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Effect of Lesson on Study on Pre-service Secondary Teachers' Technological Pedagogical Content Knowledge

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Abstract

The aim of this study was to determine the effect of Lesson Study (LS) on pre-service secondary teachers' technological pedagogical content knowledge (TPACK) for teaching mathematics with The Geometer's Sketchpad (GSP). Lesson Study is a Japanese model of teacher professional development in which small groups of teachers collaboratively plan, teach and revise a lesson to improve the quality of their teaching as well as to enrich students' learning experiences. GSP is a dynamic geometry software program for constructing and investigating mathematical objects that enhances the teaching and learning of geometry and many other areas of mathematics. A single-group pretest-posttest design was employed to examine whether there was a significant difference in the pre-service secondary teachers' TPACK for teaching mathematics with GSP after engaging in LS which was incorporated into the mathematics teaching methods course during the first semester of the 2011/2012 academic session in a public university. Forty-six pre-service secondary teachers who enrolled in the course completed the Survey of Pre-service Secondary Teachers' TPACK for Teaching Mathematics with GSP before and after engaging in LS. The results of the paired-samples t-test showed that there was a significant difference in the pre-service secondary teachers' TPACK for teaching mathematics with GSP after LS.

Keywords: TPACK; The Geometer's Sketchpad; lesson study; pre-service teachers, secondary mathematics

Abstrak

Tujuan kajian ini adalah untuk menentukan kesan Kajian Pelajaran (*LS*) terhadap pengetahuan teknologi pedagogi dan kandungan (*TPACK*) guru sekolah menengah pra-perkhidmatan untuk pengajaran matematik dengan menggunakan *The Geometer's Sketchpad* (*GSP*). *LS* adalah model pembangunan profesional Jepun di mana kumpulan kecil guru merancang, mengajar dan memperbaiki satu pengajaran untuk meningkatkan kualiti pengajaran mereka serta untuk memperkayakan pengalaman pembelajaran murid. *GSP* adalah program perisian geometri dinamik untuk membina dan menyiasat objek matematik yang meningkatkan pengajaran dan pembelajaran geometri dan banyak bidang lain dalam matematik. Satu reka bentuk kumpulan tunggal ujian pra dan pos digunakan untuk mengkaji sama ada terdapat perbezaan yang signifikan dalam *TPACK* guru sekolah menengah pra-perkhidmatan untuk pengajaran matematik dengan menggunakan *GSP* selepas melibatkan diri dalam *LS* yang telah diintegrasikan ke dalam kursus kaedah mengajar matematik semasa semester pertama bagi sesi akademik 2011/2012 di sebuah universiti awam. Empat puluh enam orang guru sekolah menengah pra-perkhidmatan yang mendaftar dalam kursus tersebut melengkapkan Tinjauan *TPACK* Guru Sekolah Menengah Pra-perkhidmatan untuk Pengajaran Matematik dengan menggunakan *GSP* sebelum dan selepas melibatkan diri dalam *LS*. Keputusan ujian-t sampel berpasangan menunjukkan terdapat perbezaan yang signifikan dalam *TPACK* guru sekolah menengah pra-perkhidmatan untuk pengajaran matematik dengan GSP selepas *LS*.

Kata kunci: *TPACK; The Geometer's Sketchpad*; kajian pelajaran; guru pra perkhidmatan; matematik sekolah menengah

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■1.0 BACKGROUND OF STUDY

The Geometer's Sketchpad (GSP) is a dynamic geometry software program for constructing and investigating mathematical objects that adds a powerful dimension to the teaching and learning of geometry and many other areas of mathematics. For example, in Geometry, students can use GSP to construct regular polygons and then investigate the properties of the regular polygons. In Algebra, students can employ GSP to construct straight lines and then investigate the gradients and equations of the straight lines. In Trigonometry, students can use GSP to construct trigonometric functions and then investigate the properties of the trigonometric functions (Chanan, 2000). Additionally, GSP "can best foster mathematical inquiry and learning through 'dynamic manipulation' experiments" (Finzer & Jackiw, 1998, p. 2) because students can directly manipulate mathematical objects represented on the computer screen but the mathematical objects remain coherent and whole at all times as they are dragged. Besides, students feel that they are involved with the mathematical objects they are manipulating and most importantly they can focus on how to achieve their mathematical goals, instead of how to use GSP. Thus, teaching mathematics with GSP which is "based on experimentation, observation, data recording and conjecturing" (Olive, 2000, p. 3) encourages "a process of discovery that more closely reflects the way mathematics is invented" (Bennett, 1999, p. viii). This inquiry-based approach to teaching mathematics with GSP should "give students the opportunity to engage in mathematics as mathematicians, not merely as passive recipients of others mathematical knowledge" (Olive, 2000, pp. 3-4).

In addition, research has shown that: (a) mathematics achievement and time of independent investigation using GSP were significant predictors of conjecture-making ability (Elchuck, 1992); (b) the abilities to conjecture and justify conjectures in a geometry class using GSP were directly related to proof-writing abilities (Frerking, 1995); (c) learning mathematics using GSP enhanced students' van Hiele levels of geometric thinking (Choi, 1996; Choi-Koh, 1999; July, 2001; McClintock, Jiang & July, 2002; Thompson, 2006); and (d) the dynamic capability of GSP, inquiry-based tasks as well as student-student and researcher-student interactions deepened students' conception of two-dimensional shapes (Driskell, 2004); and (e) learning mathematics using GSP enhanced pre-service secondary mathematics teachers' understanding of limits of sequences (Cory & Garofalo, 2011).

Further, research in Malaysia has also shown that: (a) learning mathematics using GSP enhanced secondary students' geometry achievement and van Hiele levels of geometric thinking (Nurul Hidayah Lucy, 2005; Chew & Noraini Idris, 2006; Noraini Idris, 2007; Chew, 2007); (b) most of the students also showed positive perceptions of using GSP to learn geometry (Chew & Noraini Idris, 2006; Noraini Idris, 2007); (c) learning mathematics using 'G-Reflect', a GSP-based courseware, had a significant effect on secondary students' achievement and motivation in learning the topic of 'Reflections' (Rosanini Mahmud, Mohd Arif Hj Ismail & Lim, 2009); and (d) learning mathematics using GSP enhanced primary pupils' van Hiele levels of geometric thinking of selected regular polygons (Chew & Lim, 2010).

In view of its importance, the Malaysian Ministry of Education has purchased the GSP license and supplied the GSP software to all secondary schools since 2004 and it is envisaged that this initiative will benefit many students, teachers and teacher educators nationwide. However, teacher enthusiasm and willingness to use GSP remains an issue to be addressed (Teoh & Fong, 2005). In fact, Kasmawati (2006) conducted a survey on 151 secondary mathematics teachers in Penang and found that 26% of the teachers had attended GSP training courses but only 2% used GSP to teach mathematics in the classroom. The two main reasons given by the mathematics teachers for the low percentage of using GSP in the classroom were firstly lack of time to prepare a GSP sketch, and secondly lack of skills and confidence to use GSP to teach mathematics.

According to Neiss (2005), in order for teachers to effectively use technology in their teaching, they need to develop technological pedagogical content knowledge (TPACK) for teaching with the technology. TPACK, as conceptualized by Mishra and Koehler (2006), is the integration of teachers' knowledge of content, pedagogy and technology and it is needed to effectively use technology to teach specific subject matter. More specifically, Shafer (2008) found that teachers need TPACK for teaching mathematics with GSP in order to effectively plan and implement a GSP lesson in the classroom.

Therefore, there is an urgent need to develop pre-service secondary teachers' TPACK for teaching mathematics with GSP so that they can effectively use GSP to teach mathematics in the classroom as advocated by the Malaysian Ministry of Education (2003). But to develop pre-service secondary teachers' TPACK for teaching mathematics with GSP, they need guidance, help and support (Shafer, 2008). One potential means to provide guidance, help and support is through Lesson Study (LS) which is a Japanese model of teacher professional development that teachers engage in to improve the quality of their teaching as well as to enrich students' learning experiences.

Many research studies have shown that LS improves teachers' learning and supports teachers to grow professionally in general (e.g., Stigler & Hiebert, 1997; Shimahara, 1998; Lewis & Tsuchida, 1998; Stigler & Hiebert, 1999; Yoshida, 1999; Fernandez, & Yoshida, 2004; Lim, White & Chiew, 2005) and in particular LS is a worthwhile and beneficial learning experience for pre-service teachers. Chiew and Lim (2003) conducted a LS with five pre-service mathematics teachers while they were undergoing their teaching practice in school. They found that LS helped improve the pre-service mathematics teachers' content knowledge and enhance their confidence to teach the lesson as well. The pre-service mathematics teachers also gained much more diverse teaching ideas which, in turn, helped them improve their pedagogical content knowledge. Besides, Fernandez and Robinson (2006) identified three main categories as central to the pre-service teachers' learning through LS, namely connecting theory and practice, collaboration, and reflection. Apart from that, Lim (2006) found that despite facing the problems of time constraint and peer conflict, the majority of pre-service secondary teachers suggested LS as a good way of preparing them to teach mathematics and would like to continue to be involved in LS in schools after graduation.

Furthermore, Chew and Lim (2011a) found that LS could encourage secondary school teachers to innovatively use GSP in teaching "Lines and Planes in Three Dimensions," "Loci in Two Dimensions" and "Plans and Elevations" and the teachers showed positive changes in their knowledge and skills of using GSP to teach the topics. They also gave positive feedback about LS such as providing peer support and promoting collaboration among the teachers. As a result, the teachers had more confidence in using GSP to teach mathematics in the classroom after the LS process. Chew and Lim (2011b) also found that LS could enhance pre-service secondary teachers' skills of using GSP to teach regular polygons in Form Three Mathematics.

■2.0 OBJECTIVE OF THE STUDY

The objective of the study was to examine the effect of LS on pre-service secondary teachers' TPACK for teaching mathematics with GSP. More specifically, this study aimed to address the following research questions: (1) Was there a significant difference in the pre-service secondary teachers' TPACK for teaching mathematics with GSP after engaging in LS which was incorporated into the mathematics teaching methods course? and (2) Was there a significant difference in TPACK for teaching mathematics with GSP between male and female pre-service secondary teachers after engaging in LS?

■3.0 CONCEPTUAL FRAMEWORK

The conceptual framework underpinning this study was Lesson Study (LS) which is a direct translation for the Japanese term *jugyokenkyu. Jugyokenkyu* is composed of two words: *jugyo, which* means lesson, and *kenkyu*, which means study or research. LS was already well established in Japan since the 1960s. It is an on-going practice as a form of teacher professional development whereby teachers actively engage in a continuous process of improving the quality of their teaching and to enrich their students' learning experiences (Fernandez, & Yoshida, 2004). More specifically, LS is a process by which small groups of teachers meet at stipulated time to plan lessons, observe these lessons unfold in actual classrooms, discuss their observations and to revise the lesson plans collaboratively. In general, LS consists of six main steps, namely (1) collaboratively planning the lesson plan, (2) seeing the lesson plan in action, (3) discussing the lesson plan, (4) revising the lesson plan, (5) teaching the new version of the lesson, and (6) sharing reflections about the new version of the lesson (Fernandez & Yoshida, 2004). The six steps of the LS process are discussed in more detail in the section on research procedure.

■4.0 METHODOLOGY

4.1 Research Design and Participants

The researchers employed a one-group pretest-posttest design (Campbell & Stanley, 1963) to examine the effect of LS on pre-service secondary teachers' TPACK for teaching mathematics with GSP. The participants of this study consisted of 46 pre-service secondary teachers who enrolled in the mathematics teaching methods course in the first semester of the academic session 2011/2012 in a Malaysian public university.

4.2 Instrument

A Survey of Pre-service Secondary Teachers' TPACK for Teaching Mathematics with GSP was used to assess the participants' TPACK for teaching mathematics with GSP before and after engaging in LS. The questionnaire was adapted from the Survey of Teachers' Knowledge of Teaching and Technology (Schmidt *et al*., 2009) which is based on the TPACK framework.

The TPACK framework (see Figure 1), which builds on Shulman's Pedagogical Content Knowledge, describes the relationships between three basic components of teachers' knowledge namely Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK) required for effective integration of technology in teaching and learning (Schmidt *et al*., 2009). CK refers to the knowledge about actual subject matter that is to be learned or taught and how the nature of knowledge is different for various content areas. PK refers to the knowledge about the methods and processes of teaching and includes knowledge in classroom management, assessment, lesson plan development, and student learning. TK refers to the knowledge about various technologies, ranging from low-tech technologies such as pencil and paper to digital technologies such as the Internet, digital video, interactive whiteboards, and software programs (Schmidt *et al*., 2009, p. 125).

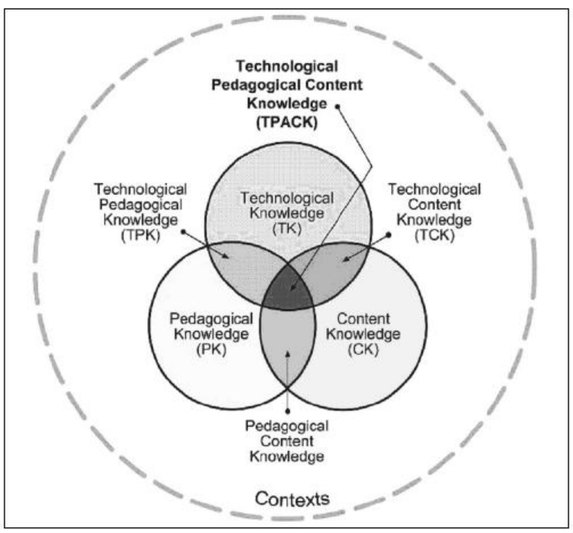

Figure 1 The TPACK framework (*Source:* Schmidt *et al*., 2009, p.124)

In the TPACK framework, the interactions among the three components of knowledge are equally important which are represented as Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). PCK refers to the content knowledge that deals with the teaching process (Shulman, 1986) and it is different for various content areas. TCK refers to the knowledge of how technology can create new representations for specific content and how teachers can change the way students practise and understand concepts in a specific content area by using a specific technology. TPK refers to the knowledge of how various technologies can be used in teaching and changing the way teachers teach by using the technologies. Finally, TPACK refers to the knowledge required by teachers for effectively integrating technology into their teaching in any content area by teaching the content using appropriate pedagogical methods and technologies (Schmidt *et al*., 2009, p.125).

Based on the above framework, the Survey of Pre-service Secondary Teachers' TPACK for Teaching Mathematics with GSP contained 9 demographic questions and seven subscales with 47 self-report items that assessed the participants' TPACK for teaching mathematics with GSP. All the items used a five point Likert scale to rate the extent to which the participants strongly disagreed, disagreed, neither agreed or disagreed, agreed, or strongly agreed with statements about TPACK for teaching mathematics with GSP.

In the Survey of Pre-service Secondary Teachers' TPACK for Teaching Mathematics with GSP, the four subscales of Content Knowledge in the original questionnaire, namely Mathematics, Literacy, Science, and Social Science were changed to Algebra, Geometry, Statistics and Trigonometry respectively. This was because most of the chapters in the Form One (the first year of secondary school) to Form Five (the fifth year of secondary school) Malaysian Mathematics syllabus are in these four main content areas. Further, the words related to technology in the original questionnaire were changed to GSP because this study only focused on the use of one specific technology (that is GSP) in the teaching and learning of the topics of Algebra, Geometry, Statistics and Trigonometry.

Using SPSS version 19 for Windows, the internal consistency reliability as estimated by Cronbach's alpha for the instrument based on the pre-survey data was .80. Thus, it was sufficiently reliable for assessing pre-service secondary teachers' TPACK for teaching mathematics with GSP for the study.

4.3 Research Procedure

In the first two-hour lecture, the course outline, the coursework (that is, an individual review of a journal article on teaching mathematics with GSP, a group 40-minute lesson plan for teaching mathematics with GSP and an individual simulated teaching of the planned lesson), Mishra and Koehler's (2006) TPACK framework, Fernandez and Yoshida's (2004) LS process as well as the research procedure were explained by the course coordinator to all the participants. Then, the Survey of Pre-service Secondary Teachers' TPACK for Teaching Mathematics with GSP was administered by the course coordinator to all the participants. After the lecture, the participants were divided into four tutorial groups. Each tutorial group met at a specific tutorial time for one hour every week.

During the first two tutorials, two GSP workshops were conducted by the course coordinator for each tutorial group. The aim of the first GSP workshop was to explain the functions of the Title bar, Menu bar, Sketch plane, and Toolbox of GSP as well as how to use the basic tools of GSP (that is Selection Arrow Tool, Point Tool, Compass Tool, Straightedge Tool, Text Tool, and Custom Tool) to construct mathematical objects such as points, segments, rays, lines, circles, and polygons. The aim of the second GSP workshop was to design GSP activities for teaching Form One to Form Five Mathematics. After the workshops, the six main steps of LS were implemented in the subsequent tutorials as follows:

4.3.1 Step 1 (Collaboratively Planning the Lesson Plan)

During the third tutorial, the participants in each tutorial group were allowed to form their own LS groups with each LS group comprising two participants. As a result, twenty-three LS groups were formed in this study with six LS groups (known as LS Group 1 to LS Group 6) in the first three tutorial groups and five LS groups (known as LS Group 1 to LS Group 5) in the fourth tutorial group. Each LS group was allowed to choose a topic in Algebra, Geometry, Statistics or Trigonometry from the Form One to Form Five Mathematics syllabus. Next, each LS group collaboratively planned a 40-minute lesson plan for teaching the chosen topic with GSP. Lastly, each LS group planned a schedule for the subsequent meetings to complete their lesson plan, GSP sketches and activity sheets before the fourth tutorial. The end product of this step would be a lesson plan, GSP sketches and activity sheets.

4.3.2 Step 2 (Seeing the Lesson Plan in Action)

During the fourth tutorial, one participant from LS Group 1 in each tutorial group taught the 40-minute lesson as planned to their peers in the Mathematics Teaching Room. The lesson was observed by his/her partner of LS Group 1 and the course coordinator using the lesson plan, GSP sketches and activity sheets to guide their observations.

4.3.3 Step 3 (Discussing the Lesson Plan)

After the lesson, the peers and the course coordinator provided comments and suggestions to improve the lesson plan, GSP sketches and activity sheets.

4.3.4 Step 4 (Revising the Lesson Plan)

After the fourth tutorial, the members of LS Group 1 in each tutorial group planned a schedule for the subsequent meetings to revise their lesson plan, GSP sketches and activity sheets based on their peers' as well as the course coordinator's comments and suggestions before the fifth tutorial. The end product of this step would be a revised lesson plan, GSP sketches and activity sheets.

4.3.5 Step 5 (Teaching the New Version of the Lesson)

During the fifth tutorial, the other partner of LS Group 1 taught the new version of the lesson to different peers in the other tutorial group in the Mathematics Teaching Room. The lesson was observed by his/her partner of LS Group 1 who had taught the first lesson as well as the course coordinator using the revised lesson plan, GSP sketches and activity sheets to guide their observations. After the lesson, the peers and the researcher provided comments and suggestions to further improve the lesson plan, GSP sketches and activity sheets.

4.3.6 Step 6 (Sharing Reflections about the New Version of the Lesson)

After the fifth tutorial, the members of LS Group 1 in each tutorial group planned a schedule for the subsequent meetings to revise their lesson plan, GSP sketches and activity sheets for a second time based on their peers' as well as the course coordinator's comments and suggestions before the sixth tutorial. The end product of this step would be a final lesson plan, GSP sketches and activity sheets for submission as their coursework during the sixth tutorial. Steps 2 to 6 were repeated for LS Groups 2, 3, 4, 5 and 6 in the subsequent tutorials. During the last lecture, the Survey of Pre-service Secondary Teachers' TPACK for Teaching Mathematics with GSP was administered to all the participants.

■5.0 RESULTS

Table 1 shows the results of the paired-samples t-tests using SPSS version 19 for Windows. All the mean scores for male, female and all pre-service secondary teachers' TPACK for teaching mathematics with GSP in the pre-survey were lower than those in the post-survey. Further, the differences between the mean scores were statistically significant for male, female and all pre-service secondary teachers' TPACK for teaching mathematics with GSP at the significance level of .05, indicating that the pre-service secondary teachers' TPACK for teaching mathematics with GSP had improved significantly after engaging in LS.

Table 1 Results of the paired-samples t-tests

TPACK for teaching mathematics with GSP	Pre-survey		Post-survey				
	M	*SD*	*M*	*SD*	*t*	df	Sig. (2-tailed)
Male (*N* = 8)	2.37	.62	3.70	.26	6.14	7	.00*
Female (*N* = 38)	2.71	.44	3.81	.44	12.06	37	.00*
All (*N* = 46)	2.65	.49	3.79	.42	13.54	45	.00*

* *significant at p < 0.05*

Table 2 shows the results of the independent-samples t-tests using SPSS version 19 for Windows. Levene's tests for equality of variances were not significant for both the pre- and post-surveys at the significance level of .05, indicating that the population variances for both the pre- and post-surveys were assumed to be equal for the two groups of pre-service secondary teachers. The mean scores for male pre-service secondary teachers' TPACK for teaching mathematics with GSP were lower than those of the female pre-service secondary teachers in both the pre- and post-surveys. But, the differences in the mean scores were not statistically significant between male and female pre-service secondary teachers at the significance level of .05 in both the pre- and post-surveys, indicating that there were no statistically significant differences in the pre-service secondary teachers' TPACK for teaching mathematics with GSP in terms of gender before and after engaging in LS.

Table 2 Results of the independent-samples t-tests

TPACK for teaching mathematics with GSP	Levene's Test for Equality of Variances		Male (*N* = 8)		Female (*N* = 38)				
	F	Sig.	*M*	*SD*	*M*	*SD*	*t*	df	Sig. (2-tailed)
Pre-survey	2.19	.15	2.37	.62	2.71	.44	-1.82	44	.08
Post-survey	.10	.75	3.70	.26	3.81	.44	-.66	44	.51

■5.0 DISCUSSION AND CONCLUSION

The results of this study showed that LS had a significant effect on the pre-service secondary teachers' TPACK for teaching mathematics with GSP. However, there were no statistically significant differences in the pre-service secondary teachers' TPACK for teaching mathematics with GSP in terms of gender before and after engaging in LS. These results are generally quite consistent with the findings of previous studies on LS and pre-service teachers. Chiew and Lim (2003) found that LS helped improve the pre-service mathematics teachers’ content knowledge and pedagogical content knowledge. In addition, Fernandez and Robinson (2006) found that the pre-service teachers valued the opportunity to apply in practice what they were learning in theory, the sharing of different points of view and understandings about teaching mathematics, as well as the feedback contributed by group members which helped them to think differently about teaching mathematics after engaging in LS. Further, Chew and Lim (2011b) found that LS enhanced pre-service secondary teachers' skills of using GSP to teach regular polygons in Form Three Mathematics.

In conclusion, we acknowledge our limitations in making any generalizations from the results of this study which used a one-group pretest-posttest design and self-report questionnaire. Nevertheless, the results of this study suggested for this sample that LS, which was incorporated into the mathematics teaching methods course, had a significant effect on the pre-service secondary teachers' TPACK for teaching mathematics with GSP regardless of gender.

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