



Investigating Characteristics of Award-Winning Grades 7-12 Mathematics Teachers from the Shandong Province in China

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International comparison studies indicate that Chinese students outperform many of their peers in mathematics tests and competitions. Since teaching is a major determinant in students' learning gains, it is reasonable to hypothesize that this learning gap is associated with their teachers. The development of teaching expertise has not received sufficient attention in research investigations in mathematics education. By examining a group of award-winning grades 7-12 mathematics teachers from the Shandong province in China, this study identified the characteristics of these teachers and illuminated how their expertise had been developed over the years. The findings provide an insightful view of effective teaching practices in China from an international perspective.

Keywords: award-winning teachers; teaching competition; teaching research; teacher collaboration; systematic lesson preparation.

International comparison studies indicate that Chinese students outperform many of their peers from other countries in mathematics tests and competitions (Siegler & Mu, 2008; Stevenson et al., 1990; Stevenson, Chen, & Lee, 1993). Researchers attributed the learning gap in mathematics to three factors: cultural variations (Andreescu, Gallian, Kane, & Mertz, 2008; Cai, 2003; Hess, Chang, & McDevitt, 1987), curriculum (Askey, 1999; Newton, 2007; Schmidt, Houang, & Cogan, 2002), and mathematics teachers' content knowledge (Ma, 1999; Stevenson & Stigler, 1992). However, little has been done to examine the teaching practices and characteristics of mathematics teachers in China.

Over the last decades, research indicates that teachers have a greater effect on students' learning than many other factors such as student ethnicity, family income, schools, and class size (Nye, Konstantopoulos, &

Hedges, 2004; Rivkin, Hanushek, & Kain, 2005; Sanders & Rivers, 1996). Rivkin and his colleagues (2005) gathered data on more than 10 million Texas students in grades K-12 during the period of 1990-2002. When they compared the performance of similar students in the same schools who had different teachers, they found that students' achievements were significantly affected by their teachers' quality.

A question arises: What defines a teacher's quality? In other words, what are the characteristics of an effective teacher? According to The Center for Public Education (2005), research provides evidence showing that effectiveness of teaching is positively related to the following factors: 1) a teacher's profound content knowledge (Daring-Hammond, 1999; Ma, 1999; Rivkin, Hanushek, & Kain, 2005), 2) a teacher's years of teaching experience (Fetler, 2001; Greenwald, Hedges, & Laine,

1996), 3) a teacher's formal training and credentials (Darling-Hammond, 1999; Felter, 1999; Fuller & Alexander's, 2004), 4) a teacher's higher academic ability (Ferguson & Ladd 1996; Greenwald, Hedges, & Laine, 1996).

It is commonly agreed that a teacher's preparation influences how he or she teaches. In the U.S, mathematics teacher preparation relies on university or college classes and several months of student teaching in classrooms. Having little support from the school and the society after completing their college degree, many new teachers struggle alone to survive in the educational system (Han, 2008). In most American schools, teachers work alone for most of the time, spend most of their school time teaching, and have little time to collaborate with other teachers (Stigler & Hiebert, 1999) or engage in teaching-related research. Teaching-related research and teacher collaboration are missing components in U.S. teacher training.

A number of studies have documented that teacher collaboration helps improve students' achievement significantly (Darling-Hammond, 1995, 1997; Garet & Porter, 2001; Hiebert, Gallimore, & Stigler, 2002; Stigler & Hiebert, 1999). Stigler and Hiebert (1999) found that "compared with other countries, the United States clearly lacks a system for developing professional knowledge and for giving teachers the opportunity to learn about teaching" (p. 12). Furthermore, they argue that there exists a teaching gap between our expectations for good teaching and the lack of resources and opportunities for improvements of teachers' teaching. This teaching gap threatens to have increasingly more serious implications in the future. To date, teacher collaboration is still a local phenomenon at American schools. However, the growing consensus among educators regarding the benefits of teacher collaboration raises hopes of establishing a school system where teacher collaboration will serve as a tool for improving teaching and learning. To this end, it is beneficial to study the mathematics teachers' practices in countries, such as China, where teacher collaboration plays an important role.

The purpose of this study is to examine the characteristics of a group of award-winning grades 7-12 mathematics teachers from the Shandong province in China and to investigate the characteristics of these teachers. The findings provide a global perspective of effective teaching practices and the characteristics of the high-quality middle and high school mathematics teachers in China from a different cultural perspective.

Background of the Study

According to Zhou and Reed (2005), "The Chinese central government is the most powerful authority in the governance structure of teacher education. Teacher education institutions have less authority and they always implement central government policies

passively" (p. 211). As a result, teacher education and practices are very similar across all schools in China. An established model of teacher education has been well developed in the past thirty years. The Chinese model of teacher education has two major components: pre-service training and in-service training. The responsibilities of pre-service training and in-service training are clearly divided. Pre-service training educates future teachers emphasizing mathematics content knowledge, while in-service training improves the teaching performance of on-the-job teachers focusing on their teaching practice. However, both components work together as a whole and form a coherent system of teacher education. Pre-service training is conducted at normal universities, colleges or normal schools. Four-year normal colleges or universities train high school teachers; three-year normal colleges train middle-school teachers; and normal schools train elementary and kindergarten teachers. In-service training is classified as continuing education that is designed to help teachers expand, improve, and update their knowledge and skills (Mei, 2008). Educational Institutes at province level focus on high school teacher training; Educational Institutes at city level focus on middle school teacher training; Teachers' Enrichment Schools at county or district level focus on kindergarten and elementary teacher training (Huang, 2003).

Because in-service training in China is closely examined in this research, we introduce an outline of this system below:

In-service training or continuing education of teachers has been actively promoted to improve the quality of teachers in China. The teachers in every school in China are organized into teaching research groups (TRG) and teaching preparation groups (TPG). A TRG is a group of teachers who teach the same subject (e.g. mathematics teachers). A TPG is a group of teachers who teach the same subject at the same grade level (e.g. 10th grade mathematics teachers). The purpose of these groups is to study and improve the quality of teaching by sharing teaching ideas and resources, discussing teaching content, collectively preparing lesson plans, and observing and evaluating lessons together. Teachers work collaboratively in TRG and TPG to conduct research that focuses on improving teaching. During the last 50 years, the teaching research network has been formed by members of the province-level Teaching Research Office, the county-level Teaching Research Office, and the school-level TRG and TPG. The goal of the teaching research network is to organize a variety of in-service training activities (Yang et al., 2008). Teaching research is the most important component of in-service training.

In China, there is an established system in place that recognizes expert mathematics teachers. Teachers who received such recognition usually go through a series of teaching competitions at the school, district, city, province, and national level. The winner of the school

level teaching competition moves to the district level competition; the winner of district level competition moves to the city level competition; the winner of city level competition moves to the province level competition; and the winner of the province level competition moves to the national level competition.

Teaching in the teaching competitions is conducted in front of a classroom of students assigned by the authority. The topic of each teaching competition is different. Participants are given several topics to prepare in advance. The final topic of each competition is drawn by the participants from these topics on the day before the competition. Winning the competitions is recognized as an important accomplishment for a teacher. The following is a sample of the teaching competition rubric used to judge the competition.

- The purpose of the lesson: the depth and breadth of content knowledge, skill, ethics and learning psychology.
- Material selections: choosing texts aligned with instructional purposes, emphasizing basics and innovation, knowledge and application, and balance between texts and instruction. Teachers must select sections, examples, and exercises based on students' needs.
- Instructional process: reflecting on the teaching and learning process that is revealed by providing students with appropriate background material, encouraging students to engage in the learning process, cultivating students' creativity and innovative thinking, and responding appropriately to students' feedback during classroom instruction.
- Instructional tools: the use of appropriate modern instructional technology, including charts, models, slides, videos, and computers.
- Instructional methodology: designing lessons appropriate to students' cognitive ability and psychological developmental stage, implementing accurate instructional principles and learning theories, being flexible to appropriately apply instructional strategies, and emphasizing development of effective study skills.
- Basic dispositions of teachers, as reflected in
 - a. Language: accurate, comprehensible, simple, and powerful.
 - b. Handwriting: accurate, neat, and well-balanced on the blackboards.
 - c. Observation: responsive to students' expressions and abilities.
 - d. Listening: listening to, and answering students' questions.
 - e. Manners: responsible, kind, and persuasive.(National Teaching Competition for Middle and High School Novice Mathematics Teachers, Scoring rubric, Draft).

Research Questions

This study intends to answer the following research questions:

- What are the characteristics of the award-winning grades 7-12 mathematics teachers in the Shandong Province of China?
- How had their teaching expertise been developed?

Our answers provide an in-depth view into effective teaching practices in China, which, we hope, will be useful for educators in their own teaching practices and also will be of interest when considering mathematics teacher preparation in the U.S.

Method

Guided by the research questions, this study used a qualitative research method to examine the characteristics of award-winning grades 7-12 mathematics teachers in China, and provided an insightful view of mathematical teaching and teacher preparation in a different cultural contexts. We used in-depth interviews as the major data collecting method, with document review as a supplemental method for data collection. Criterion sampling and intensity sampling were utilized to choose teacher samples. Criterion sampling requires the selection of all cases that meet some predetermined criteria (Miles & Huberman, 1994; Patton, 2002). A selected sample, based on the criteria can provide rich information related to the research inquiry (Liamputtong, 2009). Guided by the research question, we selected participants who met the following three criteria:

- 1) The participant must be a mathematics teacher teaching middle school or high school level mathematics.
- 2) He/she has been awarded recognition for his/her achievements in teaching mathematics as noted by the different levels: school, district, city, province, or nation.
- 3) His/her students have achieved high average scores in college entrance exams or in high school entrance exams among the classes at the same grade level.

Selections based on the criteria followed the intensity sampling strategy. Intensity sampling seeks samples with rich information related to the investigated phenomenon. According to Miles, intensity sampling is associated with "information-rich cases that manifest the phenomenon intensely, but not extremely" (Miles & Huberman, 1994, p. 28).

Typical case sampling was used to select the province of Shandong. Typical case sampling is described as a technique for highlighting what is normal or typical (Patton, 2002). Following this guideline, we wanted to choose a province that represented a common case among all the provinces in China. As stated previously, China has a centralized education system which determines that every province has similar educational practices. Shandong represents a typical Chinese province with a big population. It is located on the east coast of the north

China plain, and has a population of 95.79 million, ranked the second largest province of China. The GDP (Gross domestic product) of Shandong was ranked number 9 among 23 provinces (National Bureau of Statistics of the People’s Republic of China, 2005). Convenience was another reason to choose Shandong as the sample province, since we happened to have a contact person who could help recruit the participants in Shandong.

In order to identify the qualified participants, we used a key informant who was an administrator working in the educational system in the Shandong province of China. A key informant is someone who is specifically knowledgeable about the inquiry setting and can serve to identify who and what is typical for the research (Patton, 2002). Based on the description of sample selection criteria, the key informant chose the qualified teachers from schools located in different cities in Shandong and contacted them to ask if they were willing to participate in this research. After he confirmed with them about their participation, he emailed the first author the list of all of the teachers with corresponding contact telephone

numbers. The first author contacted these ten teachers through phone calls. On the phone, the first author explained the purpose of this study, confirmed their willingness to participate in the study, and exchanged e-mail addresses with the participants for future correspondence. Below is a table of participant information and the detailed background about each participant.

All the names appearing in the table are pseudonyms. Nine participants graduated from Normal Universities, earning a bachelor degree in mathematics. One participant, who taught middle school, attended a three-year college and received a diploma in mathematics. In China, there are three levels of professional ranks in middle school and high school. From low to high, the ranks are second level, first level, and high level. After working for three years, a novice teacher is entitled to apply for promotion to the second level; after holding the second level for five years, a teacher could apply for promotion to the first level; after holding the first level for five years,

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

a teacher could apply for promotion to the high level. The time period allows a teacher to apply for promotion while teaching performance, awards and honors received and evaluation comments are recorded so a decision can be made as to whether a teacher has earned a promotion. Seven of the teachers in this study hold the highest professional rank; three of the teachers hold the intermediate level rank.

Telephone interviews were conducted through Skype – an internet telephone device. Telephone interviewing is widely and productively used in qualitative research (Sturges & Hanrahan, 2004). Comparing the transcripts of the face-to-face interviews to those of telephone interviews, Sturges and Hanrahan (2004) found that there were no significant differences in the interviews. Their finding was also supported by Stephens' study (2007). According to these studies, telephone interviews indeed are as effective as face-to-face interviews when being utilized to conduct qualitative research.

The in-depth, semi-structured (Patton, 2002) interview protocol was designed following a literature review of research in this area, a pilot study, and the collection of research documentation relevant to the research question. The interview protocol included 49 questions in total, covering topics such as personal background information, college preparation, classroom practice and philosophy, and in-service training. Twenty-nine questions were asked about in-service training. The interview questions were designed to capture the common characteristics of these award-winning teachers and the development of their expertise over the years of their teaching practice. Each interview lasted about one hour. Follow-up phone calls and emails were made to verify some descriptions and comments with the participants. The interviews were tape-recorded and the recording of each interview was transcribed into English. The collected data was analyzed using an inductive analysis approach which generates findings and themes directly from the data. Several analysis strategies and methods were employed in the process, including constant comparison (Corbin & Strass, 2008), matrices (Miles & Huberman, 1994), coding (Boyatzis, 1998; Miles & Huberman, 1994; Patton, 2002), and making graphs (Miles & Huberman, 1994).

Line-by-line coding was conducted for each interview. Following the process, a long list of codes was produced. The codes were examined by constantly comparing and reflecting on the data, and were reduced to 4 categories that correlated to the research question – passion for mathematics and teaching, participation in teaching research, application of teaching technology, and expansion of professional opportunities.

Results

This study revealed that in-service training is connected with teachers' merit assessment and promotion

in China. As a result, teachers are motivated to participate in a variety of in-service training activities. Schools support teachers involved in in-service training by offering time and financial incentives. In this study, we found that the teachers in the Shandong province of China teach about two classes each day. Those who teach grades 6 – 11, teach 10 classes per week; those who teach grade 12, teach 12 classes each week. After classroom teaching, the teachers use their time to prepare lesson plans, to observe other teachers' classes, to collaborate with other teachers, and to conduct teaching research.

Schools encourage teachers to conduct research that addresses teaching, with the aim of improving the teaching of mathematics; they regularly have teaching-research seminars and teaching-research-achievement report meetings. Additionally, every school maintains a one-on-one mentoring system that pairs new teachers with experienced teachers who teach the same subject. There are many mutual classroom observations and after-class discussions between the new teacher and the experienced mentor. One-on-one mentoring helps new teachers grow fast and become expert teachers.

Analysis of the data identified the following characteristics: 1) these award-winning teachers are passionate about mathematics and enjoy sharing that passion through teaching; 2) they actively participate in teaching research through application of teaching research in the classroom, collaboration with peers, and systematic lesson preparation; 3) they apply technology to teaching; 4) they engage in teaching research in order to expand their professional opportunities.

Passion for Mathematics and Enjoyment in Sharing that Passion through Teaching

One of the characteristics of these teachers is their passion for mathematics and enjoyment in sharing that passion through teaching. Cheng, for example, loved mathematics since he was very young. He said:

When I was a student in the middle school, I already liked math and was ranked 4th in the mathematics competition held in our city, Binzhou. I think math is a very interesting subject, involving fun and intelligent activities.

Likewise, Yong expressed his passion for mathematics, "I have loved studying mathematics since I was kid." When asked if he likes teaching mathematics, Yong answered:

Yes, very much! Teaching mathematics is fun. Being with students is fun. Other people may think mathematics is a very boring subject, but, when you succeed making your students enjoy learning it, you have a real feeling of achievement.

Hua tries to let his students "appreciate the unique charm only the subject of mathematics can have." But, he also realized, "As a teacher, it is not enough to

have a passion for teaching and a love for students. The passion and love need to be transformed into effectively instructing students and motivating them to learn mathematics." Hua told his students, "Mathematics is not only for smart students to learn, it is a subject that makes everyone who learns it smarter." In his classroom, he promotes the creation of "an educational environment that stimulates students' interest, inspires students' thinking, and develops students' talents." He wants his students "to learn when exploring and to explore when learning."

Long described his passion for mathematics and teaching in this way:

Standing in front of the classroom with students' watching me, I forget everything but the teaching and the feeling of happiness it gives me. I enjoy teaching very much. Some people made fun of me and said: "you are happier standing in front of a class than if someone gave you a hundred thousand bucks." I love teaching from the bottom of my heart.

All the other teachers in this study shared similar sentiments about mathematics and the teaching of the subject.

Active Participation in Teaching Research

Every teacher in the study actively participated in teaching research through the application of teaching research in the classroom, collaboration with peers, and systematic lesson preparation.

Application of Teaching Research in the Classroom. Each teacher either joined a team for a teaching-research project or conducted an individual research project that applied a certain learning theory to classroom teaching. They found that the process of engaging in teaching research had significant impact on their teaching. For example, Di played an important role in the research project, "Participation and Discovery", that investigated models of teaching that would engage students in the teaching and learning process. He found that his involvement in the project had a significant impact on his teaching. Di explained,

The result of this project has been widely promoted as an exemplary teaching model in the Shandong province. In order to help implement our teaching model of "Participation and Discovery", that shows how to motivate students to participate in the teaching and learning process and how to lead students to discover [knowledge] on their own, we gave many open classes to demonstrate the model. All the open classes were taught by me.

Having participated in the research project "Mathematics Methodology", Gang realized that it is crucial for a mathematics teacher to foster students' interest in learning and to create an environment that

encourages students to explore and discover mathematics rules or principles. One of Cheng's research projects was a study that promotes the idea of students' collaborating with each other while learning mathematics. Cheng divided his class into small groups. Whenever there was a disagreement about a certain problem in class, he asked students to discuss the problem in groups. After each small group reached an agreement, the problem was discussed further by the entire class. Cheng noted:

Collaborative learning meets students' psychological needs. Students want to build up friendships with their peers and collaborative studies offer a platform for students to learn from each other, while building friendships. They learn mathematics and also learn to be tolerant and appreciate others.

Yong participated in the research project about Students' Self-assessment. Part of this project asked students to write exams and test and grade themselves. At first, several very good students joined the teachers in creating exams and learned the procedure of writing an exam. After that, these students wrote an exam on their own to test other students. Then, each class was divided into small groups, with each group taking turns to write a set of exams for the class. Yong found that, "once students are involved in giving exams, they master the content tested very well. If they don't understand the material clearly, they are not able to write an exam."

Each teacher had actively taken part in at least one research project. Yan mentioned that she and her colleagues finished the project, "Effective Integration of Information Technology and Mathematics Teaching & Learning", and have been doing another one, "Discovering Learning", which will be completed in 2012. Hui listed two research projects he was involved in: "Writing the National, Provincial, or City Exam Problems" and "Teaching Models". In Hua's case, he participated in four research projects.

Eight out of ten participants in this study published numerous teaching research papers or books. In the most extreme case, through his teaching research, Cheng published more than 500 articles in newspapers and more than 100 papers in the twenty national popular journals.

All the teachers in this study recognized that active involvement in teaching-research projects helps them become better teachers and teach in more effective ways.

Collaboration with Peers. All the teachers in this study collaborated with other teachers, especially with teachers who taught the same grade. The collaboration is conducted through collective lesson preparation, classroom observations, and after-observation discussions. Every teacher recognized the important role that collaborating with other teachers

played in their teaching. For example, Yong noted that his achievements in teaching are due in large part to his collaboration with other teachers and gave credit to the teachers in his teaching research group for his winning prizes at teaching competitions. Before each teaching competition, Yong discussed how he was going to teach his topics with all the teachers in his teaching research group. He regarded himself as only an actor presenting the research result produced by all the teachers in his teaching research group. Similarly, Yun pointed out, "The lesson presented in a teaching competition is not prepared only by the teacher who attends the competition, but is a joint work and the outcome of collective intelligence."

All the participants are actively involved in collective lesson preparation, class observations, and after-observation discussions and most of them lead weekly meetings of collective lesson preparation. They all agreed that the weekly meetings helped produce well-designed teaching plans and promoted more effective teaching. Xi noted that in their meetings they discuss problems arising in their teaching, share good teaching methods, and exchange teaching experiences; that is, "we learn from each other."

New teachers learn from veteran teachers, and vice versa. Every participant was paired with a new teacher, forming a one-on-one mentoring group. Classroom observations and after-observation discussions are regularly held between new teachers and veteran teachers. Some of the teachers noted that they also learn something from new teachers through this process. Yun pointed out, "Young teachers also have their own ways and ideas worth learning from." Xi noted, "We learn from each other and improve together." Cheng described it in this way, "...New teachers have their own strengths. For example, they are usually good at new teaching technologies and bring some fresh ideas from college. I should say that we help each other to improve teaching."

Systematic Lesson Preparation. Every teacher in this study carefully prepares each lesson before class and has developed his or her own preparation system that has been formed over the years. In addition to actively participating in collective lesson preparation with their teaching research group, they prepare lessons for their own classes because they face different students. They believe that lesson plans developed by their teaching research group should be adjusted to meet the needs of the particular students in each class. Over the years, each of the teachers has established their own system of lesson plan preparation. For example, Yan described how she prepared her lessons:

I have a 4-5-6 lesson preparation theory that I have shared with other teachers:

- 4 indicates four factors: textbook, classroom, pedagogy, and students. This means carefully study the textbook, consider students' learning abilities in the

classroom, choose the most appropriate teaching methods, and differentiate among students who have different levels of talent.

- 5 indicates five studies: study classroom timing issues, study important and difficult knowledge pieces, study resources from the internet, study the design of homework problems, study the assessment that should diagnose how much students learned from the class and the homework problems. That way, I know which piece of knowledge is not mastered by students and know that I need to make up for it.
- 6 indicates six details: carefully design pedagogy, carefully instruct students how to study, carefully design the structure of a lesson, carefully design homework, carefully handle the grading results, carefully write the after-class reflection

Yun summarized her way of lesson preparation:

- At first, if the textbook has some changes, I need to know what changes were made and what the new curriculum standards are, including the requirement of this section in the college entrance exams. So, the first thing I do is to get to know the textbook well.
- Second, I decide what knowledge I should present to students in this class.
- Third, I think how to present the knowledge. For example, should I raise a question and ask students to discuss the possible answers? Of course, I have to consider the students, too. The advanced class I taught in the past is different from the common class I am teaching now. In my current class, 1/3 of the students are good students, 2/3 of them are average. When I ask a question, I would consider how many students know how to solve it, and realize that some students may need hints to solve the problem. Some students may not be able to solve it at all. I try to make most students master as much of the material as possible by further explanations or through class discussion. So, I need to prepare a lesson by going through the textbook, taking the students into consideration, and thinking about the pedagogy.

Summarizing the process of all the teachers' lesson preparation, we see the following common themes: they carefully study the five factors including textbooks and references, students, pedagogical approaches, questions raised in class, and example and homework

problems. Some teachers also mentioned writing after-teaching reflections, which are then used as a reference for their future lesson preparation.

Application of Technology to Teaching

Every teacher in this study makes use of teaching technology in their classes. As Xi reported, “We utilize educational software and have a projector in the classroom. Voice and pictures can be sent out through multimedia. Our class has a very rich content. I often use PowerPoint and Sketchpad in my teaching.” Gang pointed out that using multimedia can increase the capacity of a lesson. For example, he stated, “in review classes, I often use PowerPoint to avoid spending too much time writing on the blackboard.” Di mentioned that he used Flash and PowerPoint in his class. He said, “When we teach geometry, we would make use of technology to help students understand change of shapes better”. Finally, Hua described the way he uses teaching technology as follows: “I utilize educational technology when teaching certain contents of mathematics such as three dimensional geometry and change of shapes. I often use Sketchpad and Z+Z Superpad”. Based on the description of all the teachers, Sketchpad, Z+Z SuperSketchpad, Power Point, and Flash are technology tools they often use in teaching their classes.

Six participants mentioned that as a teaching aid, technology should be used appropriately, taking into account the content of the course. Hui said, “I use it whenever I need to. It depends on the context of teaching and learning. For example, I use educational software to show geometrical pictures, students’ work, and after-exam analysis, etc.” Long explained:

I often utilize mathematics teaching software for my class. Based on the content of a lesson, I use Super Sketchpad (developed by a teacher, Jingzhong Zhang), Sketchpad, and Power Point. Super Sketchpad is a very good software with many good functions. Each type of software has advantages and disadvantages. Usually, I combine them to prepare my lesson plans.

Cheng pointed out:

We use it when it is appropriate. When it helps students understand [the content] in depth and helps them overcome the difficulty of a piece of knowledge, we need to use it. We also need to consider when and where to use it. It should not be used through the entire class time. If a class is just a show of educational technology, students would feel visually tired. This is not good for learning.

Two teachers in this study also emphasized that writing on the blackboard cannot be replaced by technology. For example, Hua used Sketchpad, Z+Z SuperPad to teach classes involving three-dimensional

geometry or the changing of shapes. However, he does not use technology for every class. He explained:

The characteristics of mathematics determine that teachers’ classroom actions, such as writing on the blackboard, drawing graphs, and exploring together with their students, are precious in classroom teaching. By conducting these teaching activities, teachers set examples of the ways of learning mathematics for their students.

Engagement in Teaching Research in order to Expand Professional Opportunities

The teachers in this study take an active role in teaching research. When actively conducting teaching-research projects, most of them are the leaders of their teaching research group, and they published numerous research papers sharing their research results with other teachers. Although all teachers are required to do teaching research, the teachers in this study took a leading role in teaching research and went beyond minimum expectations. Di enjoys the professional gains he receives from engaging in teaching research. He shared his experience:

In the beginning, I really didn’t want to do [teaching research]. Gradually, I started receiving benefits from doing teaching research. Our school offers some awards to encourage us to do teaching research. For example, our school selects the subject leaders or gives honor titles in consideration with performance in teaching research. On the one hand, I must meet the school’s requirements; on the other hand, I have tasted the sweet. In fact, research really has helped me improve my teaching and in recent years I have conducted teaching research without being pushed by our school.

Yong realized that teaching research often involves collaborating with other teachers and the outcome generated by “collective intelligence” facilitated his “learning faster and saving time”. He also pointed out that he was motivated to take an active part in teaching research, because “your achievement in teaching research is useful for your future honor and promotion. If you don’t have any research papers, you will have a problem being promoted to a higher professional rank.” Similarly, Gang stated, “I must do teaching research. That helps me understand the textbooks at a deeper level and prepare better lessons. On the other hand, we also need to conduct teaching research for promotion to a higher professional rank.”

Cheng has published more than 100 research papers in national magazines and about 500 articles in newspapers. He also edited many teaching reference books. This is how he explained his reasons for

conduction teaching research:

By doing teaching research, I published my research results. My teaching has improved constantly, and my achievement has been recognized by society. This recognition encourages me to continue conducting teaching research... Teaching research helps me teach more effectively in class and improve student's grades. When I see my students' grades are increasing and students are developing in a good direction, I am very happy.

Like Cheng, Long published many papers and several reference books. He is a columnist for the magazine *数学天地* (*Mathematics Field*). When asked what motivated him to do teaching research, he responded, "I am a kind of person who always wants to do my best. Teaching research can update my knowledge. I wouldn't know the developing trends of education without active involvement in teaching research." He also made the comment, "The process of research is hard, but also sweet." Long noted a very close relationship between teaching research and teaching: "Teaching research helps improve teaching, while teaching gives me ideas for teaching research." He gave an example from his own experience:

... when I taught probability, I gave an example in class: "how many ways are there to put 3 different balls into 2 different boxes, each box having at least one ball?" (This problem is easy to solve; to reach the goal that each box has at least one ball, we must put two different balls into the same box and put another ball into the other box. So the number of ways is $C_3^2 C_1^1 \cdot A_2^2$). After the class, a very smart student came to me and asked "how many ways are there if 100 different balls are put into 10 different boxes and each box has at least one ball?" This is a reasonable question. However, once I thought about it, my head was about to explode, because reaching the goal of at least one ball in each box, dividing 100 different balls into 10 groups is very complicated. I did not solve this problem! I had thought for one week, still I could not solve it. I realized that this is a valuable question. I made this problem more general: to put N different balls in m different boxes, each box having at least one ball ($m \leq N$)? After research, I reached this result:

$$\text{There are } \sum_{k=1}^n C_n^k (-1)^{n-k} k^N$$

This result led me to study the problem further with the given condition: "put N balls into m boxes. Both boxes and balls can be chosen to be the same or different, and a box can be either empty or not." By studying this problem, I became familiar with the second mathematical deduction method and some related probability formulas, and got many interesting conclusions.

Good performance in teaching research may create more development opportunities. Six of the teachers in this study had been selected to attend professional training workshops organized by the authorities. For example, Hui participated in a leading teacher training at the national level; Yun attended a leading teacher training at the province level; Xi and Yan went to a leading teacher training in Weifang city and Yantai city, respectively. These kind of professional training opportunities are only provided to the limited number of teachers who have high achievement in teaching and teaching research. Three teachers mentioned that they competed for "Qilu Famous Teacher" (齐鲁名师) selection. As one of the winners, Yun described:

The "Qilu Famous Teacher" selection is also a professional training. After we are selected, we have to study and do some work for a period of time and then our title "Qilu Famous Teacher" is finalized. If you are selected, you are given 60,000 Chinese Yuan for your studying expenses. You can go to a university to study. We went to China East Normal University, where some people were active in education research. There, expert researchers present talks on how to conduct teaching research while teaching. We also visited some schools that were doing well in research and learned how they conduct research and what they have done. I had been in the United States and visited their high schools and elementary schools. Several groups were sent to The United States to observe their classrooms and learned what education reform they have completed. During the study period, we are required to hand in a reflection paper that states what we learned through the study.

The better teaching research a teacher conducts, the more professional opportunities are provided to him/her. All the teachers interviewed have benefited from taking an active role in teaching research. They noted that teaching research leads to a professional life that makes them happier. The positive effect motivates them to keep going. As Long explained, "Once you've gained a good reputation, you want to maintain it by improving your

teaching even more. This is a really a healthy cycle. When you are good, you want to be better.”

Conclusion and Discussion

One theme emerging from this study is that in-service training played a significant role in building these teachers' teaching expertise. Teaching research, as an important component of in-service training, was conducted continuously throughout the teachers' entire professional life. Teaching research is accomplished by activities such as collective lesson preparation, teaching research projects, and seminar participation. All the teachers in this study participated actively in teaching research and either had published numerous research papers in journals or had presented their research in the professional conferences in order to share their findings with other teachers. They were motivated to conduct teaching research, because it helped them improve their teaching and provided them with a greater sense of profession satisfaction and with professional advancement.

This study indicates that the schools in China encourage teachers to conduct teaching research and reward those who perform well in teaching research by giving honors or early promotion, and more opportunities for professional development and advancement. These incentives reinforce the teachers' motivation of active involvement in teaching research. The award-winning teachers in this study consider teaching research a vehicle that helps them become more effective teachers and expands their professional opportunities. The process of teaching research benefits, not only the teachers who engage in it, but also the teaching profession as a whole. The sharing nature of teaching research offers a channel for teachers to preserve and pass on their good insights and experience to the present and future teachers.

According to the teachers interviewed, teaching research is often conducted through teacher collaboration. Teaching research and teacher collaboration are integrated activities. Teacher collaboration can motivate teachers to think reflectively about their teaching. When teachers work together and have regular discussions, they must engage in reflective thinking. Discussion itself is a process of teachers' collective reflection, which helps generate effective instructional strategies. Teaching research and teacher collaboration reinforce each other and play a powerful role in improving teaching effectiveness. Both are fundamental for an in-service training system geared toward improving teaching.

This study is limited in that it provides an insight into the characteristics and teaching practices of ten award-winning mathematics teachers from the Shandong province of China. As stated earlier, Shandong is a typical Chinese province and China possesses a centralized educational system. Still, a large scale research may be conducted to verify whether the results of this study are common throughout China. In addition, possible

implementations of our findings in the U.S. system are worth further investigation. Additional extensive studies in this direction would be beneficial to the field of teacher education.

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