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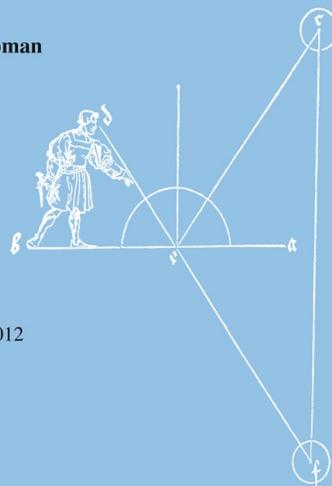
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Abstract This paper presents the findings of a study that examined the preparation and teaching practice of ten teachers of grades 7–12 from the Shandong province in China. This study revealed that a multi-dimensional training system has been developed to help the teachers gradually build up their knowledge base for teaching. The findings of this study indicated that the prospective teacher education emphasized a deep understanding of advanced mathematics, while the teacher professional development provided meaningful and effective ongoing activities for the enhancement of teaching skills. The teacher professional development appears to be an essential supplement to the prospective teacher education for improving teachers' performance and developing teaching expertise.

Keywords Prospective teacher education · Teacher professional development · Teaching research activities · Open class · Teaching competition · Collective lesson plan preparation · One-on-one mentoring · Teacher collaboration

Introduction

The People's Republic of China was founded in 1949. Following the new government's policy, schools of education were separated from comprehensive universities and merged with normal universities in the early 1950s (Yang et al. 2008). Over the years, except for the special period of the Cultural Revolution between 1966 and 1976 when education was halted, China established an efficient teacher education system to prepare grades K-12 teachers. Teacher training institutions included four-year normal universities and teachers' colleges, three-year teacher training colleges, and secondary normal schools (Teacher Education in China (I) 2004). In the past three decades, four-year normal universities and

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normal colleges trained high school teachers, three-year teachers' colleges trained middle school teachers, and secondary normal schools trained elementary school teachers.

For many years, the teacher education curriculum in China has remained uniform and stable, with the Ministry of Education setting general curriculum guidelines for all teacher training schools to follow (Mak 1999; Zhou and Reed 2005). Recently, local governments have had more liberty to modify the curriculum set by the Ministry of Education to meet their local needs; however, they tend to keep their teacher education programs in close adherence to the guidelines (Mak 1999). As a result, teacher preparation programs have similar practices throughout the country.

The foundation of the teacher education curriculum in China followed the former Soviet Union's model, emphasizing subject knowledge courses (Yang et al. 2008). According to Hayhoe (1998), in China, "all parts of the higher education system have tended to be narrowly focused and professionally oriented under the influence of the Soviet Union's model" (p. 79). College courses include subject content knowledge and educational studies that consist of pedagogy, psychology, and subject-teaching methods. Under the Ministry of Education guidelines, the educational courses have increased twofold since the 1980s (Yang et al. 2008). Besides college coursework, students in teacher education institutions participate in a teaching internship ranging from four to six weeks.

In addition to prospective teacher education, teacher professional development (teacher PD) plays an essential role in teacher education in China. Chinese educators have realized that teacher PD is critical to teachers' practice (Zhong and Wu 2004). Teachers are provided school-based teacher PD such as "mentored teaching, basic skill training, modern technology training, short-term training in holidays, classroom observations, and collective lesson planning." (Zhang and Sang 2001) Teacher educators in China believe that teacher PD should integrate learning and practice; teachers learn from practice, and practice enhances learning.

Some of the teacher PD activities include classroom observations and follow-up observation discussions, as well as teaching research, which involves a variety of activities, such as open classes, project-based research, and workshop-based activities. In some schools, teachers who teach the same subject form a teaching research group (TRG), and teachers who teach the same subject at the same grade level form a teaching preparing group (TPG). Both TRGs and TPGs are organized to study teaching, to solve practical problems faced by teachers, and to improve teaching effectiveness. Since 1949, China has established a teaching research network formed by a province-level Teaching Research Office, a county-level Teaching Research Office, and a school-level TRG and TPG (Yang et al. 2008).

Because of the centralized education system, the practice of teacher preparation is similar across China. The setting of this study is Shandong, a typical Chinese province, which follows the central government's education policy and regulations for teacher preparation practice and would be a good representative of China. The purpose of this study was to examine the preparation of ten grades 7–12 mathematics teachers from the Shandong province in China.

The study was motivated by both national, Chinese, and international considerations. In recent years, the educational system in China has been undergoing significant changes, including the relaxation of the nationwide standards and the introduction of more local input. This study aimed at highlighting aspects of the teacher preparation in China that could be affected by these changes in educational system. On the international level, comparison tests have shown that there exist differences in mathematics performance between Chinese and US students with the Chinese students outperforming their counterparts. Recently, a number of researchers have begun to study why these differences occur and have attributed the variations in mathematics achievement to three main areas:

cultural variations (Andreescu et al. 2008; Cai 2003; Hess et al. 1987), curriculum (Askey 1999; Newton 2007; Schmidt et al. 2002), and mathematics teachers' content knowledge (Stevenson and Stigler 1992; Ma 1999; Schmidt et al. 2010). However, there is little research to date that has closely examined the preparation of secondary teachers in China. This study addresses this gap in the literature by providing a closer look at the preparation and practice of secondary mathematics teachers in a typical province of China.

Methodology

A qualitative research design was employed in this study in order to understand the nature of ten grades 7–12 mathematics teacher preparation in China and in particular, in the Shandong province. With the help of an administrator working in the educational system in the Shandong province of China, ten grades 7–12 mathematics teachers were recruited to participate in this study from schools located in different cities in the Shandong province. Nine of the participants graduated from normal universities, earning a bachelor degree in mathematics and one is a middle school teacher who attended a three-year college and received a diploma in mathematics. In China, there are three levels of professional ranks among middle and high school teachers—second level, first level, and high level. For example, a beginning teacher after working for 3 years is entitled to apply for promotion to the second level; after holding the rank of second level for 5 years, a teacher could apply for promotion to the rank of first level; finally, after holding the rank of first level for 5 years, a teacher could apply for promotion to the rank of high level. Teaching performance, awards, honors received, and evaluations are factored in as to whether or not a teacher has earned a promotion. Out of the ten participants, seven teachers hold the rank of high level, while three teachers have earned the rank of first level. Table 1 provides descriptive information of the participants.

As shown in Table 1, ten participants taught at ten different urban schools located in eight cities within the Shandong province of China. Eight of the teachers were males and two were females, all of them with 11–24 years of teaching experience.

Telephone interviews were conducted through Skype—an Internet telephone program. The interviews were tape-recorded with each interview lasting one to 2 h. Follow-up phone calls and e-mails were used for clarification and additional information. The recording of

Table 1 Participant Information

Name	Gender	Age	Education (highest degree earned)	Grades taught	Location	Professional rank	Years of teaching
Yun	Female	43	Bachelor	10–12	Jinan	High level	20
Hui	Male	42	Bachelor	10–12	Jinan	High level	19
Long	Male	36	Bachelor	10–12	Jining	First level	12
Yong	Male	41	Bachelor	10–12	Weifang	High level	18
Gang	Male	33	Bachelor	10–12	Huantai	First level	11
Xi	Male	45	Bachelor	10–12	Rizhao	High level	24
Hua	Male	43	Bachelor	6–9	Jinan	High level	21
Yan	Female	39	3-year college diploma	6–9	Laizhou	High level	17
Di	Male	32	Bachelor	7–9	Dezhou	First level	11
Cheng	Male	40	Bachelor	7–9	Binzhou	High level	17

Transcript-06
Teacher Di

Question: How are teaching-research activities conducted at your school?

Response:

The professional study I just mentioned is held every other Wednesday. Our
PS
teaching-research group has activities every Friday. The teaching-research
TRP
group is the mathematics-teaching group I mentioned before. For example, we
do collective lesson preparation; we do classroom observations; we do
CLP CO
research projects. The project "Participation and Discovery" is done by our
RP
mathematics teaching-research group. Every Friday, we brought up the
problem that emerged when applying the theory of participation and discovery
ATT
in our own teaching, to discuss at the meeting.

Fig. 1 An example of line-by-line coding

each interview was transcribed into English. In addition to interviewing each participant, a review of documents was used as a supplemental method of data collection. This method is commonly used to supplement other data-collecting methods, such as in-depth interviews (Hesse-Biber and Leavy 2005; Silverman 2001). The documents included books and articles about mathematics education in China, the mathematics teacher preparation curricula of two normal universities, the school websites of the participants, and online archived materials. These documents not only helped validate the participants' descriptions of their college preparation and teacher PD, but also served to capture the general background information of each school setting.

An inductive analysis approach was utilized, since the intention of this study was to generate findings and themes directly from the data. The methods used included constant comparison (Corbin and Strauss 2008), matrices (Miles and Huberman 1994), coding (Boyatzis 1998; Miles and Huberman 1994; Patton 2002), and graphs (Miles and Huberman 1994). Line-by-line coding was conducted for each interview (see Fig. 1). After coding each interview line-by-line, a long start list of codes was developed.

Following the line-by-line coding, "master code(s)" (Miles and Huberman 1994, p. 58) were created based on the research questions and the protocol. In the next step, subcodes were created by classifying the codes from the start list into the master codes. For example, the subcode PT-TI indicates teaching internship as a subcode of prospective teacher education. Following this coding scheme, about one hundred codes were established. The codes were examined by constantly comparing and reflecting on the data and were reduced to four categories for teacher PD, three categories for prospective teacher education, and three categories for self-directed learning. For example, noting that several participants related some professional development activities to teaching research activities, other interviews were checked and this confirmed that many professional development activities indeed were regarded as teaching research activities (Fig. 2).

Results

The results of the study indicated that the teachers in this study learned to teach through prospective teacher education, teacher PD, and self-directed learning. Prospective teacher

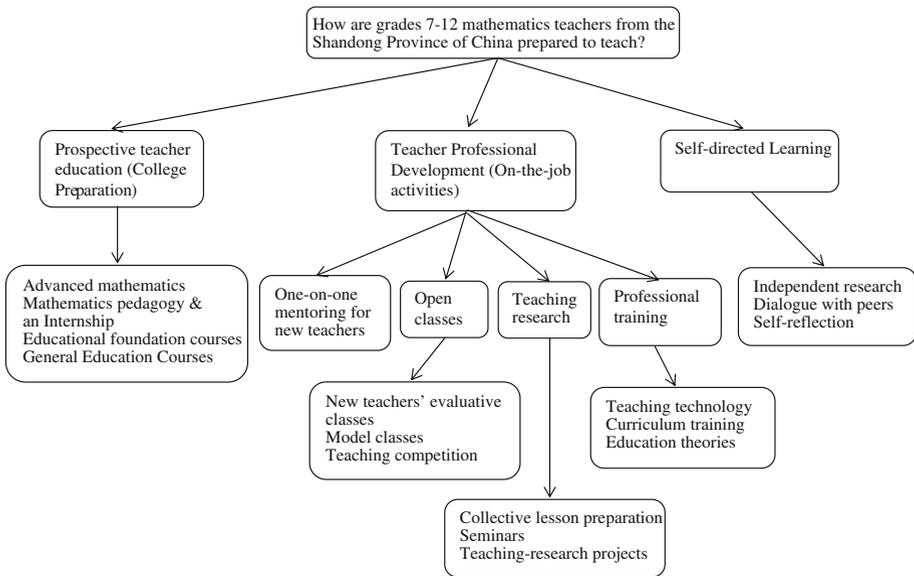


Fig. 2 Outline of the finding

education included coursework in advanced mathematics, mathematics pedagogy, educational foundation courses (e.g., educational psychology, philosophy), and general education courses. Teacher PD included on-the-job activities such as one-on-one mentoring for new teachers, classroom observations, teaching research, and professional training. Every teacher interviewed in the study pointed out the importance of teacher PD in helping them improve their teaching. Self-directed learning included independent research via the Internet, professional readings, dialogue with peers, and self-reflection. The figure below represents the outline of the findings. A description of each component of both the formal and informal learning processes is described next.

Prospective teacher education

The teachers received their prospective teacher education at normal universities. Since China has a centralized education system, teacher preparation programs have similar curricula. Although these teachers graduated from different normal universities, they had completed similar coursework in their prospective teacher education. In general, the courses taken in college include advanced mathematics, mathematics pedagogy, teaching internship, education foundation courses (e.g., educational psychology, theoretical pedagogy, philosophy), and general education courses.

For example, Yun (see Table 1) listed the core mathematics courses she took at the normal university as follows: mathematical analysis, advanced algebra, real analysis, complex analysis, differential equation, analytic geometry (three dimensional), abstract algebra, physics, and topology. Long listed similar courses he had taken at his university and commented, “The mathematics courses we learned in college are very helpful for us.” He explained that sometimes it was difficult to explain problems to his students using high

school mathematics. For example, one of his students asked: Why is the area of a circle πr^2 ? He recognized that the problem could not be answered with the knowledge they had learned; however, he did not want to tell the student “we can’t answer this question now. Just remember it.” Instead, he remembered what he learned in a mathematical analysis course about Riemann Sums and used that knowledge to craft an answer to the student’s question. The mathematics learned in college made it possible for him to explain the answer in a clear and interesting way. In general, all the teachers interviewed had noted that their understanding of mathematics allowed them to teach in a more effective manner.

During their prospective teacher education at college, the teachers in the study received pedagogical training through a pedagogy course which integrated theory with teaching practice. Other pedagogy-related courses taken by the teachers included education, psychology, teaching internship, putonghua (standard Chinese), calligraphy, handwriting on the blackboard, electronic technology for teaching, education theories.

Teacher professional development

For teachers in this study, teacher PD consists of on-the-job activities. After graduating from normal universities or colleges, new teachers start teaching and begin the process of teacher PD. Teacher PD is conducted through a variety of activities, such as one-on-one mentoring for new teachers, open classes, teaching research, and professional training. A detail description of these professional development activities is provided below.

One-on-one mentoring

This is the most basic professional development activity for new teachers at every school. All the teachers interviewed mentioned one-on-one mentoring as one type of teacher PD. Once a new teacher is hired, the new teacher is required by the school to pair up with an experienced teacher who teaches at the same grade level, forming a one-on-one group. According to Gang:

After they (the new teachers) enter our school, the veteran teachers pair up with the new teachers. The relationship is like master and apprentice. The veteran teacher will follow up with instructions from planning to actual teaching.

Yan explained, “Experienced teachers are required to observe the new teacher’s class at least once a week, and give feedback.” Some schools require experienced teachers to observe 50–60 new teachers’ classes each semester, and new teachers can observe the experienced teachers’ class as often as they wish.

The teachers in the study pointed out how one-on-one training benefit new teachers. For example, Xi noted:

Classroom observation and face-to-face discussion have huge effects on new teachers. They shorten the time of new teachers’ improvement. I can see that new teachers have been improving every week, every month.

In addition, Yong pointed out:

Textbooks don’t have enough content. A lot of materials taught in class are added by teachers based on their experience. New teachers don’t have this additional content. They have to learn it from the experienced teachers.

Open class

Another important component of teacher PD is the open class. An open class is a class that is open for observation to a group of teachers. Cheng identified the open class as “more like the process of conducting research.” He recognized that an open class was “a learning process” and “it benefited teaching.” All the teachers interviewed had taught numerous open classes and realized that they learned about teaching by observing open classes. Before an open class, all the teachers in the same teaching research group (teaching the same grade) help prepare for it. From designing a lesson plan to actually teaching, all the teachers contribute their ideas. Discussions, trial teaching, and observations take place among the teachers before an open class. As Di realized, “Indeed, the process of preparing an [open] lesson is the process of improving [teaching].”

The participants often mentioned that their schools require all the teachers to give open classes at least once each semester. Gang saw the benefits of the open class and stated:

Open classes can motivate me, inspire me, and force me to best use the textbook, to design the best examples, and to stimulate students' learning interests. Through the problems exposed in the open classes and the comments from other teachers, I can keep improving myself and move forward.

Teaching research

Teaching research is another vehicle for teacher PD. It is conducted by the teachers through collective lesson plan preparation, teaching research projects, and seminars. Each of the three activities is described next.

Collective lesson preparation Collective lesson preparation is the most basic teaching research activity conducted by a teaching research group at every school. It is a typical example of peer collaboration and is an important activity for teacher PD in China. Teachers who teach the same grade form a teaching research group, which meets once a week for the purpose of discussing lesson plans. As noted by Cheng, “Usually we meet to prepare next week's lessons. We discuss how to teach, which parts need special attention when teaching, what problems students are expected to have.”

All the teachers in the study agreed that collective lesson preparation benefited their teaching. Yun said, “When I was young, I benefited from collective lesson preparation. When you just start teaching, if you depend only on your own ability and not learn from other teachers, you would not improve very fast.” Seeing it as a way of teacher collaboration, Yong pointed out, “It is teamwork. The outcome comes from collective intelligence. If you do it yourself, you would not improve as fast, especially for young teachers.”

Teaching research projects Teachers are encouraged by their school administration to conduct teaching research projects. At many schools, doing teaching research projects is a requirement. Every teacher interviewed for this study had conducted one or more teaching research projects. These teachers recognized that the projects had a positive impact on their teaching. For example, Di had conducted a teaching research project called *Participation and Discovery*. The project involved students in constructing knowledge in multiple formats. He realized that conducting this project helped him grow and become a better teacher.

Some other teaching research projects conducted by the participants included research and implementation of high school mathematics discovery learning, students' cooperative study, fostering students' creativity, active learning, high school mathematics applications, students' self-assessment, writing problems for national provincial, or city exams, teaching models, teaching problem-solving—theory and practice, and students' group work.

Seminars Schools in the Shandong province hold regular seminars (i.e., research presentations) presented by expert teachers from other schools and also by teachers in their own schools. In addition to on-site presentations, several teachers mentioned that watching Internet videos of experts teaching were another means of conducting seminars.

Every teacher interviewed recognized the important impact of seminars on teaching. Hui stated, "By attending teaching seminars, I reflect on my own teaching. That significantly improved my professional ability and teaching." Hua realized that "teaching seminars can spread new teaching and learning ideas and methods, keep teachers open-minded about teaching approaches, and update their knowledge of teaching and learning."

Professional training

Professional training is offered by the school, district, city, and province and consists of activities such as teaching technology training, curriculum training, and studying education theories and ideas.

Teaching technology training Modern technologies and software, such as Power Point, Sketchpad, and Flash, are commonly used in teaching in the Shandong province. Every teacher in this study mentioned that they incorporated the use of software in their mathematics lesson plans. Technology training workshops for teachers, designed to enrich teachers' professional skills, are organized by both the school and the district teaching authorities. For example, Gang stated, "Zhibo city offers us computer training at beginner, intermediate, and advanced levels. I have finished the advanced level. They even test mathematics teachers' Sketchpad skills by exams."

Curriculum training In the last 10 years, China has been carrying out a curriculum reform. In order to implement the new curriculum effectively, the authorities provide training for teachers. Every teacher in this study mentioned that, since 2008, authorities in the Shandong province held two-week new curriculum training for all of the teachers in the province. According to Long, the curriculum training was conducted by experts who are renowned nationwide. They helped teachers understand the new curriculum as a whole and also learn effective approaches to handle a variety of classroom situations.

Education theories and ideas Schools offer many opportunities for teachers to learn the most recent educational theories and ideas. At Di's school, every teacher is required to participate in biweekly professional studies. Professional studies include watching videos, listening to experts' reports, studying education theories, exchanging ideas, and discussing newly acquired knowledge. The schools also ask outstanding teachers to give talks introducing new methods of teaching. After such talks, the teachers in the audience engage in discussions on the presented ideas.

Hua indicated that his school sent teachers to schools in other cities to study. Additionally, schools provide their leading teachers with opportunities to attend professional

workshops run by university professors and national experts. The period of training is from 1 month to 3 months. Many of the teachers in this study were chosen to participate in this type of training and felt that the training they received enhanced their knowledge base for teaching and changed their perspective and vision of teaching.

Self-directed learning

Teachers in the study were also engaged in self-directed learning involving activities that can be categorized as independent research, dialogue with peers, and self-reflection. For example, most of the participants in this study have published teaching research papers and books. Cheng shared his experience, "I do a lot of teaching research. Every day, I write something and it accumulates day by day. I have published many papers." Cheng also noted that he went through a similar learning process when preparing either an open class or a seminar talk, because both activities require conducting research and consulting with other people.

The teachers in this study reported that they had gained their knowledge through continuously reading research papers and books in education, conducting research projects, preparing for open classes, and reflecting on their own teaching. They mentioned that they write after-class reflections about their teaching, which is an activity required by many schools. According to Gang, "After a lesson, I summarize the part of my teaching I need to improve and how to change the lesson plan to reflect the desired improvement." These teachers found that writing after-class reflections helped them identify the problems in their teaching and look for solutions by incorporating ideas from other teachers. In Di's case, writing teaching reflections helped him discover interesting teaching research topics. He pointed out that when I went back to read my teaching reflections, I found that some very good teaching research topics came out of my own discoveries. These discoveries can be written up as very good and publishable research papers.

Discussion

Prospective teacher education

Based on the descriptions of the teachers in this study, their prospective teacher education included many advanced mathematics courses, such as mathematical analysis, advanced algebra, analytic geometry (three dimensional), ordinary differential equations, complex analysis, real analysis, and abstract algebra. The prospective teacher education equipped the teachers with a deep understanding of mathematics. Shulman (1987) pointed out that subject matter knowledge is one of the critical components of effective teaching. The data of this study revealed that a profound knowledge of mathematics affected the teachers' ability to teach in several ways: (1) they understood the curriculum and how it fits into what needs to be taught at a particular grade level; (2) it helped them explain abstract mathematical ideas in an easy and simple way; (3) it increased their problem-solving ability and helped them recognize different methods for teaching and solving a problem; and (4) it helped them build esteem and respect as teachers by their students.

Although prospective teacher education equipped the teachers with a deep understanding of mathematics and some pedagogical knowledge, they pointed out that knowledge learned in college was not sufficient to make them effective teachers. As Yun said, "four-year college knowledge is not enough to teach effectively." Other teachers

mentioned that effective teaching needs a wide range of knowledge beyond college learning, such as the knowledge acquired through continuous teacher PD.

Teacher professional development

When first starting to teach, a new teacher begins the journey of teacher PD, that is, a continuous process of learning about teaching. Teacher PD plays an important role in teachers' professional growth. It continues throughout a teacher's teaching career until a teacher leaves the profession. Oriented toward teaching practice, teacher PD involves a variety of activities such as one-on-one mentoring for new teachers, open classes, collective lesson preparation, seminars, teaching research projects, and professional training. These activities are often carried out through classroom observations and peer collaboration and are interwoven tightly, making the system of teacher PD function in a highly effective way.

One-on-one mentoring for new teachers makes full use of experienced teachers' expertise. Mutual classroom observations and after-class discussions help new teachers acquire the knowledge, skills, and ability to reflect on ways to improve teaching. They learn how to write a lesson plan, how, when, and what to ask students during a class, how to teach different types of classes, such as review classes, new content classes, or exam-analyzing classes, as well as what teaching approaches may be appropriate for a certain class. Through one-on-one mentoring, experienced teachers pass on their knowledge of teaching to the next generation of teachers. The accumulation of this teaching wisdom is a valuable asset to teachers from generation to generation. In addition, one-on-one mentoring provides support for new teachers to develop and flourish in their profession. New teachers learn from and are supported by experienced teachers. They do not need to go through a lonely journey like many of their American peers, who barely have opportunities to learn from experienced teachers (Han 2008; US Department of Education 1997).

The open class is another component of teacher PD. Each open class has to go through a careful preparation process, which involved repeated modifications and collaboration with other teachers. Open classes employ teachers' collective wisdom to create lessons of the highest quality. Every participating teacher benefits from the process. Furthermore, a teacher's performance in presenting an open class is closely related to his/her professional development such as promotion, honors, and better training opportunities. As a result, teachers are motivated to work hard on preparing and presenting a better open class.

Teaching research, a critical part of teacher PD, is conducted through collective lesson preparation, seminars, and research projects. All the teachers in this study realized that they benefited from collective lesson preparation in terms of sharing effective teaching ideas and helpful resources, learning from each other, and finding ways to improve their teaching.

Seminars are held to provide teachers with expertise, teaching ideas, and techniques, to show them how to conduct teaching research and to keep them updated with new educational theories and ideas. All the teachers in this study reported that seminars provided opportunities for them to learn from experts and broaden their scope of teaching knowledge.

Teaching research projects incorporate learning theories into teaching. They not only provide opportunities for teachers to learn through the process but also allow teachers to share their research results publicly with other teachers. The teachers in this study published research papers and presented open classes to demonstrate how they incorporate a certain theory or idea into their classroom teaching.

Self-directed learning

In addition to prospective teacher education and teacher PD, self-directed learning also helped the teachers in this study acquire knowledge for teaching. Self-directed learning is a learning process in which an individual sets the learning goals, locates materials and resources, decides what to learn, and how to learn it (Knowles 1975). For example, the results of this study found that the teachers were engaged in self-directed learning when preparing for an open class or a seminar talk or when conducting teaching research projects. In addition, the teachers read a tremendous number of reference books and related articles, collected related materials from the Internet, and talked to other teachers or experts. Additionally, most of the teachers mentioned that after-class reflection helped improve their teaching. For example, after teaching a class, Gang wrote after-class reflections in the back of his lesson plan as a reference for future teaching.

Final remarks

The results of the study indicated that the teachers' knowledge base for teaching is constructed through prospective teacher education that emphasized a deep understanding of advanced mathematics, a meaningful and effective teacher PD system for practicing teachers that supplements their prospective teacher education and enhances their pedagogical effectiveness, and a strong commitment to self-directed learning that provides continuous improvement to their teaching.

The prospective teacher education provided a strong mathematical foundation that the teachers in the study were able to draw upon in order to help their students fully understand the mathematics being taught and clarify mathematical misunderstandings held by the students. It also allowed the teachers to see the "big ideas" across the mathematics curriculum and provide that understanding to their students. The teacher PD activities provided a supportive environment where new teachers learned from an exchange of ideas and encouraged teachers to learn from each other and to conduct inquiry and research in order to improve their teaching.

By looking at the whole process of mathematics teacher education in the Shandong province, this study uncovered that secondary mathematics teachers in China acquire a strong content understanding of mathematics while attending prospective teacher education programs and continue to learn the craft of teaching by participating in a sophisticated and comprehensive ongoing set of professional development activities as practicing teachers. This study highlighted and brought to center stage important aspects of the teacher education process in China which can affect and be affected by the recent changes in the educational system in China. The extent to which some of the teacher PD activities in China either make sense or can be incorporated into the PD activities of secondary mathematics teachers in US or other countries needs further research.

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