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DEVELOPING PRESCHOOL TEACHERS' MATHEMATICAL TEACHING KNOWLEDGE THROUGH PEER DISCUSSION USING THE LOMT MODEL

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ABSTRACT

The purpose of this study was to inquire into five preschool teachers' mathematics teaching practice knowledge development in Taiwan. Through a community called a "Learning Organization of Mathematics Teaching" (LOMT), the researchers provided the participants with opportunities to better understand the theories of teaching activity design, design mathematics activities and to share them with others. Various data were obtained through observations, interviews and the collection of relevant documents. From analyses of these data, it was found that changes took place in terms of the preschool teachers' views about mathematics teaching, their understandings of mathematics conceptions and of students' learning of mathematics, and the operation of classrooms. Finally, from reflection on the process of investigating participating preschool teachers' teaching practice knowledge development in mathematics, the researcher developed a gateway for the operation of the LOMT model.

Keywords: Mathematical Teaching, LOMT, PCK, Reflect Teaching, Learning Community

INTRODUCTION

In the past years, the use of reflective practice as a means to facilitate teachers' growth in professional knowledge has been explored by a number of educational scholars (Schön, 1987; LaBosky, 1994; Louden, 1991; Manouchehri, 2002). Several researchers have suggested that teachers working in small groups and making efforts to think about their experiences of teaching is a way of instruction that creates cognitive change in teaching knowledge (Barnett, 1991; Thompson & Thompson, 1996; Manouchehri, 2002). This view guides the practice for many innovative teacher education programs, and indeed, develops teachers as reflective practitioners in their own teaching practice.

Besides, based on his analysis of the research, Shulman (1987) concluded that teacher education programs cannot expect to be effective until they work with the beliefs that guide teacher actions, and examine the principles underlying the choices teachers make. Moreover, Matsumura and Steinberg (2002) pointed out that building a cooperative professional development atmosphere for teachers, by way of discussing, talking and viewing and emulating teaching, contribute to improvements in teaching practice and the student's study quality in the classroom.

In this study, we set up a "Learning Organization of Mathematics Teaching" or LOMT. During their involvement in the LOMT, we led five preschool teachers to design teaching activities which they implemented in the classroom, and we reviewed all the behaviors during the process of taking part in the LOMT.

Based on the above ideas, the aims of the study were as follows:

1. To investigate preschool teachers' professional development in teaching knowledge of mathematics during their involvement in the lomt;
2. To identify what problems the participants faced during their involvement in the lomt and how they solved them; and
3. To construct a feasible way to promote preschool teachers' professional development in mathematics teaching knowledge.

THEORETICAL GROUNDING

The purpose of this study was to determine the ways in which peer discussion might contribute to developing reflective thinking related to the knowledge of mathematics teaching. This derived from Senge's theory (1990) of learning organization. On the other hand, the theories of Shulman (1986) and Fennema and Franke (1992) about teachers' knowledge also influenced our study. The goal was to focus on the issue of how to construct a learning organization for preschool teachers and promote their professional knowledge development.

Learning Organizations

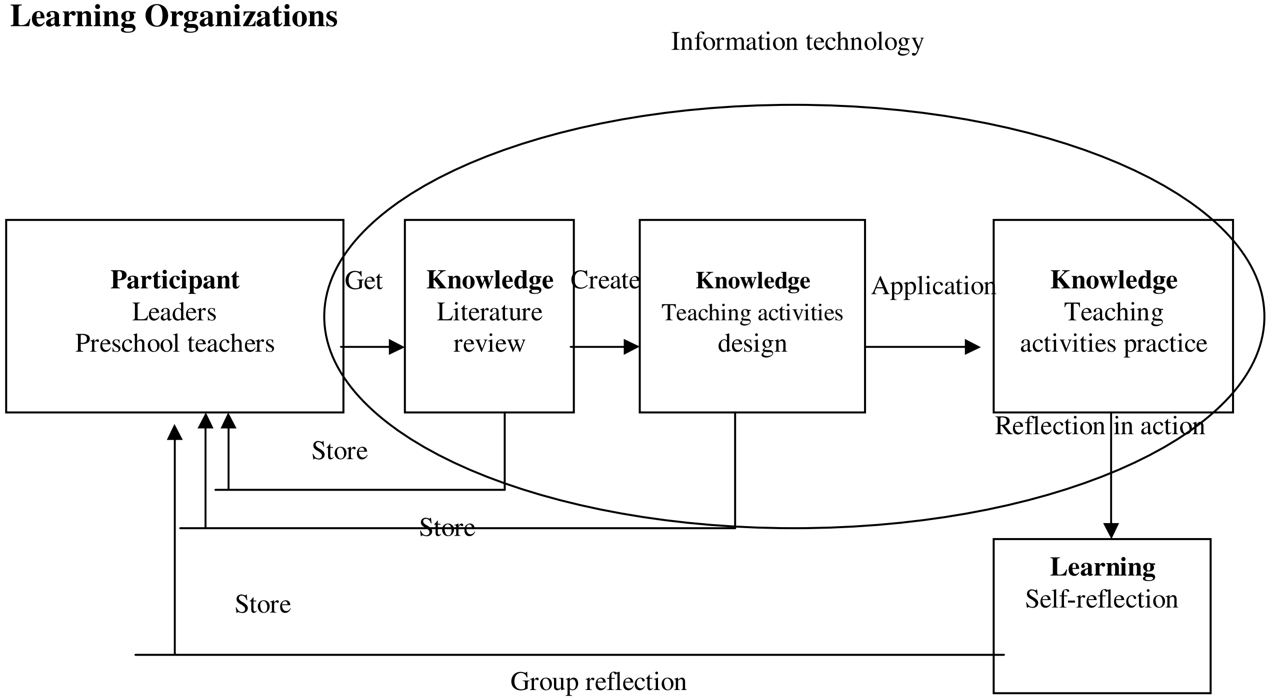

Figure 1. The LOMT process

Senge's (1990) book "The Fifth Discipline: The Art and Practice of the Learning Organization" brought about the "Learning Organization" wave of change. However, in recent years, schools have also begun to think about how to construct a learning type of school to improve the educational quality and efficiency of the school. Marqudart (1996) proposed one learning organization model consisting of the five subsystems of "learning", "organization", "participant", "knowledge" and "technology", with "learning" being the key subsystem.

In sum, the LOMT in this study used "self-reflection" and "group interaction" to promote five preschool teachers' development of their mathematics teaching knowledge. During their involvement in the LOMT, we used "individual learning" to construct each learner's knowledge, and "cooperative learning" to construct social knowledge. The LOMT process can be represented in Figure 1.

Theories of Teaching Knowledge

Shulman (1986) pointed out that teaching knowledge means that teachers teach students in accordance with their abilities and interests of learning in terms of specific themes. The ways of teaching include explaining, demonstrating, likening, giving examples etc., with a kind of knowledge that helps students' learning. Grossman, Wilson and Shulman (1989) pointed out that teaching knowledge includes content knowledge and teaching method knowledge. Teachers with teaching knowledge could help students understand the subject knowledge.

In this study, we integrated the views of Shulman (1986), Fennema and Franke (1992), and Cochran, DeRuiter and King (1993), based on mathematics curricula and preschool teachers' teaching to propose that mathematics teaching knowledge includes the four components of "mathematics content knowledge", "pedagogical knowledge", "pedagogical content knowledge", and "the situation knowledge of mathematics". These four components were used to analyze the five preschool teachers' mathematics teaching knowledge development.

METHODOLOGY

Sample

The sample in this study included five preschool teachers (all female) in Taiwan. In this study, the researcher separated the research process into four stages, namely "Theory awareness and construction", "Knowledge transformation and practice", "Image representation and interpretation" and "Outcome and feedback". In the "Theory awareness and construction" stage, the researcher provided the teachers with the intentions of preschool mathematics conceptions, the theories about mathematics teaching and learning, and theories and examples of curriculum design. In the "Knowledge transformation and practice" stage, the researcher guided the five teachers to develop mathematics teaching activities, to share the difficult points and think about how to solve the problems. In the "Image representation and interpretation" stage, the teachers shared, discussed and revised the mathematics teaching activities. Finally, in the "Outcome and feedback" stage, they put the teaching activities they had designed into operation in the preschool and discussed the problems they met when implementing them.

Data Collection

The data collected in this study included 16 meeting records, personal reflective notes taken after meetings, interview coding, finished materials for the mathematics teaching activities designed by the participants, and teaching videos.

Meeting Records

During the implementation of the LOMT, we had one meeting every two weeks. Each meeting involved discussion of theories, sharing of reflections, peer critiques, and discussion for four hours depending on the requirements of that time. In each meeting we took notes as well as tape-recording the discussions.

Participants' Post-Meeting Reflective Notes

After each meeting, all of the participants (including teachers and the two researchers) were required to complete reflective notes within three days and send them to the researchers by e-mail. The information was then organized and summarized into some issues for discussion in the next meeting.

Interview Cording

We also carried out structured formal interviews with the five participants before and after the fourth stage of the LOMT. Using this information, we could compare their changes to determine their professional development in terms of mathematics teaching knowledge. The interview questions were as follows (see Table 1).

Table 1. Interview questions

No	*Questions*	*Pre-LOMT*	*Post-LOMT*
1	What are your opinions about preschool mathematics content?	V	V
2	What factors do you consider when designing mathematics teaching activities?	V	V
3	What teaching methods should be used by preschool teachers when teaching preschool mathematics?	V	V
4	What are your opinions about the mathematics knowledge or misconceptions of children?	V	V
5	How do you arrange the environment when teaching preschool mathematics? Do you use any natural resources?	V	V
6	What difficult situations do you face in designing preschool mathematics teaching activities? How do you solve these problems?		V
7	What are your opinions about the LOMT? Do you have any suggestions?		V

Besides, after analyzing the pre- and post-LOMT interview recordings, we provided the participants with the data about their change in mathematics teaching knowledge, and used "stimulation-memory" to ask them to look back at the source and factors which promoted their change. Thus, we could summarize the factors which led them to experience professional development in their mathematics teaching.

Mathematics Teaching Materials

During the implementation of the LOMT, the teachers developed their own preschool mathematics teaching materials. The materials were finished after personal creation, peer critique, and personal correction. These materials provided us with information for analyzing their mathematics teaching knowledge. The content of the mathematics teaching activities of the five teachers were as follows (see Table 2).

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Table 2. Mathematics teaching activities of the 5 preschool teachers

Preschool teachers	*Subject*	*Age*	*Contents of activities*
S1	Sum from two numbers and resolution into two numbers under ten	5 yrs	1. Reviewing pair to pair within number and quantity under ten. 2.Exercising and operating with life objects in b＋○＝？（□、○ were known）situated questions. 3.Exercising and operating with life objects in ＋？＝○（□、○ were known）situated questions. 4.Exercising and operating with life objects in？＋？=□（□was known）situated questions.
S2	Sum from two numbers and resolution into two numbers under ten	6 yrs	1. Exercising and operating "number cards" in？＋？=□（□was known）situated questions. 2.Writing down？＋？=□（□ was known）all solutions
S3	Pattern	6 yrs	1.Children could make out the regular pattern as「※※＊※※＊※※＊」 2.Children could operate repeated pattern with life objects as「※※＊※※＊※※＊…」 3.Children could operate increasing pattern with life objects as「※＊※※＊※※※＊…」 4.Children could fill up the repeat form pattern activities with regalia 5.Children could fill up the growth form pattern activities with regalia 6.Children could create pattern activities with regalia by themselves
S4	Figure recognition	6 yrs	1. Identifying rectangular forms. 2. Identifying square forms. 3. Identifying circle forms. 4.Possessing rectangular, square, circle forms conservation conceptions
S5	Geometry apart in two dimensions	6 yrs	1.Knowing the structure of "seven boards" including square, triangle, parallelogram forms 2.Conjecturing and arranging the given figures by "seven boards"

The researcher also used video-record the teaching activities. This information provided us with a method of checking the participants' mathematics teaching knowledge performance.

Data Analysis

In this study, the researcher analyzed and interpreted all the data gathered from the meeting records, the participants' post-meeting reflective notes, the interview recordings and video-recordings by continued reading, comparing, concluding and forming the findings. Besides, we proposed the findings after discussion amongst the researchers and the five preschool teachers. The data coding and data analysis are described as following.

Data Coding

In this study, the coding system used is described as follows (see Table 3).

Table 3. Coding system

Source	*Coding Example*	*Note*
Meeting records	20070424-05	This means the data came from the fifth point in the meeting records.
Participants' post-meeting reflective notes	20070522-note-S2-03	This means the data came from the third point in the reflective notes of the second preschool teacher
Interview recordings	20070821-interview-S4-015	This means the data came from the fifteenth point in the interview recording of the fourth preschool teacher.
video-recordings	S3-05-038	This means the data came from the thirty-eighth sentence said by number five child in the third preschool teacher's teaching.

Data Analysis

In this study, we analyzed the growth in the participants' mathematics teaching knowledge using the structure based on the perspectives of Shulman (1986, 1987), Fennema and Franke (1992), and Cochran, DeRuiter and King (1993). This structure included four categories: (1) mathematics curriculum knowledge, (2) teaching methods knowledge, (3) mathematics knowledge about learners, and (4) mathematics knowledge about environment. The detailed contents of the four categories of knowledge are given in Table 4.

This research analyzed the materials collected according to the content of Table 4 above. The orientation of the analysis can be divided into "Interview orientation" and "Process orientation". "Interview orientation" relates to the participants' interview materials in the "pre-LOMT" and "post-LOMT" interviews as the main analyzed information, which allowed us to compare their transition from before and after participating in this research. "Process orientation" relates to the participants' behavior during their involvement in the LOMT, which allowed us to annotate their growth in the course of participation.

In order to prevent the analysis of the materials in this study from causing bias, we used "triangulation of different persons" and "triangulation of different information" as two channels of "triangulation" (Patton, 1990).

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Table 4. The contents of mathematics teaching knowledge in this study

Mathematics teaching knowledge	Contents	Example
mathematics curriculum knowledge	1.Mathematics concepts for preschool level 2.The contents of each mathematics concept for preschool level	1. Number and Operation, Patterns, Geometry, Space, Statistics, Reasoning. 2. Number and operation includes numbers, ways of representing numbers, relationships among numbers, number systems, and meanings of operations and how they relate to each other, using computational tools and strategies fluently, and estimating appropriately (NCTM, 1998).
teaching methods knowledge	1.Teaching methods 2.Representation of mathematics concepts	1. Co-operative learning, hands on, group discussion, etc. 2. Represented by life objects, pictures, etc.
mathematics knowledge about learners	1.Different age levels' understanding of mathematics concepts 2.Children's alternative concepts	1.3-year-old children can understand the meanings under five, etc. 2.Children's misunderstandings of conservation concepts of quantity, etc.
mathematics knowledge about environment	1.Arrangement of the mathematics situation 2.Application of teaching resources	1.The teacher will arrange appropriate tools for srudents. 2.The teacher will utilize the existing environment, and such resources as parental assistance, etc.

FINDINGS

In order to respond to the purpose of this research, the research findings are presented in the following order: first, the professional development of mathematics teaching knowledge during the operation of the LOMT; second, determination of the potential teaching problems of subjects during the process and their solutions; and finally, the construction of the practical model of the LOMT.

The Operational Evolution of the LOMT: The Growth of the Participants

In this study, we compared the pre and post interviews and analyzed the operating process of the LOMT to interpret the evolution of the subjects' mathematics pedagogical content knowledge. We addressed two findings based on the two aspects of performance and process.

The Evolution of Participants' Mathematics Pedagogical Content Knowledge: Interviews

Both before and after their involvement in the LOMT, the researcher held interviews with the five preschool teachers to identify their mathematics pedagogical content knowledge. The researcher expected to compare the participants' evolution during the operation of the LOMT from the aspects of their knowledge of the mathematical curriculum content, the teaching approach, the learners' ability, and the teaching situation.

The Growth of Mathematical Curriculum Knowledge: Through Study of Theory, Teaching Program Design and Interaction

Prior to involvement in the LOMT, S1 said "The mathematical activities for preschool children should include connecting the dots, matching, timing, counting, shape, length and maze! (20070206-interview-S1-003)" Obviously her cognition of the contents of preschool mathematical teaching curriculum is only up to the shape of fragmental memory. However, after her involvement in the LOMT, S1 answered with exciting solutions "Well, it includes number, quantity, shape, logical reasoning and statistics. Furthermore, each of them contains various ideas. (20070904-interview-S1-012)"

Besides that, S2 mentioned in the post interview "With the references the teachers gave us, I learned that mathematical curriculum content is much more than counting and addition. There is a structure, and concepts are based on it. In this aspect, I think I learned a lot. (20070918-interview-S2-031)" This shows that the theory discussion and teaching program design had the same effect for both S1 and S2.

The evidence of the third factor, that the group discussion helped members become better teachers, comes from S3. She said, "I chose shape as the topic of my teaching program just because circle, triangle, rectangle and so on seemed easy for me to design. S4 made me realize that the idea of shape includes not only identifying different shapes but also recognizing their characteristics. (20070918-interview-S3-042)" This shows that the operation of the organization in the second stage of group interaction is another factor which helps participants' evolution in mathematics pedagogical content knowledge.

Improvements in Teaching Approach: Through Program Design, Interaction and Reflection

What is teaching approach? For these five preschool teachers, their knowledge in this area was relatively insufficient. S4 promoted her ability in this area after writing a teaching plan and discussing it with the other group members, while S5 was also inspired by observing other subjects' classes. First, S4 said, "As far as I know, the common methods teachers in kindergarten use are topic teaching and corner learning. (20070206-interview-S4-072)" When the researcher kept asking, "Are there any others besides these two? And, how do you pass the knowledge to students? (20070206-interview-R1-073)" Obviously before participating in the organization's operation, S4's knowledge of teaching approach was only up to the fragmentary teaching mode. With regard to how to pass mathematic content knowledge to children with different characteristics,

Through observing other teachers' classes, S5 was further enlightened. She said, "Before writing the teaching plan, I went to other teacher's class who had been my supervisor while I was in my internship. She was introducing shapes by using various objects in daily life. (20070918-interview-S5-087)" It can be seen that, from the need of program design, S5 sought the chance to observe practical demonstration to gain the source of developing her teaching approach. This shows that reflection reinforced S5's capability of transforming content knowledge into forms.

Understanding learners' cognitive development: through teaching program design, theory study and sharing the experience of senior teachers

These five preschool teachers' understanding of learner's mathematical intelligence was relatively the most deficient in the beginning. "I have less information about students' mathematical ability. One thing is for sure that the mathematical pedagogical content should be based on the students' cognitive development. (20070206-interview-S2-058)" Moreover, they were not familiar with the children's other concepts. At the end, S2 gave a different answer:

"The trigger of my change might be the demand for designing the teaching project. I paid close attention to articles related to numeral composition and resolution. (20070918-interview-S2-035)" S2 replied in the post interview. According to S2's response, study of theory and pedagogical program design contributed to her achievement of a new comprehension of student characteristics.

On the other hand, for S3, the supportive teaching experiences offered by the senior teachers tended to provide the main assistance. "I totally had no clue about how to project a course introducing 'pattern'. Neither did I know to what degree students' have understood. After talking to an experienced teacher who taught in the kindergarten next to my home, I learned a lot. (20070918-interview-S3-051)" Before this project, study of theory has been the main strategy used in teaching pre-vocational educators till now. Through this project, the researchers found that the sharing of experience by front-line instructors is another powerful stimulant for growth.

Developing a complete understanding of the teaching situation: through theory study and reflection

It was found from the pre interviews that all subjects were inclined to the arrangement of the physical learning surroundings and rarely cared about creating a supportive environment that encourages students to learn, and which employs the school's resources. "Generally speaking, it takes approximately 4 to 6 weeks to complete one topic. (20070206-interview-S3-062)" However, S3 had a more specific answer for the same question after involvement in the project. She said "The hardware equipment in a classroom is just part of the knowledge of the teaching situation. 20070904-interview-S3-035)" What is meant by teaching content? "It refers to the subjects whom a teacher is going to teach, such as mathematics, science, literature, etc. (20070904-interview-S3-037)" What is meant by teaching itinerary? "It means the teaching or learning mode that teachers are going to adapt. Take Montessori for instance; by operating tools, children acquire mathematical concepts. It carries the spirit of self-exploration. (20070904-interview-S3-039)" And what is meant by manipulating environmental resources? "It implies the accessible and employable resources around a classroom, such as the natural materials on campus and the assistant and physical materials offered by students' parents. (20070904-interview-S3-041)" It is obvious that involvement in the group worked effectively on the growth of S3's knowledge of the pedagogical situation.

In conclusion, the pre and post interviews disclosed that all five preschool teachers reformed their mathematical pedagogical content knowledge. The motivators were also revealed in the 'Stimulus-Recall' interviews.

Conclusions of the four stages of the LOMT

The development of the participants' pedagogical content knowledge will be interpreted from the four stages of the LOMT.

Theory Study and Comprehension

For the purpose of this research, i.e. to upgrade pedagogical content knowledge by instructing participants to design and put into practice a teaching program as part of a Learning Organization, five debates mainly focusing on 'The components of children's mathematical concepts', 'Theories for mathematical teaching and learning' and 'Theories for teaching program design' were held in the first stage.

When this stage was completed, all participants' perceptions of the mathematical curriculum as punctual memory changed to solid recognition. "Before the conferences, I thought mathematics for pre-school was limited to counting, addition, shapes, etc, yet, it has a framework; I finally knew. It includes number, quantity, shape, space, logical reasoning and statistics. Additionally, various texts are covered under these subjects. (20070313-note-S4-05)" S4 drew the following picture in her reflection (see Figure 2):

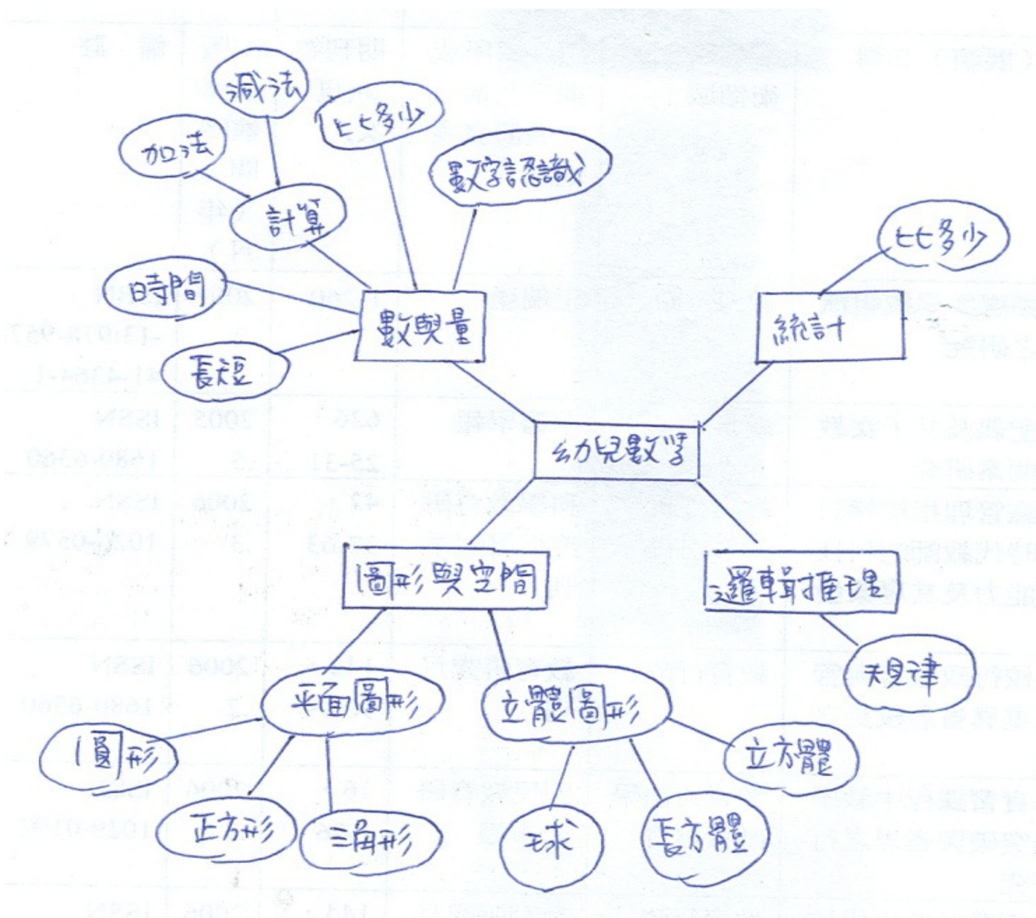

Figure 2. Mathematics concepts structure of kindergarten age represented by S4

S3 also grasped the concepts of 'hands on' and 'exploration' in the 'Theories for teaching program design' seminar. "I considered Montessori pedagogy nothing more than a teaching mode before. After the teacher explained it, I eventually understood the information it carries, which is how a student develops personal constructs of mathematical concepts through self-exploration and how a teacher provides a learning environment which urges students to DIY. (20070410-note-S3-02)" S3 applied this idea to her design of teaching activities related to 'Pattern', and implemented her discipline through making cards and blocks with diverse colors and figures for children as probing tools.

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In the same way, S1 grasped the essence and concept of collaborative learning, and reflected it in her description. "There is the possibility to implement collaborative learning amongst children; I knew that only after joining the conferences of this project. From a developmental aspect of children in play, children in the second or third grade in kindergarten have reached the stages of associative play and cooperative play, so that they could finish an assignment collaboratively. (20070327-note-S1-11)" Furthermore, in S1's teaching activity, she offered a learning list to students and expected them to accomplish the task cooperatively and to share their opinions, which is powerful evidence of putting theory into practice.

Teaching Program Design

In the second stage, the participants were requested to submit a pedagogical activity design. Two meetings occurred in this stage. In the first one, the subjects asked questions and determined the central concepts of their pedagogical activity according to the researchers' clarification. In the second discussion, each subject presented the individual pedagogical target of the teaching activity and initiative pedagogical approach.

Both functions of 'Knowledge Administration' and 'Knowledge Distribution' held in this LOMT worked effectively on members' construction of knowledge as well. S3 witnessed it, "From other students' reports, I advanced in my mathematical understanding on other aspects too. (20070508-note-S3-08)

Besides, three dimensions: (1) the present order of ideas, (2) the evaluation of learning achievement during the teaching process, and (3) the obtainment and employment of teaching resources, indicated by researchers as references for subsequent lesson activity design also widened the participants' field of view.

"In today's meeting, the teacher lectured on the utilization of teaching resources. I finally knew that teaching tools and materials are accessible through parents and communities.. (20070424-note-S2-01)"
In the third stage, the design content of the pedagogical exercises was reported by each participant and consulted during four seminars.

"Through peer communication, critiquing and subsequent reflection, the majority of members were able to see the defects in their pedagogical designs and further modify them. (20070703-10)"

Team discussions encouraged participants to distribute and transfer their knowledge evenly. "Although each of us only needed to complete one pedagogical project, for me, I was actually involved in five by sharing with the other teachers. (20070605-note-S3-07)"

Through involvement in the LOMT, all members have reversed their attitudes toward knowledge from the aspect of knowledge construction, and all of them are approaching the ideal of social construction.

Implementation and Feedback

In this stage, the members observed and critiqued the video recordings and exchanged their reflections in the organizational seminars. The growth of the subjects is analyzed from three perspectives:

Inspired by implementing pedagogy

Originally lacking pedagogical experience, the participants were expected to be more comprehensive of child mathematical learning by practicing their teaching plans in person. S1 said, "Children are definitely hard to control in class. It took me 20 minutes to finish an activity which was originally supposed to take 10 minutes. After this demonstration, now, I do understand why people say 'a 3-minute performance on stage takes 10 years hard work to achieve.' (20070717-note-S1-01)"

Two facts are obvious from these two participants' comments: (1) in a teaching situation, not only does the lesson need to be given, but the class order also has to be maintained; (2) students' active patterns of mathematical conceptual learning are able to be observed when teaching.

Inspired by learners

For the five participants, the students' feedback in class promoted their knowledge of the subject matter to a new level of comprehension.

S4: "My students were children in junior kindergarten. In this class, I was astonished by the fact that they were not able to judge whether a square is still a square or not when I simply turned it around. (20070814-note-S4-06) I didn't believe in the 'concept of conservation', but I do, now. (20070814-note-S4-07)"

Thus, the responses given by the students after class offered the participants an opportunity to have an inside look at pedagogical content knowledge (PCK).

Inspired by peer scrutiny

Peer scrutiny is another reason for the improvement in the subjects' PCK. By inspecting each other's pedagogical videotapes, all participants improved their mathematical erudition. S4 mentioned, "While watching my videotape, the teacher guided me to draw a diagram to illustrate the intersection and union among various shapes and it would reveal the children's learning weakness in the relationship between different shapes. That's a brand new idea to me. (20070814-note-S4-12)"

From the three aspects of 'disciplinary implementation', 'the presentation of students' learning' and 'peer scrutiny', these transcriptions record the participants' step-by-step development and demonstrate that the LOMT operated successfully.

The Potential Teaching Problems and their Solutions

The researcher witnessed a positive change for all participants during their involvement in the learning organization in the last section. Next, from the conference records and the transcriptions of the subjects' reflection, the problems facing these teachers and the solutions they adopted will be defined and analyzed from psychological, cognitive and environmental perspectives.

Psychological Breakthrough: Positive Emotional Support and Real Demonstrations

During the experimental process, members were afraid of speaking, writing and teaching. S1 recorded in her notes: "Today is our first meeting, and everyone rarely spoke. It might be because we haven't been face to face at such a close distance before and felt awkward! (20070213-note-S1-09)" The conference coordinator also recorded: "Nobody was eager to speak. They should be given some encouragement. (20070213-11)"

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How can we overcome these obstacles? S3 said: "I hope the teacher could give us some advice or certain directions for consideration. Thus, I shall be able to be stimulated and then, have my own thinking. (20070227-note-S3-11)" These descriptions indicate that members need positive emotional support and real demonstrations from the instructor.

Cognitive Breakthrough: Literature Study and Brainstorming

S3 reflected on the difficulty of 'insufficient knowledge': "I think I haven't studied sufficient theories related to the composition and resolution of numbers up to10. So, when I was designing pedagogical activities, I still couldn't master the students' limits to learning. (20070424-Note-S3-05)"

To overcome this obstruction, the members suggested, "I hope our teacher provides more literature to stimulate my thinking on pedagogical program design. (20070424-Note-S3-09)" and "I hope my classmates would talk more about what's on their minds. Sometimes, what they think about is that I would never give a thought to. (20070424-note-S4-07)" Therefore, what they require is ample literature to study, and brainstorming with their partners.

***Providing Environmental Resources and Arranging in* Advance**

S5 and S3 addressed two more hardships facing them. "Making the teaching materials also upset me while programming teaching activities. (20070828-Note-S5-10)" Apparently, 'timing' and 'human resources' trapped them, as well.

To overcome these impediments, S5 suggested: "If I have the fortune to join such an organization in the future, I hope I can work in a group of 2 or 3. (20070828-Note-S5-12)" With 'cooperative team work', members could overcome the shortage of human resources by cooperating with each other.

On balance, during their involvement in the LOMT, the participants were faced with a psychological predicament, i.e. low self-confidence in their own abilities, a cognitive predicament, i.e. insufficiency of professional knowledge and lack of creative ability, and an environmental predicament, i.e. lack of time and human resources for their teaching. Therefore, the researchers consider taking the following actions to overcome these problems in the future: (1) to consult with school teachers and set up a teaching schedule ahead of time, (2) to replace individual work with cooperative team work, (3) to render positive emotional support and abundant real cases and literature as reference in the 'theory comprehension and construction' stage, (4) to encourage members to express their opinions by brainstorming with the purpose of 'converting knowledge into practice' and 'the symbolization and interpretation of concept' stages.

The Construction of the Practical Model of the LOMT

With the theory of 'Learning Organization' in the background, combining research design practice and process analysis, and taking 'pedagogical program design' as the core, the researchers in this study projected a 'Learning Organization of Mathematical Teaching'. Through the four stages of the conferences held in 'theory comprehension and construction'→ 'converting knowledge into practice'→ 'the symbolization interpretation of concepts' →'implementing and feedback', the researchers induced the factors affecting the growth of participants' pedagogical content knowledge. Based on the results, we constructed a "Learning

Organization of Mathematical Teaching, LOMT" model and expect it to play a reference role for future study.

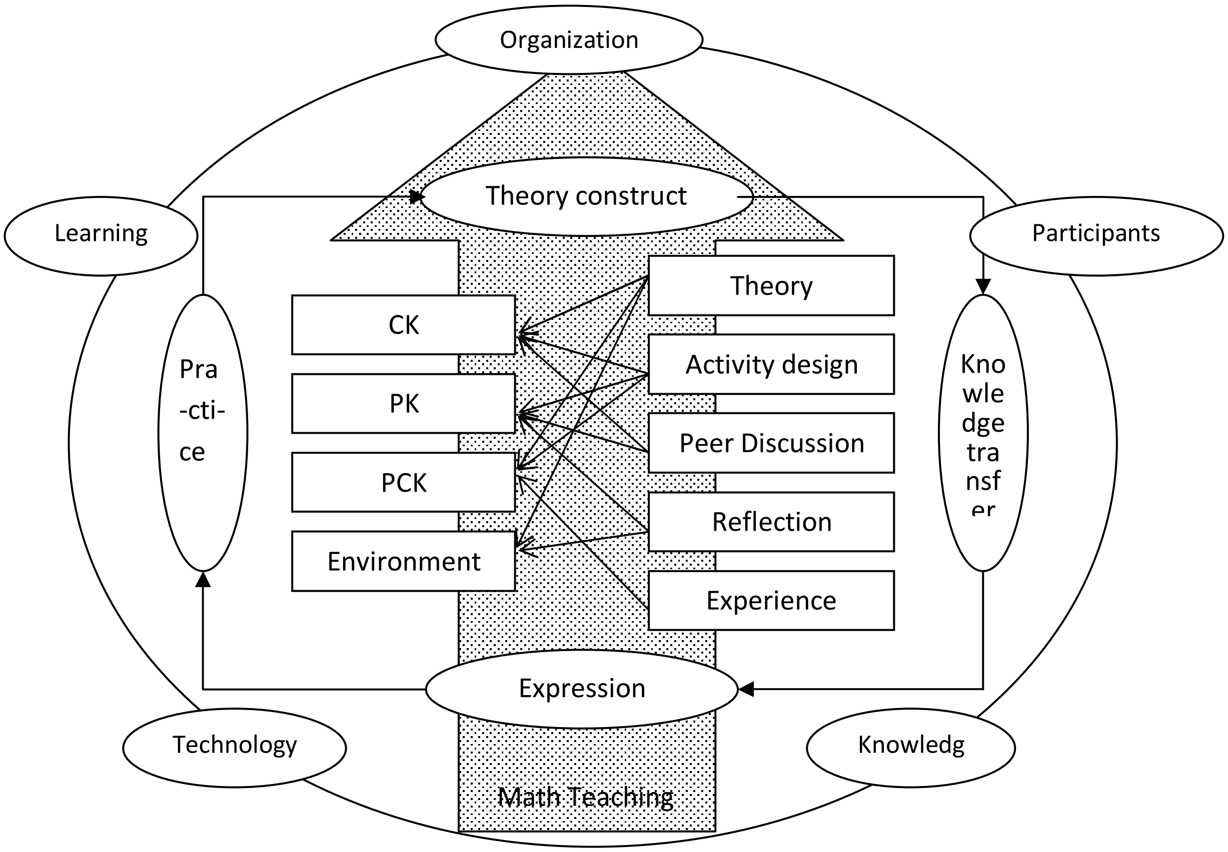

Figure 2. The LOMT model

DISCUSSION AND CONCLUSION

A great amount of study has indicated that sufficient time, resources, and on-going professional support are necessary for teachers' cognitive construction and the changing of classroom practice (Glasson & Lalik, 1993; Tobin, 1999). Based on this, the researchers planned this study adopting the 'Learning Organization of Mathematics Teaching' model with sufficient time, i.e. six months, sufficient resources, i.e. the reviewing of literature and consultation with researchers and access to a science and education professional, and on-going professional support, i.e. seminars, teaching practice and the sharing and peer coaching of teaching demonstrative videotapes to enhance the pre-service pre-school teachers' mathematical pedagogical knowledge in the process of their cognitive construction and implementation.

Both the results obtained from the comparison between the first and the follow-up interviews, and the analysis of the process proves the development of the five pre-service pre-school teachers' PCK. The motivators of their growth originate in the 'literature review', 'pedagogical activity design', 'peer interaction', 'observation and reflection' and 'senior teachers' experiential support'. Such a professional developmental context, which is based on the body of 'collaboration', through discussion, reflection and pedagogical observation perfectly corresponds to Jaworski's comment that a collaborative professional developmental context facilitates teachers to promote pedagogical practice and students' learning (2004). Next, the developmental path of the five pre-service preschool teachers' PCK and the factors affecting it will be discussed in broad terms and compared with the relevant research. The implications of the study results for future teacher cultivation will also be discussed.

Discussion

A collaborative group based on a 'Learning Organization' model extracts members' perspectives and craft knowledge

The results show that it was peer interaction that offered opportunities for the five subjects to exchange their personal opinions and extract their existing knowledge and perspectives of PCK. Barnes and Todd (1997) came up with the idea of 'collaborative dialogue' in a professional group which successfully distributes a learner's individual comprehension elicited in a teaching practice scenario to the others. Just as Barnes and Todd stated, collaboration can reconcile peer conflicts and create peer-to-peer communication. As a learning individual in a group tries to understand other members' thoughts, he or she ought to expand his/her personal cognitive structure and reach a common agreement with the others (Barnes & Todd, 1977). The fifteen organizational conferences, in which group members consulted and discussed consistently, and eventually developed relevant mathematical PCK, played such a role. The results of the study support the argument that peer interaction assists in reforming mathematical craft knowledge and is powerful evidence for peer contribution, feedback and observation of learner and colleagues' practical introspection.

Group members' PCK is extended by literature review, practice, peer interaction, reflection and experiential support

A survey of the subject teachers' developmental track of PCK, shows that there is an axis structured by their understanding of the connection among contents. For illustration, starting with theory study, they gradually acquired the knowledge of their subject matter and the development of the children's mathematical concepts, and were able to design. Next, they became acquainted with the children's mathematical learning specifics in implementation and, even more, reinforced their reflective ability in peer observation and interaction. This result is consistent with Courtney, Booth, Emerson and Kuzmich's (1987) finding that as soon as educators get a deeper insight into students' learning, they will gradually adjust their pedagogical methods to cohere with the students' requirements. The developmental procedure of PCK: literature review (Halim & Meerah, 2002)→ design and implementation of pedagogical activities (Jenkins & Veal, 2002)→ peer interaction (Appleton & Kindt, 1999)→ self-reflection and experiential support from senior teachers, also corresponds to Shulman's 'Model of pedagogical reasoning' (1987): comprehension→ transformation→ interpretation→ evaluation→ reflection→ new comprehension. This result expresses that PCK is affected by professional educative courses and professional subject curricula.

Conclusion

The establishment of an LOMT assists pre-service preschool teachers' PCK

This study found that the key factors influencing the constant evolution of the subjects' PCK were the researchers' consultation and theory support, peer discussion and self-reflection. This differs from traditional teacher education programs which focus on the first factor only. Therefore, this study suggests that teacher educators organize learning groups similar to the one in this study to enhance pre-service preschool teachers' PCK.

The priority of the LOMT is to achieve a new comprehension of teachers' mathematical professional knowledge and knowledge of student characteristics

Another finding in this study is that the comprehension of mathematical professional knowledge and the knowledge of student characteristics is the major reason the five subjects could design and implement their pedagogical programs successfully. Based on this finding, this study suggests that teacher educators arrange courses on mathematical content and student characteristics before other courses.

The combination of theory and teaching practice extracts educators' mathematical PCK

Finally, this study revealed that the development of subject members' mathematical PCK follows a procedure which originates from a literature review, proceeds to curriculum design then practical teaching, and finally, introspection and peer reflection. This result shows that teachers develop their mathematical PCK with a theoretical foundation and through putting theories into practice in real teaching situations, and integrating and advancing the accumulative experiences. Thus, this study suggests that teacher educators stress the debate on theory and practical pedagogical experiences to extract teachers' mathematics PCK while improving it.

REFERENCES

Barnes, D. and Todd, F. (1977). *Communication and learning in small groups*. London: Routledge & Kegan Paul.

Barnett, C. (1991). Building a case based curriculum to enhance the pedagogical content knowledge of mathematics teachers. *Journal of Teacher Education, 42*(2), 1-9.

Capenter, T.P., Fennema, E., Peterson, P.L. and Carey, D.A. (1988). Teacher's pedagogical content knowledge of students' problem solving in elementary arithmetic. *Journal for Research in Mathematics Education,* 19(5), 385-401.

Cochran, K.F., DeRuiter, J.A, and King, R.A. (1993). Pedagogical content knowledge: An integrative model for teacher preparation. *Journal of Teacher Education, 44*(4), 263-272.

Courtney, R., Booth, D., Emerson, J. and Kuzmich, N. (1987). *No one way of being: A study of the practical knowledge of elementary art teachers*. (ERIC Document Reproduction Service NO. ED 305 296)

Fennema, E. and Franke, M.U. (1992). Teachers' knowledge and its impact. In Grouws, D. A. (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 147-164). N Y: MacMillan.

Glasson, G.E. and Lalik, R.V. (1993). Reinterpreting the learning cycle from a social constructivist perspective: A qualitative study of teachers' beliefs and practices. *Journal of Research in Science Teaching, 30*, 187-207.

Grossman, P.L. and Richert, A.E. (1988). Unacknowledged knowledge growth: A reexamination of the effects of teacher education. T*eacher & Teacher Education, 4*(1), 53-62.

Grossman, P. L., Wilson, S.M. and Shulman, L.S. (1989). Teachers of substance: Subject matter knowledge for teaching. In M.C. Reynolds(Ed.), *Knowledge base for the beginning teacher*(pp.23-36). New-York: Pergamon Press.

Halim, L. and Meerah, S.M. (2002). Science Trainee Teachers' Pedagogical Content Knowledge and its Influence on Physics Teaching**.** *Research in Science & Technological Education, 20*(2), 215-225.

Jaworski, B. (2004). Grappling with complexity: *Co-learning in inquiry communities in mathematics teaching development*. Proceedings of the 28th conference of the international group for the psychology of mathematics education, I, 17-36.

Jenkins, J.M. and Veal, M.L. (2002). Preservice Teachers' PCK Development during Peer Coaching. Jo*urnal of Teaching in Physical Education,* ***22***(1), 49-68.

Klein, R. and Tirosh, D. (1997). Teachers' pedagogical content knowledge of multiplication and division of rational numbers. In E. Pehkonen (Ed.). *Proceedings of the Conference of the International Group for the Psychology of Mathematics Education, 3*, 144-151.

LaBosky, V.K. (1994). *Development of reflective practice: A study of preserves teachers*. New York: Teachers College Press.

Louden, W. (1991). *Understanding teaching: Continuity and change in teacher's knowledge*. New York: Teachers College Press.

Manouchehri, A. (2002). Developing teaching knowledge through peer discourse. *Teaching and Teacher Education, 18*, 715-737.

Marquardt, M.J. (1996). *Building The Learning Organization: A System Approach to Quantum Improvement and Global Success*, London: McGraw- Hill.

Matsumura, L.C. and Steinberg, J.R. (2002). *Collaborative, School-Based Professional Development Settings for Teachers: Implementation and Links to Improving the Quality of Classroom Practice and Student Learning*. CSE Technical Report 568. The Regents of the University of California.

National Council of Teachers of Mathematics. (1989). *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: NCTM.

Patton, M.Q. (1990). *Qualitative evaluation and research methods.* Sage Publications, Inc.

Schön, D.A. (1987). *Educating the reflective practitioner*. San Francisco: Jossey-Bass.

Senge, P.M. (1990). *The fifth discipline: The art and practice of the learning organization*. Boston: Doubleday.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *American Education Research Journal, 15*(2), 4-14.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Thompson, A.G. and Thompson, P. (1996). Talking about rates conceptually, Part II: Mathematical knowledge for teachers. *Journal for Research in Mathematics Education, 27*(1), 2–25.

Tobin, K. (1999). The Value to Science Education of Teachers Researching Their Own Praxis. *Research in Science Education, 29*(2), 159-169.