments (majors), and (3) universities with teacher education centers. Teacher education programs for grades 1-12 are separated into two levels, primary teachers who teach grades 1-6 for various subjects and secondary teachers who teach grades 7th-9th or 10th-12th for a single subject.

The number of teacher education institutions at the primary and secondary level changed rapidly after the 1994 reformation. In 1995, a total of 29 institutions expanded to 67 in 2004, and then gradually reduced to 49 in 2010 (MOE, 2011a). The number of pre-service mathematics teachers differs among different teacher education universities. In 2007, there were 46 mathematics teacher-education institutions; the number of pre-service mathematics intern teachers, per institution, ranged from 1 to and 90 at the secondary level and 2 to 443 at the primary level.

The teacher-education program is an additional program that includes pedagogical and professional studies and is taken while pursuing academic degrees. Regulated by the TEA, the teacher education curricula (TEC) comprises three parts: General Curriculum, Subject Matter Curriculum (SMC), and Education Professional Curriculum (EPC). Universities or colleges establish the TEC under the guidance and approval of the MOE. After pre-service teachers complete academic degrees and TEC, they spend another half-year completing the Educational Practicum (EP) in primary or secondary schools. The MOE (2005a) also created an EP guideline to ensure its quality in different schools. To become qualified for applying for a teaching job, pre-service teachers must further pass the national common Teacher Qualification Assessment.

The Taiwan government decreed the types of learning experiences and opportunities teacher education programs must provide, the qualifications and process of becoming a teacher, what levels of students teacher education institutions can enroll, and what types of accreditation is required of these institutions.

1.3.2 Screening and selection of mathematics teachers

The government requires public schools and most Taiwanese schools to hold public screenings and selections when employing tenure teachers (MOE, 2005b). The

screening and selection for tenure teachers are conducted through written tests, oral tests, teaching demonstrations, and on-site performance tests. Applicants are assessed through a combination of more than two of these methods. Two methods are used to screen and select tenure teachers. One is joint screening and selection held by the department of education of each city/county government and entrusted by schools. Other schools hold screenings and selections by themselves.

Generally, the screening and selection of tenure teachers occurs in two rounds. The first is through written tests to assess the applicant education professional knowledge and subject matter knowledge. Typically, the examination questions are compiled by university professors or senior teachers. Certain applicants, two to five times the quota of tenure teachers, are allowed to move to the second round, which assesses applicants through a 20- to 25-minute teaching demonstration and a short personal interview. Judges for the teaching demonstration are mainly school teachers; occasionally, a university faculty member may be included as an expert from the outside system. The teaching demonstration is a high-pressure one. The teaching topics are drawn by the applicants 20 minutes before the time of the actual demonstration and the applicants can use these 20 minutes to prepare. Those judging the personal interviews are mainly administrative staff, such as school principals. They check applicant educational background, experience, ideas of education, classroom management, willingness to participate in school administration, and so on.

The screening for tenure teaching positions is highly competitive, and is not only held for pre-service teachers, but for all in-service teachers who want to change schools. The average passing rates for screenings and selections across the country during 2007-2010 at the primary, lower secondary, and upper secondary levels are 3.5%, 11.9%, and 6.5%[1] (MOE, 2008, 2009, 2010a, 2011a). Regarding to the pre-service teachers, the average employment rates for tenure teaching positions of pre-service teachers for 2007-2010 are lower than 3.4% for the primary level and 20.2% for the secondary level.

1.3.3 Structure of Pre-service Teacher Education Curriculum

I.3.3.1 General Curriculum

The government does not clearly regulate General Curriculum content. Therefore, most teacher education universities accept the completion of a bachelor's degree as completing this curriculum, which requires 128 credits (semester units) and meets the requirements of a specific major.

I.3.3.2 Subject Matter Curriculum (SMC)

SMC is defined as a specific curriculum aimed to improve the strengths of

[1] People may attend many screenings; thus, the actual rates of people who pass the screenings should be higher than these data.

pre-service teachers in subjects they will teach in the future. An SMC for secondary level pre-service mathematics teachers consists of their university mathematics courses. The upper and lower credits of mathematics courses are 30 and 48, respectively, regulated by MOE (2002). For the primary level, there is no regulated SMC because of the nature of interdisciplinary education.

I.3.3.3 Education Professional Curriculum (EPC)

The EPC aims at improving the educational competencies of pre-service teachers. The MOE (2003) has provided a pool of various courses in different areas for the teacher education university to select. The areas of EPC for secondary mathematics pre-service teachers include: Foundation of Education Curriculum, General Pedagogy Curriculum, Materials and Methods of Teaching for Mathematics, and Teaching Practice for Mathematics. A total of 26 credits are required.

The EPC for the primary level differs from the secondary level to include a course in Basic Subject Matter Curriculum in Teaching and increases the Materials and Methods of Teaching course to comprise three to four fields, and the Teaching Practice course is not restricted to mathematics. A total of 40 credits are required.

1.3.4 Educational Practicum (EP)

EP is designed to train pre-service teachers in actual teaching. According to TEAER and other related regulations (MOE, 2005a), intern teachers need to be in schools on a full-time basis for half a year to learn the following content: actual teaching internship (40%), "homeroom" teaching (general class affairs) supervision (30%), administrative work practice (20%), and study and training activities (10%). Each EP school has a team to supervise intern teachers under a systematic plan. The teacher education universities are obligated to visit and counsel the EP schools and intern teachers, handle "back to university training activities" for intern teachers, edit EP counseling literatures, and so on. Fifty percent of intern teacher evaluations are scored by internship supervisors, principals, or directors of EP schools; the other 50% are scored by internship supervisors from universities who typically visit an intern one to three times during his/her EP period.

1.3.5 Quality Assurance of Teacher Education and Teachers

Every phase of the process from entering TE to becoming a certified teacher in Taiwan involves clear requirements. At the entry point to the TE program, the MOE decides the number of admissions for each university, and TE universities have the autonomy to employ their own screening and selection content, criteria, and processes to select qualified entrants from applicants who are eligible after completing their first academic year in university. Many TE universities base their selection on applicant grade in the first academic year, and may support it with tests such as general educational knowledge tests, language tests, attitude tests, or personality inventories. Certain universities also consider student character, moral conduct, and extracurricular activities.

At the exit point, pre-service teachers must take the annual paper-and-pencil Teacher Qualification Assessment. The average passing rates for the 2007-2010 period was 67.4%.

To ensure the quality of teacher education programs, the MOE has conducted periodical evaluations of TE universities. Institutions receiving a third level rating have to stop admitting students. Those that receive a second level rating must decrease student admissions by 20%, and those that receive first level rating can retain the same admission quota (MOE, 2006b, p. 204). In 2007-2009, six TE universities received third level ratings and were disqualified to provide TE programs.

Section 2: OTL in the Context of International Comparison

The information in this section is based on the results of the international comparison study, the Teacher Education and Development Study in Mathematics (TEDS-M). For details of TEDS-M, please see the series of international reports authored by Teresa M. Tatto and her research colleagues (Tatto et al., 2012) and reports prepared by the authors of this paper (Hsieh et al., 2010).[2] The data were collected from the end of 2007 to mid- 2008. The opportunity to learn various topics in teacher education programs and the preparation outcomes of mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK) for lower secondary pre-service mathematics (SPM) teachers and primary pre-service mathematics (PPM) teachers were studied.

2.1 Structure and Substance of Teacher Education Curricula

2.1.1 Topics in Teacher Education Programs

Pre-service mathematics teachers in TEDS-M responded to numerous items that explored whether they had studied various topics in tertiary and school level mathematics, mathematics pedagogy, and general pedagogy as part of their teacher education programs. All topics were classified into areas by TEDS-M according to the results of exploratory and confirmatory factor analyses (Tatto et al., 2012).

2.1.1.1 Topics in Tertiary and School Level Mathematics

Taiwanese SPM teachers reported studying 16.56 tertiary level mathematics topics of the 19 topics listed in the questionnaire. This amount ranked third among 15 participating countries, which is 1.28 less than leading Russia and 6.75 more than East Asian Singapore. Ten topics were studied by more than 90% of Taiwanese SPM teachers. Most SPM teachers studied topics in the area of Continuity and Functions and Probability and Statistics. The studied rates of all four areas (see Table 1) are

[2] The analysis prepared for this report and the views expressed are those of the authors and do not necessarily reflect the views of the International Association for the Evaluation of Educational Achievement or the International Study Center of TEDS-M.

significantly and sizably higher than the mean rates of all participating countries or higher-achieving countries.[3]

In the seven listed school-level mathematics topics, Taiwanese SPM teachers studied 6.25 topics and four were studied by more than 90% of SPM teachers. Although Taiwanese SPM teachers had explored the two areas of school level mathematics (see Table 1) extensively when they were at primary or secondary schools, significantly more SPM teachers studied topics in either area than those in other countries.

At the primary level, Taiwanese PPM teachers reported studying 8.64 tertiary level mathematics topics. This magnitude is slightly lower than the international mean of 9.50, but substantially lower than the leading country of Thailand at 15.44. Probability was the only topic taken by more than 90% of teachers. In contrast to the secondary level, the study rates of different areas of tertiary level mathematics are either the same or significantly lower than the mean rates of all participating countries or higher- achieving countries, except for the area of Probability and Statistics (see Table 1).

In the seven school-level mathematics topics, Taiwanese PPM teachers studied 4.51 topics, with a middle ranking. Two of them were studied by more than 90% of PPM teachers. The two areas of school level mathematics show a significantly lower percent of PPM teachers studying topics in the area of Numbers/Measurement/ Geometry than teachers in other countries.

Table 1: Studied rates of each area of tertiary level and school level mathematics

Levels	Tertiary Level Math Area				School Level Math Area	
	Geometry	Discrete Structures & Logic	Continuity & Functions	Probability & Statistics	Numbers Measurement Geometry	Functions Probability Calculus
Taiwan-Sec	0.81**	0.87**	0.97**	0.97**	0.93*	0.86**
M-Sec	0.66	0.72	0.71	0.77	0.91	0.73
MH-Sec	0.68	0.75	0.72	0.78	0.89	0.75
Taiwan-Pri	0.51	0.57	0.25**	0.86**	0.85**	0.49
M-Pri	0.51	0.58	0.40	0.70	0.87	0.50
MH-Pri	0.49	0.57	0.39	0.67	0.88	0.50

Note. *M-Sec*=international mean of all participating countries at secondary level. *MH-Sec* =mean of Higher-achieving countries at secondary level. *M-Pri*=international mean of all participating countries at primary level. *MH-Pri* =mean of Higher-achieving countries at primary level.
* $p < .05$; ** $p < .01$

2.1.1.2 Topics Taken in Mathematics Pedagogy

Of the two areas, composed of eight mathematics pedagogy topics, Taiwanese SPM teachers studied fewer courses in the area of Foundations than Instruction (see Table

[3] Countries that achieved MCK and MPCK levels beyond the international mean of 500.

2). Within each area, the Taiwan pattern of the magnitudes of studied rates for different topics differs from the average approach for all participating countries or higher-achieving countries.

The situation of less OTL than other countries for mathematics topics appeared again for the study of mathematics pedagogy topics, specifically in the area of Foundations, at the primary level in Taiwan (see Table 2).

Taiwanese teachers studied significantly fewer topics in the Context of Mathematics Education, and Affective Issues in Mathematics than did other countries. Further, Taiwanese primary level TE did not emphasize Foundation of Mathematics as much as did other countries.

Table 2: Studied rates for mathematics pedagogy topics in two areas

Levels	Foundations				Instruction					
	FM	CME	DMAT	*Mean*	MI	DTP	MT	MSC	AIM	*Mean*
Taiwan-Sec	0.74**	0.13**	0.76	0.54	0.95**	0.83**	0.88*	0.79	0.39**	0.77
M-Sec	0.69	0.47	0.80	0.65	0.91	0.76	0.83	0.78	0.53	0.76
MH-Sec	0.65	0.37	0.79	0.60	0.93	0.77	0.86	0.86	0.48	0.78
Taiwan-Pri	0.32**	0.11**	0.56**	0.33	0.91	0.76	0.74	0.80**	0.35**	0.71
M-Pri	0.58	0.48	0.76	0.61	0.90	0.74	0.77	0.74	0.52	0.73
MH-Pri	0.50	0.38	0.76	0.55	0.90	0.73	0.79	0.84	0.55	0.76

Note. FM = Foundations of Mathematics; CME = Context of Mathematics Education; DMAT = Development of Mathematics Ability and Thinking; MI = Mathematics Instruction; DTP = Developing Teaching Plans; MT = Mathematics Teaching: observation, analysis and reflection; MSC = Mathematics Standards and Curriculum; AIM = Affective Issues in Mathematics.
*$p < .05$; **$p < .01$

2.1.1.3 Topics Taken in General Pedagogy

In the two areas, composed of eight general pedagogy topics, both Taiwanese SPM and PPM teachers studied fewer topics than did other countries (see Table 3). Within each area, Taiwan patterns of the magnitudes of studied rates for different topics differ from the approaches of international patterns or higher-achieving country patterns. Taiwan underemphasized the philosophy and sociology of education compared to international trends. The Method of Educational Research did not gain equal value compared to other countries. However, the topics of Educational Psychology and Knowledge of Teaching, which are more practical in terms of highly relating to how to teach, gained considerable emphasis in Taiwan.

Table 3: Studied rates for general pedagogy topics in two areas

Country	Social Science				Application					
	HEES	PE	SE	*Mean*	EP	TS	MER	AM	KT	*Mean*

Taiwan-Sec	0.56**	0.63**	0.67**	0.62	0.97	0.73**	0.34**	0.80	0.93**	0.75
M-Sec	0.63	0.74	0.77	0.71	0.96	0.87	0.61	0.82	0.83	0.81
MH-Sec	0.62	0.66	0.73	0.67	0.96	0.82	0.52	0.74	0.85	0.78
Taiwan-Pri	0.61**	0.54**	0.63**	0.59	0.97	0.79**	0.50**	0.72**	0.92**	0.78
M-Pri	0.70	0.77	0.80	0.76	0.97	0.90	0.70	0.81	0.88	0.85
MH-Pri	0.68	0.71	0.78	0.72	0.98	0.89	0.63	0.82	0.91	0.85

Note. HEES = History of Education and Educational Systems; PE = Philosophy of Education; SE = Sociology of Education; EP = Educational Psychology; TS = Theories of Schooling; MER = Methods of Educational Research; AM = Assessment and Measurement; KT = Knowledge of Teaching.
* $p < .05$; ** $p < .01$

2.2 Relationship of OTL and Teaching Knowledge

This subsection reports the relationships of OTL of taking different levels of mathematics (school level and tertiary level) and pre-service teacher MCK and MPCK outcomes in Taiwan.

2.2.1 Types of OTL Contributing to MCK and MPCK Outcomes

Few would argue against the influence of learner background on potential to learn. This study formulated two-level hierarchical models relating both selection and OTL variables to MCK and MPCK outcomes. Specific OTL and selection variables were included in the regression analyses as predictors at two levels, the individual level and the mean level, for each participating institution.

Table 4: Multi-level analyses relating MCK and MPCK to OTL at the secondary level

Secondary level	MCK			MCK-Tertiary			MCK-Sec.			MPCK		
	Est	(se)	*p*	Est	se	*p*	Est	se	*p*	Est	se	*p*
Intercept	-95.5	(143.2)	0.505	184.8	(130.1)	0.155	-117.1	(124.0)	0.345	-32.0	(105.4)	0.761
Future teacher level												
University level math OTL	**5.6**	**(1.8)**	**0.002**	**3.9**	**(1.9)**	**0.042**	**5.6**	**(1.9)**	**0.003**	**6.5**	**(2.4)**	**0.007**
School level math OTL	-4.0	(4.5)	0.372	-1.3	(3.9)	0.739	-3.2	(3.4)	0.354			
Math Education OTL										-5.2	(3.2)	0.103
General Education OTL												
Marks/grades level received in sec.	-3.9	(3.2)	0.228	0.9	(2.8)	0.741	5.1	(3.3)	0.124	0.4	(3.3)	0.902
Highest math level in sec.												
Institution level												
University level math OTL	**24.2**	**(5.8)**	**0.000**	**18.6**	**(5.8)**	**0.001**	**24.8**	**(5.1)**	**0.000**	**24.8**	**(3.9)**	**0.000**
School level math OTL	**22.1**	**(9.3)**	**0.018**	**18.3**	**(6.7)**	**0.007**	**22.4**	**(10.4)**	**0.032**			
Math Education OTL										8.7	(8.9)	0.333
General Education OTL												
Marks/grades level received in sec.	**65.2**	**(15.2)**	**0.000**	**46.6**	**(15.9)**	**0.003**	**67.7**	**(10.1)**	**0.000**	**62.3**	**(19.9)**	**0.002**
Highest math level in sec.												

Note. Blank spaces indicate that the independent variables in the corresponding row were tested but excluded in the final models for the dependent variables defining the corresponding column. None of the negative coefficients are statistically significantly different from zero at the .05 level.

Results for the secondary level show that at the individual level only the number of topics taken in tertiary level mathematics had a significant relationship to SPM teacher MCK outcomes, but the estimated effect was small (see Table 4). At the

institution level, three variables contributed to MCK achievement with sizable estimated effects; they were the OTL of tertiary level, school level mathematics, and marks/grades level received in secondary school, a selection variable. These OTL and selection variables also contributed to tertiary level MCK and secondary school MCK outcomes. The relationships of OTL and MPCK show that the OTL of school level mathematics was no longer a variable contributing to MPCK.

Results for the primary level show that both tertiary level and school level mathematics OTL at the individual level contributed to the MCK and secondary school MCK outcomes; however, the estimated effects were small (see Table 5). Unlike the secondary level case, no significant effects generated from the institution level at the primary level study. For the primary school MCK, the school level mathematics OTL was replaced by the selection variable as a variable related to this level of MCK outcomes. School level mathematics OTL was also not a variable for MPCK; however, tertiary level mathematics OTL at the institution level joined to contribute to MPCK.

Table 5: Multi-level analysis results relating MCK to OTL in the primary level

Primary level	MCK			MCK-Sec.			MCK-Pri.			MPCK		
	Est	(se)	*p*	Est	se	*p*	Est	se	*p*	Est	se	*p*
Intercept	478.7	(68.6)	0.000	448.3	(54.9)	0.000	453.5	(204.1)	0.026	458.0	(48.8)	0.000
Future teacher level												
University level math OTL	**4.2**	**(0.9)**	**0.000**	**3.7**	**(0.7)**	**0.000**	**3.3**	**(0.7)**	**0.000**	**2.5**	**(0.4)**	**0.000**
School level math OTL	**4.0**	**(1.6)**	**0.012**	**3.8**	**(0.9)**	**0.000**	2.4	(2.0)	0.239	3.5	(2.0)	0.081
Math Education OTL	1.8	(1.8)	0.321				1.1	(1.6)	0.484	0.9	(1.5)	0.570
General Education OTL										-1.1	(1.0)	0.264
Marks/grades level received in sec.							**9.2**	**(2.6)**	**0.000**			
Highest math level in sec.	-5.0	(8.9)	0.576	-9.9	(8.6)	0.248				-9.0	(7.7)	0.240
Institution level												
University level math OTL	20.2	(10.7)	0.059	20.1	(11.8)	0.088	-0.2	(29.2)	0.995	**18.8**	**(5.4)**	**0.000**
School level math OTL	27.5	(17.2)	0.110	14.9	(17.7)	0.399	21.9	(39.7)	0.581	1.9	(9.4)	0.836
Math Education OTL	-12.0	(7.9)	0.131				-5.1	(7.4)	0.491	-4.0	(4.0)	0.310
General Education OTL										3.5	(4.0)	0.376
Marks/grades level received in sec.							23.3	(35.9)	0.516			
Highest math level in sec.	-25.4	(15.1)	0.094	-18.7	(9.8)	0.057				-9.7	(7.5)	0.192

Note. Blank spaces indicate that the independent variables in the corresponding row were tested but excluded in the final models for the dependent variables defining the corresponding column. None of the negative coefficients are statistically significantly different from zero at the .05 level.

2.2.2 Relationship of Individual Topic OTL and Teacher knowledge

To study the relationship between individual topics and pre-service teacher knowledge, a *t* test was used to test whether the means of knowledge scores for studied and non-studied participants differed. Whether the difference between the two means was not only significant, but practically relevant, was evaluated with Cohen's parameter of effect size *d* (the difference between independent means expressed in units of the within-population standard deviation). According to Cohen, the cut points for small, medium, and large effect size based on means were 0.2, 0.5, and 0.8. Differences were regarded as practically relevant if they exceeded 0.2 of a standard

deviation.

2.2.2.1 Relationship of Individual Topic OTL and MCK

In the 11 tertiary level mathematics topics studied by less than 92%[4] of Taiwanese SPM teachers, seven topics significantly contributed to SPM teacher MCK outcomes. Six of these topics fall into the areas of Geometry and Discrete Structures and Logic (see Table 1 for the four areas). The topic of Abstract Algebra has a large effect size of 0.89 and the Theory of Real/Complex Functions/Functional Analysis has a medium effect size of 0.73.

In the four school level mathematics topics studied by less than 92% of Taiwanese SPM teachers (see Table 2 for all seven listed topics), only measurement significantly influenced SPM teacher MCK, with a small effect size of 0.38.

For the primary level, in the 19 listed tertiary level mathematics topics, 11 topics significantly related to PPM teacher MCK. These topics fall into the four areas of mathematics. The area of Continuity and Functions included the most, all five topics in this area; the OTL of Advanced Calculus/Real Analysis/Measure Theory enjoyed the largest effect size of 0.96 and Differential Equations were the second largest at 0.72. The remaining tertiary level mathematics topics had small effect sizes.

All school level mathematics topics, except the topic of Functions/Relations/ Equations, had significantly small effects on PPM teacher MCK.

2.2.2.2 Relationship of Individual Topic OTL and MPCK

The OTL of studying six tertiary level mathematics topics influenced the SPM teacher MPCK with all small effect sizes. Four topics fall in the area of Discrete Structures and Logic. Axiomatic Geometry (d=0.44) and Number Theory (d=0.43) had the largest effect sizes.

In school level mathematics, Validation/Structuring/Abstracting is the only topic influencing SPM teacher MPCK with a small effect size of 0.31.

None of the OTL of mathematics education topics related to SPM teacher MPCK. The studies of general pedagogical topics, Philosophy of Education (d=0.23) and Sociology of Education (d=0.24), had even smaller negative effects on SPM teacher MPCK.

For the PPM teachers, the studies of nine tertiary level mathematics topics influenced the MPCK outcomes of PPM teachers. These topics were similar to the topics influencing MCK, but the effect sizes were smaller and no larger than 0.55.

Two of the six school level mathematics topics influencing MCK for PPM teachers were no longer topics influencing MPCK outcomes, but included Measurement and

[4] This percentage was chosen to ensure that the participants in the non-studied group met a large sample requirement (30 entries of data) for the *t* test.

Geometry. The remaining four influenced MPCK.

In contrast to the SPM teacher case, the OTL to study three mathematics pedagogy topics had a positive influence (with small effect sizes) on PPM teacher MPCK outcomes; these topics were Mathematics Instruction, Developing Teaching Plans, and Mathematics Teaching Observation/Analysis/Reflection. Studies of the general pedagogical topic did not significantly influence PPM teacher MPCK outcomes.

Section III: Mathematics Teacher Education Research and Activities

3.1 General Description of Mathematics Teacher Education Research

From 1996 to the present, Taiwan has undergone a curricular reformation and has continued with a major reform that links primary and lower secondary curricula. The dramatic change in the structure of mathematics curricula and teaching strategy influenced by constructivism has received intensive debate because of unfamiliarity with the theory and practice of teaching by most in-service teachers. As a result, the policy, content, and practice of pre-service and in-service teacher education have transformed and research activity has thrived accordingly. According to the search data from the National Science Council (NSC) Web site, 810 mathematics education projects were granted from 1998 to 2010. Among them, 82 projects were teacher education and professional development-related (see Figure 1).

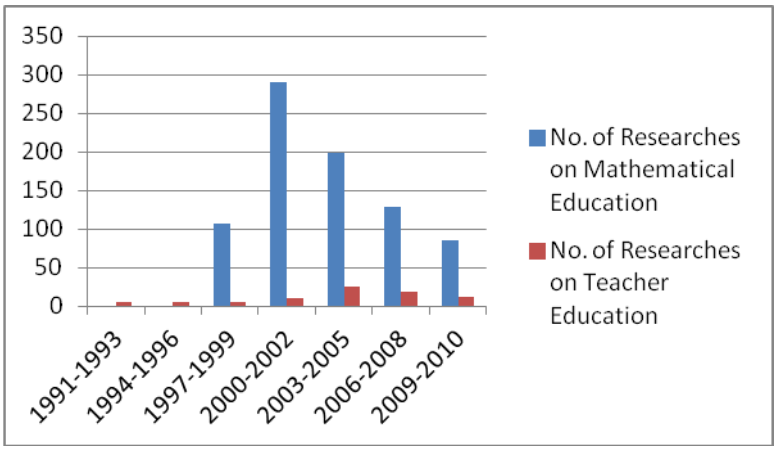

Figure 1: Biannual statistic of research projects granted by NSC from 1991 to 2010. Note that the final column includes only one year of data.

Driven by government policy, many in-service teachers since 1994 have returned to university to obtain credits, master's degrees, PhDs, or EdDs to promote their professional knowledge. The effect of this trend has enlarged academic activity more than ever. In-service teacher engagement in research, supervised by teacher education scholars, has fueled research on valuable authentic teaching problems, and enabled in-service teachers to resolve their own problems more scientifically, such as when using action research. The backbone of research activity in Taiwan consists of

scholars in 40 secondary teacher education institutions. Among them, the most active institutions are eight traditional normal or education universities (MOE, 2011b). The major platforms for sharing research findings are journals (SSRCNSC, 2011), such as the *Chinese Journal of Science Education* and the *Contemporary Educational Research Quarterly*. More than 15 international conferences on education have been sponsored by NSC annually and a range of 19 to 41 conferences have been sponsored by MOE in teacher education universities (MOE, 2011c) in the past three years. Research activity has been flourishing in the past two decades. Teachers holding graduate degrees are increasing rapidly and the research network is expected to evolve into a prosperous organism. Various academic societies also hold academic education sessions during their annual meeting or conference.

3.2 Academic Activities from the Perspective of Professional Development

Academic activities in Taiwan are boosted by laws, a regulation system, and an operating system (see Figure 2), which consists of a teaching advisory group and a professional learning community supported by schools and professional scholars.

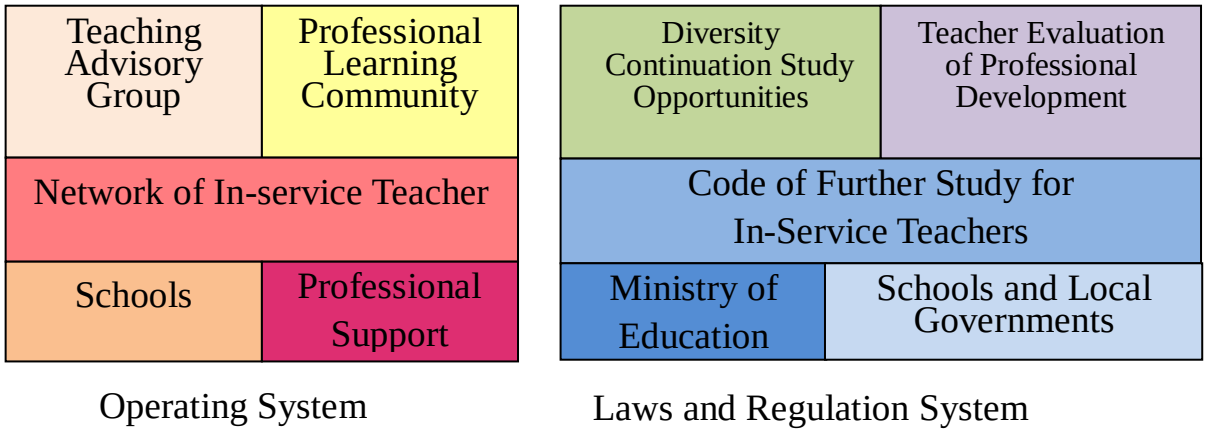

Figure 2: Systems and structures of in-service teacher professional development.

Professional development in Taiwan is threefold according to the type of organization conducting academic activities: university-based, government-based, and Internet community-based. University-based activities offer diverse opportunities for continuation study. Government-based academic activities for professional development of mathematics teachers can be classified into three levels:

(1) Intra-school: In each school, mathematics teachers form a professional group. The class schedule at school is arranged for all mathematics teachers to share a free teaching morning or afternoon per week. Mathematics teachers hold a monthly meeting to resolve problems in their teaching. Scholars and experienced teachers from other schools are invited to give special interest talks.
(2) Countywide: In each county, the county department of education supports all local education programs. The County Compulsory Education Advisory Group

(CCEAG), consisting of selected experienced mathematics teachers across the county, conducts classes, workshops, or teaching demonstrations.

(3) Nationwide: The Department of Secondary Education of the MOE supports all national education programs and projects. The National Compulsory Education Advisory Group (NCEAG), consisting of invited expert teachers and professors from universities in different national regions, is an official organization that coordinates all CCEAG activities and offers training courses and workshops for CCEAG members.

Academic activity through the Internet is growing at an amazing speed. Some scholars in Taiwan, such as Lee (2003), and Lee and Wang (2005) have pioneered this topic for years and have yielded fruitful results using information and communication technology in promoting in-service teacher professions. In-service teachers also frequently visit Web sites to share their teaching experiences both in MCK and MPCK. Internet-based professional development is expected to become increasingly important in the future. Table 6 shows the total hours teachers spent attending e-learning in-service education activities by school levels.

Table 6: Total hours teachers spent attending e-learning in-service education activities by school level in 2010

Teachers at each level	Total no. of teachers	No. of teachers attended	Total no. of hours spent	Average of hours spent
Upper Secondary	33,699	2,161	22,009	0.65
Lower Secondary	14,849	596	5,952	0.40
Primary	47,286	2,757	39,161	0.83

Table 7 shows data collected in 2010 of academic activities for in-service teacher professional development (MOE, 2010b).

Table 7: Teacher attendance hours of assorted professional development programs

Teachers at each level	The average attendance hours of each teacher per year	
	2008	2009
Upper Secondary	24.85	34.85
Vocational Secondary	32.52	39.38
Lower Secondary	37.21	47.50
Primary	71.34	88.42

Other than these academic activities, the MOE authorizes teacher education institutions to offer continuation programs for in-service teachers. Table 8 shows the

number of teachers attending the continuation programs from 2003 to 2010.

Table 8: Number of teachers attending continuation programs

Year	2003	2004	2005	2006	2007	2008	2009	2010
No. of teachers	2150	2823	6690	5435	6427	6475	6390	6360

3.3 Involvement Opportunities in Mathematics Education Research

According to MOE statistics (2012), the percentage of teachers with master's or doctoral degrees has consistently increased, and reached an all-time high in 2010 (see Figure 3). The percentage is expected to climb to exceed 60% in ten years. A master's degree in Taiwan requires writing a thesis. Thus, all graduate students must perform research to write their thesis. As a result, most in-service teachers are capable of conducting research and are connected well with scholars in institutions.

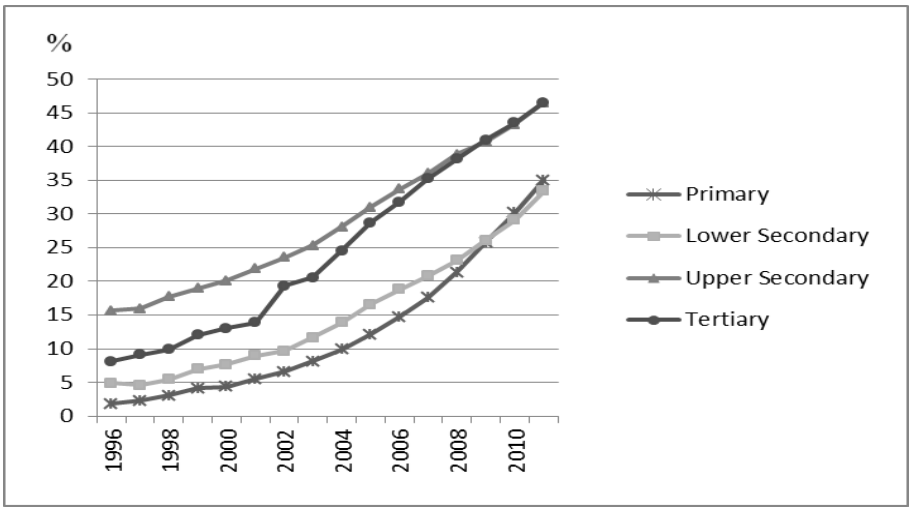

Figure 3: Percentage of teachers with graduate diploma by levels.

Because Taiwan government intends to withdraw the upper secondary school entrance examination by 2013, students must demonstrate their potential and ability by various evidences such as medals won in different types of competitions. National and international science fairs are becoming more important than ever. The National Primary and High School Science Fair is a competition on many levels, with projects winning local exhibitions before being selected to participate in national competitions. According to the 51st science fair bulletin, more than 20,000 projects have been presented annually by teams from primary and secondary schools nationwide in recent years, and over 5,000 projects won the first round in the countywide competition (NTSEC, 2009). Table 9 (NTSEC, 2011) shows the

mathematics projects that entered the final list of different levels in 2011. Teachers instructing students to compete in the science fair are intensively engaged in academic activity where they promote their research proficiencies and simultaneously lead their students through projects that are demanding in both mathematics knowledge and creativity. As a prominent competition, the science fair provides a great opportunity for students and teachers to engage in academic activity.

Table 9: Mathematics projects of different levels in the final list in 2011

Math project at each level	No. of projects	No. of students participated	No. of teachers participated
Upper Secondary	22	49	32
Lower Secondary	19	47	31
Primary	15	51	27

Section VI: Conclusion

Teaching in Taiwan provides an attractive career in terms of income, working hours, career development opportunities, and job security. The recent teacher education movement started in 1994 as the Teacher Education Act has opened multiple means to teacher education. Becoming a teacher has become an extremely competitive task. A positive side of this situation is that serious competition and a rigorous evaluation and selection process may raise teacher quality. However, the Taiwan teacher education system faces many challenges.

Rapid changes in the numbers of teacher education universities and pre-service teachers have created an unstable teacher education system. Low birth rates in recent years have reduced the quota of new teachers and dramatically increased the number of reserve teachers. Taiwan faces the pressure of reducing the number of reserve teachers; however, it must consider the free market in the teacher profession.

The extremely low passing rates of on-site screening and selection for tenure teaching positions has led many teacher education programs to focus on how to prepare for the 20-25 minute teaching demonstration rather than how to become a good teacher in a real classroom.

The international comparison results have released many figures of Taiwan teacher education. In Taiwan, both individual opportunities to study tertiary level or school level mathematics, within or between universities, influence their mathematics content knowledge achievement. Although Taiwanese secondary level teachers have many opportunities to learn both levels of mathematics, they have fewer opportunities to learn mathematics pedagogy. Teacher education programs at the primary level do not require pre-service teachers to study both levels of mathematics. This is a disadvantage to the mathematics content knowledge of teachers because the

TEDS-M findings show that the study of many tertiary and school-level mathematics topics influences teacher performance in mathematics content knowledge.

The lack of opportunity to learn the topic of Affective Issues in Mathematics does not shed light on resolving the problem of low motivation of Taiwanese school students to study mathematics, revealed by TIMSS results.

The Multi-level analyses also show that the academic performance before the entrants enter teacher education programs is a significant variable that influences their preparation outcomes. Taiwan though ranks at the top in the TEDS-M knowledge achievement tests; an attempt to elevate teacher quality continuously is evidenced by the government encouraging universities to increase the ratio of master's to non-master's students in both secondary and primary teacher education programs.

Because the number of teachers earning graduate degrees is increasing rapidly, the research network is expected to evolve into a prosperous organism. As in-service teachers have formed Internet communities, Internet-based professional development is expected to become increasingly more important in the future. In addition to these approaches, the strategic actions for improving teacher education in response to the results of TEDS-M announced in 2010 (MOE, 2010c) indicate enhanced teacher education in Taiwan.

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