

HOW DO MATHEMATICS TEACHERS DEVELOP TEACHING CONCEPTIONS: KNOWLEDGE, PRACTICE AND COMMUNITY

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This paper explores the developmental processes about the teaching conceptions of practice teachers in mathematics. Six cases of practice teachers in different secondary schools, their mentors and students were involved in the final year study of a three-year longitudinal research project. The case study method, including classroom observations and pre and post-lesson interviews, was used as the major approach to investigate the development processes and values about their teaching conceptions. We preliminarily addressed some reasons that led the teaching conceptions of practice teachers to change, adjust or maintain. We thought that there appeared to be some implications in activating the developments of practice teachers' teaching conceptions, then to develop their professional competencies.

INTRODUCTION

Student teachers of secondary mathematics in Taiwan study both mathematical and educational courses in the university departments, followed by a paid placement of teaching practice at a junior or senior high school as practice teachers. Some experienced school teachers are assigned to be their mentors. It is necessary for teachers to pursue professional growth in the process of teacher education continually; however the stage of teaching practice is a very important period for practice teachers to learn professional competencies. Wenger (1998) proposed a social theory of learning, and the primary focus of this theory viewed learning as social participation. He indicated that “a social theory of learning must therefore integrate the components necessary to characterize social participation as a process of learning and of knowing” (p. 4) and “these components include *meaning, practice, community* and *identity*” (p. 5). When practicing in school, we view such school as a kind of scale-down society. In schools, there are not only many experienced teachers, but varied social status and identities. Thus, the circumstance of school shapes a large-sized learning *community of practice* (COP) (Wenger, 1998) naturally; and the classroom including mentor and students shapes another miniature learning COP. So, practice teachers learn to develop their professional competencies of teaching in such two-level COP simultaneously. Mentors may play important roles to improve practice teachers' “mathematical power” and “pedagogical power” (Cooney, 1994). Wang & Chin (2007) found that mentors could intervene in practice teachers' teaching to enhance their professional power when mentors thought practice teachers were lack of varied professional knowledge.

Simon (1994) asserted that “the Learning Cycle consists of an exploration stage, a concept identification stage, and an application stage which triggers a new

exploration stage” (p. 76) and proposed a six-learning-cycle model. On the other hand, Tzur (2001) distinguished the professional development of mathematics education participants into four levels including learning mathematics, learning to teach mathematics, learning to teach teachers, and learning to mentor teacher educators. Because practice teachers are unexperienced in teaching, they must learn to reinforce their profession of teaching; that is, they mainly learn how to develop their mathematical and pedagogical power. Proulx (2007) asserted that professional development intervention in practice could offer secondary mathematics teachers learning opportunities to experience and explore school mathematics at a conceptual level. Lerman (1994) described critical incidents as ones that could provide insight into classroom learning and the role of the teacher, challenge our opinions, beliefs and notions of what learning and teaching mathematics are about, as well as offer a kind of shock or surprise to the observer or participant. In the light of this, critical incidents can be conceived from teaching aspects, because the incidents might invoke the conflicts and challenges of practice teachers’ beliefs and values, as well as their thinking about professional identities from teacher’s stand to make the best teaching decisions.

Sullivan (1999) indicated that teaching is a kind of complicated activity involving student’s cognitive process, motivation and learning, as well as teacher’s designing of teaching activities and framing of classroom norms; at the same time, he thought that teachers could be aware of the teaching questions and possible methods to solve them in specific contexts, and be able to make teaching decisions. When teachers decide and choose how to design lesson activities, and think about when to address the critical questions, they have held important guiding principles of teaching in their hearts to lead them to make final decisions. These guides or principles leading classroom actions are conceived as the pedagogical values of mathematics teachers (Bishop, Seah & Chin, 2003; Chin, Leu & Lin, 2001; Gudmundsdóttir, 1990). So, we assert that teaching conceptions mean that practice teachers reveal their thoughts about the mathematical contents and pedagogical strategies when they are taking the teaching of specific topics. Such thoughts are involved in mathematics teachers’ value judgments and choices of pedagogies. So, teaching conception is a kind of objective and intended mental action based on a variety of knowledge, and it is adjusted in terms of the topics, learners, learning circumstances and learning contexts. But some researchers showed that it is difficult to change the mathematics conceptions of teachers (Cooney, 1999; Lerman, 1999; Thompson, 1992), because of their own pre-experience of learning, social identification, or lack of teaching competencies (Chen, 2002). We thought that mentors could play the role of instructor to tutor practice teachers’ teaching, and then influence their conception development of teaching. We intend to explore the reasons about the developmental processes of practice teachers’ teaching conceptions and what roles mentors play.

Boaler (2002) described the relationship of practice, knowledge and identity as the three major conceptions of the learning theorem based on COP. The framework

describes that students learn mathematical knowledge through classroom practice, in which the practice and the arising of knowledge are highly correlative. At the same time, they would develop their learning identities when engaging in the practice of mathematical learning; and the connection of identity and knowledge is then constructed through disciplinary relationship. Chang (2005) further extended the relationship of student teacher's teaching identity, practice and conception paralleled to that of Boaler's framework (as Figure 1). We use the framework to explore the development about the relationship of teachers' teaching identities, classroom teaching practices, and teachers' conceptions of mathematics and pedagogy. Thus, mathematics teachers undertake their teaching practices according to their teaching conceptions, and at the same time, they may renew such conceptions through classroom teaching practices, which in turn enhance or extend the educational knowledge and theorems that they have already known and thus might develop their own styles of mathematics teaching (that is teaching identities). We intend to investigate the effects of practice teachers' teaching conception development in varied practice circumstances and the relationship of teaching conception and practice.

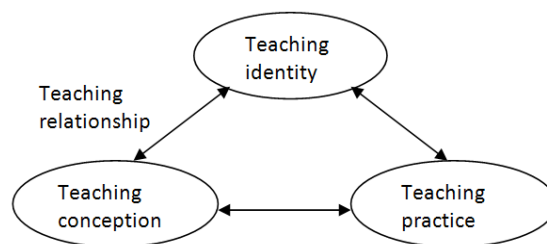


Figure 1. The relationship of student teacher's teaching identity, conception and practice (Chang, 2005, p.165).

RESEARCH METHODS

In this study, we adopt the case study method, including classroom observations and pre and post-lesson interviews, as the major approach of inquiry to investigate the development processes and the values of mathematics practice teachers about teaching conceptions. The systematic induction process and the constant comparisons method based on grounded theory (Strauss & Corbin, 1998) were used to process data and confirm evidence characterized by the method of the present study. Six practice teachers (A_i , $i=1\sim6$), their mentors (M_i , $i=1\sim6$) and students (S) participated in the 2005 academic year as the third of this three-year longitudinal case studies on the beliefs and values of pre-service teachers for secondary mathematics. The second author of this paper was the university tutor of the six practice-teacher cases. We as both the researcher and tutor visit every A_i twice during the academic year (2005.9-2006.6), one in the first semester (2005.9-2006.1) and the other in the second semester (2006.3-2006.6), observing one lesson of A_i 's classroom teaching with M_i and interviewing A_i . Post-lesson interviews are used to clarify the critical issues or events emerging from the observations, and could also be used to explore the

conceptions of and underlying values for the A_i 's teaching decision-making. During the interviews, we respected all of practice teachers' perspectives and there was no attempt to correct their statements and opinions. And then all classroom observations and post-lesson interviews were tape recorded and transcribed later.

RESEARCH RESULTS AND DISCUSSIONS

According to the data collected through classroom observations and interviews, we initially find some reasons leading the changing, adjusting or maintaining of practice teacher's teaching conceptions. Those include the personality and learning willingness, the teaching circumstance practice teachers engaged in and the teaching resources they could utilize, as well as their professional competencies and future goals settled. It is impossible for us to report all 6 cases in detail, but an outline of our discoveries for the developmental process categories and underlying reasons about practice teachers' teaching conceptions is given in table 1. We will describe in detail the transcripts and interpretations of 3 representative cases about their conception development processes which include the forms of maintaining and changing/adjusting.

Category	Maintaining (A_1, A_2, A_4)			Changing/Adjusting (A_3, A_5, A_6)		
Case	A_1	A_2	A_4	A_3	A_5	A_6
Reason	Mentor's attitudes Teaching circumstance	Teaching circumstance Professional competencies Mentor's attitudes	Mentor's attitudes	Mentor's attitudes Learning willingness	Personality Mentor's attitudes	Professional competencies

Table 1. Preliminary categories of the development processes of practice teachers' teaching conceptions observed

Case of A_2

A_2 took a paid placement of teaching practice in a form like "co-mentoring" (Jaworski & Watson, 1994) which is different from the form of traditional internship. So, she could observe varied teaching of mentors, interact with students and actually teach. Because A_2 's mentor (M_2) designed the mentoring strategies carefully and the teaching resources matched with A_2 's teaching needs sufficiently, so, A_2 had more opportunities to centralize the learning focus in teaching and to teach. At the same time, A_2 possessed more resources in teaching practice, and she could learn the teaching styles and skills of varied mentors. In the situation, A_2 can reveal her thoughts and conceptions about teaching fully. We found that A_2 maintained her teaching conceptions during the 2 teaching observations.

A_2 had much more own autonomy in teaching, and could plan the teaching contents. In the first visit, we found that A_2 emphasized the use of some activities or examples related with real life to develop the mathematical conceptions, which connected her

own thoughts with the suggestions of mentors. She indicated that “I integrate some mentors’ thoughts in teaching which are useful for me about my own conceptions, in other words, I reorganize those to be my own teaching activities”. At the same time, she said that “my professional competencies are still insufficient, so I must refer to the teaching contents of other teachers”. In the second visit, we found that A_2 tried to integrate other teachers’ suggestions in her teaching designs much more. We found that teaching circumstance, professional competencies and mentor’s attitudes caused the maintaining of A_2 ’s teaching conceptions.

Case of A_5

A_5 ’s mentor (M_5) wished her not to copy her materials when A_5 was preparing her teaching materials. We found that although A_5 designed materials by herself, however, she would first observe M_5 ’s teaching before she actually taught, so, A_5 almost copied M_5 ’s material contents to design her teaching contents. In the first visit, we found that A_5 ’s teaching about mathematical conceptions was not problematic, and we thought that it was related with observing the same topic of M_5 ’s another class before teaching. At the same time, M_5 would discuss the teaching contents with A_5 before her teaching, so, there was less difference between M_5 and A_5 ’s teaching contents. So, we viewed A_5 ’s teaching as ‘copying’ M_5 ’s teaching in the period.

In the second visit, M_5 changed her mentoring strategies to give A_5 more freedom and let A_5 teach directly without observing M_5 ’s teaching. So, we found that A_5 changed much more in the period. A_5 seemly could ask students some questions to lead their thoughts actively after M_5 guided A_5 how to question and lead students’ conception development. A_5 gradually trended to connect her own teaching conceptions with M_5 ’s. Because A_5 ’s personality, she accepted the opinions of other persons easily, so, she had fewer self-opinions in learning to teach. So, A_5 copied M_5 ’s teaching conceptions in the first period, although M_5 asked A_5 not to teach according to her materials fully, however, M_5 didn’t give many suggestions. But, in the second period, M_5 asked A_5 to prepare her teaching materials by herself, so, A_5 began to connect her own thoughts with M_5 ’s methods, not only to copy M_5 ’s materials. We thought that A_5 had already changed from the copying to trying to add her own designs and thoughts of teaching. At the same time, she changed her teaching conceptions from listening to students’ questions passively to questioning students actively.

Case of A_6

Although A_6 would observe M_6 ’s teaching before her own teaching, M_6 gave A_6 much more freedom and hoped that A_6 could try to teach and learn how to teach first, and then discussed with her in pre and post-lessons. In the first visit, we found that A_6 designed her teaching materials according to M_6 ’s materials, and then taught some lessons using those materials. But she didn’t observe all M_6 ’s lessons of the same topics which she would teach. During the A_6 ’s teaching, she would choose the contents of teaching materials, examples and exercises in terms of the discrepancies of students’ competencies. Because A_6 emphasized the interactions with students and

their learning very much, so she would change the designs of materials and the order of conception developments, and she could intend to approach with students through many 'affective vocabularies' and represented the mathematical symbols using colloquial words. We thought that those are A_6 's original teaching conceptions.

We observed that M_6 intervened in A_6 's teaching when she was teaching, and most of the interventions occurred when A_6 had difficulty in developing students' mathematics conceptions or solving mathematics or pedagogical questions. When A_6 felt that she was lacking of teaching competency and her teaching made students confused, she would begin to think whether her designs and materials of teaching were inappropriate or not. In the second visit, we found that A_6 paid much attention to the suggestions of M_6 in the designs of teaching contents, and she copied M_6 's materials to design her own materials massively. When A_6 's teaching could not match with the expectation of M_6 , it would yield enormous pressures for her to adjust her teaching methods and conceptions. We thought that A_6 had already adjusted from her original ideas to accepting M_6 's suggestions fully because of her deficiency of professional knowledge. At the same time, she adjusted her teaching conceptions from using many affective vocabularies to close students to reducing those words according to M_6 's suggestions.

RESEARCH CONCLUSIONS AND IMPLICATIONS

Designing the contents of teacher education programs appropriately

We know that the traditional teacher education programs in Taiwan focused on the development of theories, and fewer programs were connected with real teaching. And teacher educators could perhaps not understand student teachers' conceptions about teaching fully, and didn't improve varied opportunities to motivate student teachers' learning of teaching and to correct their learning attitudes and willingness. In the study, we found that teaching contexts in COP and the accumulation of practice experiences could influence the developments of the cases' teaching conceptions significantly. So, we think that teacher educators could use the exemplar teaching critical incidents as practice materials to connect with pedagogical theories, to stimulate student teachers' thoughts and to challenge their perspectives. But student teachers still need to possess solid mathematics knowledge except having correct learning attitudes, high learning willingness and accumulated practice experiences. Therefore, teacher educators should think how to reinforce the mathematics knowledge of student teachers, to modify their learning attitudes, to enhance their learning willingness, and to assist them to collect practical experiences in teacher education programs.

Emphasizing the responsibility and strategies of mentoring

We found that mentors' attitudes and mentoring strategies play important roles in the transformation of practice teachers' teaching conceptions. Mentors must comprehend the sublime responsibilities in developing their professional competencies. Practice teachers engaging in the different contexts of COP will be influenced by the varied learning forms of COP and mentoring perspectives of mentors. Mentors can adopt the varied mentoring strategies to improve their professional development by asking

practice teachers to observe their own mentors' teaching, discussing some critical teaching incidents after lessons with them, and letting practice teachers actually teach some topics. For example, first, mentors may invite other mentors to observe practice teachers' teaching in their own classes, and then analysis practice teachers' teaching each other. Secondly, mentors could encourage practice teachers to observe other mentors or mathematics teachers' teaching, and then share and interchange substantial ideas of and about teaching mathematics with them. Thirdly, mentors could arrange practice teachers to teach other mentors or mathematics teachers' classes, and then involve other school teachers in a form of co-mentoring. Finally, mentors could invite university tutors to engage in mentoring jointly.

Providing appropriate teaching resources of schools

In the study, we identified the reasons about the transformative situations of practice teachers' teaching conceptions were that what teaching circumstances they engaged in and whether they had enough applicable teaching resources or not. For example, A_2 who possesses more abundant teaching resources is relatively active in learning to teach; A_6 increases her own teaching experiences through teaching observations and discussion with other practice teachers; M_5 's experience of being as a practice teacher influences her mentoring strategies and methods to mentor A_5 ; and because of lots of administrative works in the practice school and lack of the opportunities of teaching, A_1 's learning of teaching was influenced. We also find that the amount of teaching will influence the transformative forms of their teaching knowledge. For example, A_3 , A_5 and A_6 have more opportunities to correct their contents and methods of teaching because of constant accumulations of teaching experiences, and to compare and implement varied pedagogical methods. So, their changes of teaching conceptions are more significant during two periods. Thus, practice teachers who have exposed many pedagogical theories from teacher education institutes must possess much more teaching opportunities to accumulate their practice teaching experiences.

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