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THE EFFECTS OF PLATFORM SYSTEM ON TEACHERS' MATHEMATICAL PEDAGOGICAL CONTENT KNOWLEDGE FOR REMEDIAL INSTRUCTION

Yuan-Horng Lin[1]
Jinn-Min Yang[1]
Shih-Hsuan Wei[1]

[1] Department of Mathematics Education, National Taichung University of Education, Taiwan

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Abstract: *The purpose of this study was to establish an internet platform system for the need of teachers to carry out mathematics remedial instruction. This study was action research and the platform was developed based on the cooperation of scholars and primary school teachers. In the two-years longitudinal study, team of scholars from universities provided primary school teachers with theoretical guidance and effective strategies for remedial mathematics instruction. These guidance and strategies included worked examples of life mathematics, children's schema of learning mathematics and instructional strategies for mathematics reading comprehension. In addition, this platform also helped primary school teachers assess mathematics achievement and detect mathematics misconceptions of students. Totally all the 227 primary school teachers participated in two workshops each semester and one conference. All the above information and materials of guidance and strategies were accessed in the platform system. Those primary school teachers adopt these remedial instruction strategies within their mathematics classroom, especially for those students of low mathematics achievement. Moreover, they must do reflections about their own mathematics remedial instruction. The assessment analysis concluded that the platform could help teachers with remedial instruction and improve students' mathematics achievement. Results showed that teachers' mathematical pedagogical content knowledge has been improved. Therefore, the mathematics achievement of students made progress. Based on the feedback from teachers and findings of the results, some suggestions and recommendations were discussed for future research.*

Keywords: *Mathematics Instruction, Mathematical Pedagogical Content Knowledge, Knowledge Management Platform, Remedial Instruction*

Introduction

Promotion of teachers' mathematical pedagogical content knowledge (MPCK) to accomplish remedial instruction was an important issue (Ball, Thames, & Phelps, 2008; Harris, & Sass, 2007). Teachers' MPCK could help students' make progress in mathematics achievement (Darling-Hammond, 2000; Kukla-Acevedo, 2009). The purpose of the current study was to establish an internet platform system for the need of teachers to carry out mathematics remedial instruction. Owing to the useful utilities and feasibility of internet, this study adopted action research methodology and investigated the effects of the platform system to help primary teachers' improve their MPCK. The MPCK was guidance and strategies for teachers' mathematics instruction which included worked examples of life mathematics, children's schema of learning mathematics and instructional strategies for mathematics reading comprehension. In addition, this platform also helped primary school teachers assess mathematics achievement and detect mathematics misconceptions of students. All the resources on the platform system and professional activities were scheduled according to theoretical foundation of learning psychology of mathematics.

Literature Review

Mathematical knowledge

The National Council for Accreditation of Teacher Education (NCATE) (2008) made the following statement: "Teacher candidates are expected to meet professional standards for the subjects that they plan to teach. Information from the program review process should be used to address the elements on content knowledge, professional and pedagogical knowledge and skills, pedagogical content knowledge, and student learning" (NCATE, 2008, p.21-22).

A growing body of research has argued that subject matter knowledge is necessary for effective teaching. Numerous studies have showed that a greater of student achievement growth is being assigned to a teacher with deeper content knowledge, and the evidence is most persuasive in mathematics (Begle, 1972; Betts, Zau, & Rice, 2003; Darling-Hammond, 2000; Kukla-Acevedo, 2009; Harris & Sass, 2007; Hill, Rowan, & Ball, 2005; Monk, 1994; Monk & King, 1994; Tchoshanov, 2008; Wenglinsky, 2000). As described in the earlier literatures, findings on teachers' degrees completed (Darling-Hammond, 2000; Goldhaber & Brewer, 2000) and the number of coursework took (Monk, 1994; Rowan et al., 1997) were positively associated with student achievement, and the evidence was most persuasive in mathematics. It suggested that teachers' knowledge of mathematics have a strong influence on student achievement when that knowledge was directly relevant to their teaching. Owens (2008) interviewed 68 teachers to investigate the impact of classroom connectivity of 1,128 students completed pre- and post-surveys on their attitude toward mathematics. The study found that students tent to score higher in algebra tests when their teachers knew more about how students were thinking about mathematics. Similarly, Hayden (2011) interviewed 10 teachers at one middle school in Florida to examine the perception of mathematics teachers' motivation. The finding suggested that teacher motivation affected students' mathematics achievement. Additionally, all participant teachers believed motivation played an important role in their student' academic performance and some teachers were dissatisfied that students' academic performance was associated to their salary increases. In a related research, Marat (2005) investigated the relationship between students' self-confidence and their academic achievement. Students' science and mathematics gains were higher when they received positive feedback on their performance. Giving students effective feedback requires not only the teacher's knowledge on a subject and the students, but also a deep understanding of the subject using various ways to explain a single concept. In sum, the results of the above findings all indicated the importance of mathematical knowledge in effective mathematics instruction.

With regard to improve mathematics instruction, numbers of educational researchers focused on different types of mathematical knowledge on what K-12 teachers should possess, and several mathematical organizations offered specific recommendations on what K-12 teachers should know (Hartman, 2010).

Mathematical Knowledge for Teaching (MKT)

The interest in knowledge for teaching initially gained prominent attention when Shulman (1987) introduced several dimensions of teacher knowledge as follows: (a) content knowledge, (b) general pedagogical knowledge, (c) curriculum knowledge, (d) pedagogical content knowledge, (e) knowledge of learners and their characteristics, (f) knowledge of educational contexts, and (g) knowledge of educational ends, purposes, and values. Coinciding with Shulman's (1987) central dimensions of subject matter and pedagogical content knowledge, Ball and her colleagues proposed a special kind of knowledge required only for teaching mathematics "Mathematical knowledge for teaching (MKT)" (Ball, Thames, & Phelps, 2008; Hill, Rowan, & Ball, 2005).

It represented the proficient knowledge of mathematics needed by teachers and asserted that such knowledge was different from that needed by other occupations. Rather than describing what teachers need to know based on what they need to teach or the curriculum they use, MKT makes an explicit focus on the work of teachers. The work of the teachers includes how they interpret the work of students and analyse errors students make. Further, the teacher must be able to choose the best model example, or representation for a given situation, and to utilize other model examples and representations as needed. (Hill, Rowan, & Ball, 2005, p.386). Ball, Thames, and Phelps (2008) proposed a diagram as a refinement to Shulman's categories. (See Figure 1)

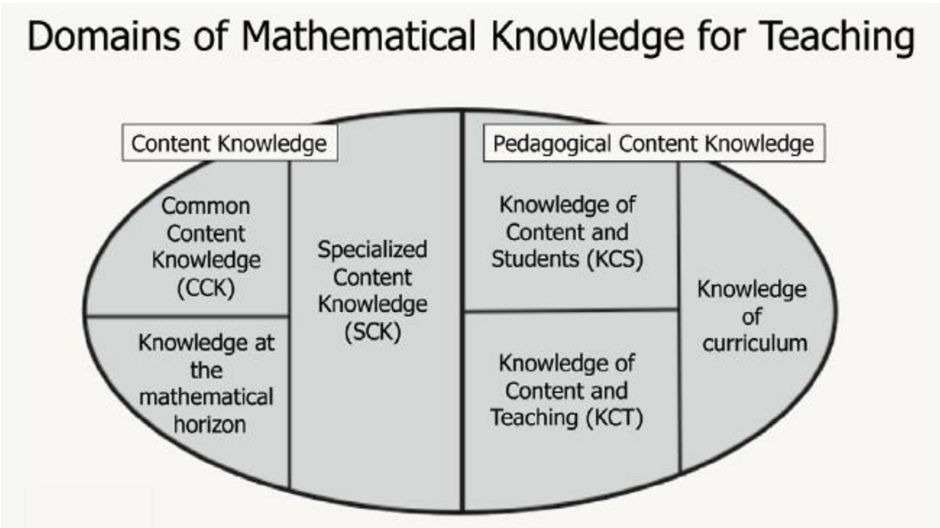

Figure 1: Domain Map for Mathematical Knowledge for Teaching

Adapted from "Content Knowledge for Teaching," by Ball, Thames, and Phelps, 2008, p. 403.

While the knowledge of the subject matter of mathematics refers to one's depth and breadth of understanding of mathematical concepts and processes, a teacher's pedagogical content knowledge is directly related to his or her ways of taking subject matter and making it accessible to students. Pedagogical content knowledge is not found in isolation as teachers must know how to use content knowledge in the tasks of teaching.

Organizations, such as the National Council of Teachers of Mathematics (2003), have long written about teacher knowledge consistent with ideas found within Ball et al.'s (2008) emerging theory: Teachers need several different kinds of mathematical knowledge—knowledge about the whole domain; deep, flexible knowledge about curriculum goals and about the important ideas that are central to their grade level; knowledge about the challenges students are likely to encounter in learning these ideas; knowledge about how the ideas can be represented to teach them effectively; and knowledge about how students' understanding can be assessed (NCTM, 2000, p. 17).

Teaching and learning mathematics

During the past decades, there has been a considerable attention given to the fact that students need a better understanding of mathematics and science for the immense technological changes world. In their study, Romberg and Carpenter provided and refined in a great detail of research on teaching and learning of mathematics (Romberg & Carpenter, 1986). In responding to the needs of reform mathematics education, they suggested "we need to rethink the content of the school mathematics program, but in doing so we need to take into account implications derive from two disciplines: how students learn mathematics and how teacher teach mathematics" (Romberg & Carpenter, 1986, p. 850).

Furthermore, the study provided schools and teachers with recommendations and guidelines on how the reforms have an influence on student academic learning. First of all, it is necessary to create the shift in epistemology about learning mathematics with understanding in varied and reflective ways. The emphasis underlying this aspect is for students become mathematically literate. "The epistemological shift involves moving from judging student learning in terms of mastery of concepts and procedures to making judgments about student understanding of the concepts and procedures and their ability to mathematics problem situations" (Romberg, 2000, p. 6).

Secondly, it is necessary to reform schooling that follows from the shift in epistemology. A set of implications about schooling practices has been associated with mathematical literacy. For example, regardless of socio-economic class, gender and ethnicity that students need to have the opportunity to learn important mathematics in order to be ready in tomorrow's world; students need to develop certain skills to engage the new technological environment; "critical learning of mathematics by students occurs as a consequence of building on prior knowledge via purposeful engagement in activities and by discourse with other students and teaching in classrooms" (Romberg, 2000, p. 7).

Thirdly, it is necessary to document the appropriate evidence related to the schooling practices. In fact, educational leaders, policymakers and professors are the entities that formed the visions for school mathematics. However, not every entity or person agrees with the current goal of mathematical literacy; some believes that the traditional mathematics course works reasonably well. As Romberg (2000) suggested that "in conventional classrooms the mathematical content is cut off from practical situations and taught in isolation from other subjects, … instruction is grounded in textbooks and delivered in a teacher-centered environment" (Romberg, 2000, p. 8). Instead of reforming the schooling practices, it is needed to document the impact of any vision of school mathematics that has been implemented.

Finally, it is necessary to assess students' mathematical literacy to meet the needs of today's society. Mathematics literacy does not imply detailed knowledge of higher mathematics such as calculus, abstract algebra, topology, etc., but of what mathematics is capable of achieving (Ojose, 2011). In other words, a new assessment system is needed. Further, this new system should enhance "what concepts and procedures students know with understanding and how students can use such knowledge to mathematize a variety of non-routine problem situation" (Romberg, 2000, p. 8).

ICT and TPACK

Nowadays, information and communication technology (ICT) has brought us new ways to access and process knowledge in every field. ICT is also transforming pedagogy by providing new ways to engage learners. Expert teachers are those who can bring knowledge of subject matter and technology together. The process of integrating ICT in education is rarely a simple task. Teachers play a key role in the teaching-learning context. Different teachers use different tools to improve their teaching skills. Accordingly, teachers from all disciplines have widely integrated ICT to improve their teaching styles (Liu 2011; Donnelly, McGarr & O'Reilly 2011). ICT plays an important role in promoting new instructional methods for teaching and learning (Khan, 2014).

Shulman (1986) also addressed the theoretical framework pedagogical content knowledge (PCK) as the notion of the transformation of the subject matter for teaching. It has been shown that teachers' PCK could be highly associated with teaching effectiveness and efficiency (Shulman, 1987). Mishra and Koehler (2006) defined another framework technological pedagogical content knowledge (TPCK) which was built on PCK to include technological knowledge as situated within content and pedagogical knowledge in a specific context and introduced to the educational research field for understanding of what teacher knowledge required for effective technology integration. The TPACK framework is shown in Figure 2. In 2007, the acronym TPCK was changed to TPACK to form a more integrated whole for the three kinds of knowledge (Thompson & Mishra, 2007). TPACK contains seven elements or categories: 1) technology knowledge (TK), 2) content knowledge (CK), 3) pedagogical knowledge (PK), 4) pedagogical content knowledge (PCK), 5) technological content knowledge (TCK), 6) technological pedagogical knowledge (TPK), and 7) TPCK (Mishra & Koehler, 2006; Koehler & Mishra, 2009). Angeli & Valanides (2009) integrated ICT and TPACK and addressed an ICT- TPACK framework and two brand-new components, knowledge of learners and knowledge of environmental context, were added. ICT-TPACK is conceptualized as a strand of TPACK, thus ICT-TPACK constituent knowledge bases include TPACK's three contributing knowledge bases (Angeli & Valanides, 2009). The ICT-TPACK framework is shown in Figure 3.

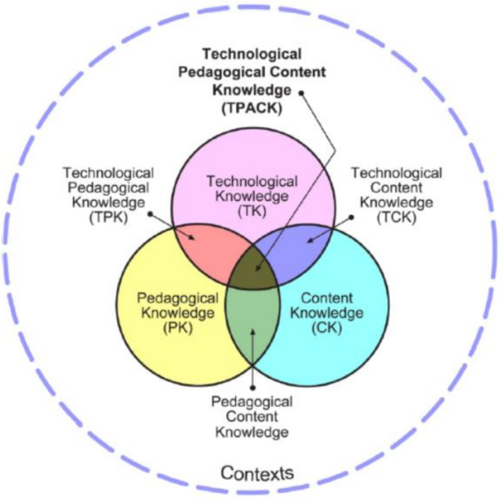

Figure 2: TPACK framework and its components (Adopted form Koehler & Mishra, 2009)

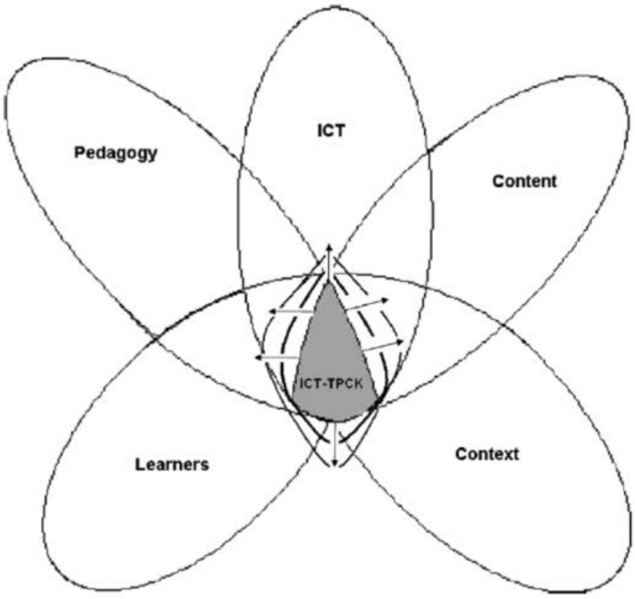

Figure 3: ICT-TPACK (Adopted form Angeli & Valanides, 2009)

Research design

This study adopted action research which invited 227 primary school teachers participated in two workshops each semester and one conference. Participated teachers learned how to adopted effective strategies and resources in their classroom. All the resources of guidance and strategies were accessed in the platform system. Those primary school teachers must adopt these remedial instruction strategies in their mathematics classes and for those students who needed remedial instruction. They were organized as professional learning community (PLC) to improve MPCK. The details of research design are as follows.

Professional learning community

In Taiwan, the primary school teachers major in different fields, including mathematics, science, education, literature and so on, as being pre-service students in college. Upon completing of the teacher education program and passing the qualification examination, they qualify for teaching in primary schools. Most of the in-service teachers have to teach mathematics, and definitely, lots of problems aroused because they teach concepts of mathematics that they themselves have not mastered. For in-service teachers, professional experience is typically regarded as one of the most important aspects of their preparation for the classroom (Le Cornu, 2012). One feature of successful professional development models is the ability to create community (Cobb, McClain, Lamberg, & Dean, 2003; Franke & Kazemi, 2001). The professional learning community (PLC) is one of the good solutions for providing these teachers a way to enhance these in-service teachers' PCK. PLC represents widely used to describe almost any gathering of educators (DuFour, DuFour, & Eaker, 2008). They share and interrogate their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented, growth-promoting way (Mitchell & Sackney, 2000; Toole & Louis, 2002). A key idea of PLCs is to improve teachers' efficiency and effectiveness as professionals for fostering student's learning. Once a time, PLC means all teachers are learners with their colleagues (Louis, Kruse, & Associates., 1995). Nowadays, teachers can learn with other teachers through internet because of the rapidly developed ICT materials.

Figure 4 demonstrates the important components of the study's platform: 1) Assessment analysis module, 2) Video analysis module, 3) Supplement, 4) Forum, 5) Q&A. In the beginning, the platform was implemented be a simple website and the teachers use a desktop or laptop to access the resources through internet. Following, the responsive web design (RWD) was introduced to modify it to be accessible by smartphones and tablets which teachers can survey resources in the website by a smartphone or a tablet. These key parts will be described in detail as follows.

Assessment analysis module

Recently, much attention has been drawn in the remedial instruction in Taiwan (Chao & Tseng, 2013; Chien, 2015; Hsieh, Lee, & Su, 2013; Lin et al., 2013; Lin, Wu, & Hsueh, 2014). In order to remediate students in mathematics, an efficient and effective remedial instruction is built on a good diagnosis of students' misconceptions or error patterns. Teachers can arrange the remedial instruction processes and manage the aided materials to help struggling students to improve bettering understanding of the concept.

The good diagnostic results of student's achievement performance can definitely save a mass of remedial time. The diagnostic processes were performed by scholars from universities. Therefore, the core spirit of the platform aims to serve as an interface for participant teachers to access remedial information of their students, and to manage their suitable remedial instruction strategies for those students with misconceptions. For diagnosing students' learning difficulties, two or three diagnostic assessments were administrated, and analyzed by the module developed by the author, Lin, and reports the learning results of the students. After receiving the remedial reports, teachers can realize the students' misconceptions, introspect self-teaching context, arrange remedial teaching process and manage teaching materials in a more direct, efficient and effective way.

Video analysis module

Every participant teacher was asked to film his/her own teaching in class at one for each semester, which would help the scholars to understand these teachers' practical teaching. The video analysis module was determined by some scholars and some comments are proposed to these teachers for improving their teaching in mathematics. In workshops, several teaching film would be selected as a model example and teachers could learn, think and discuss together.

Meanwhile, to analyze these films, several dimensions observed from these films were under specifying by the scholars for quantitative and qualitative analyses in the future.
Supplement

The scholars from universities provided primary school teachers with theoretical guidance and effective strategies for remedial mathematics instruction. These guidance and strategies included worked examples of life mathematics, children's schema of learning mathematics, instructional strategies for mathematics reading comprehension. More importantly, the scholars filmed several demo videos of integrating these theoretical strategies for helping teachers to get more insightful understandings.

Forum and auto reply email system

The participant teachers were volunteers from different primary schools, so for communication convenience, a forum and an auto reply email system were necessary. Therefore, the participants could ask questions to the experts or propose valuable issues each other in the platform. Meanwhile, an auto reply email system helped to send important information to the participants.

Q&A

Any questions, asked by teachers, relating technology (T), pedagogy (P), content (C), and knowledge (K) or remedial instruction for improving students' learning were documented, answered by the scholar team and next put on the website.

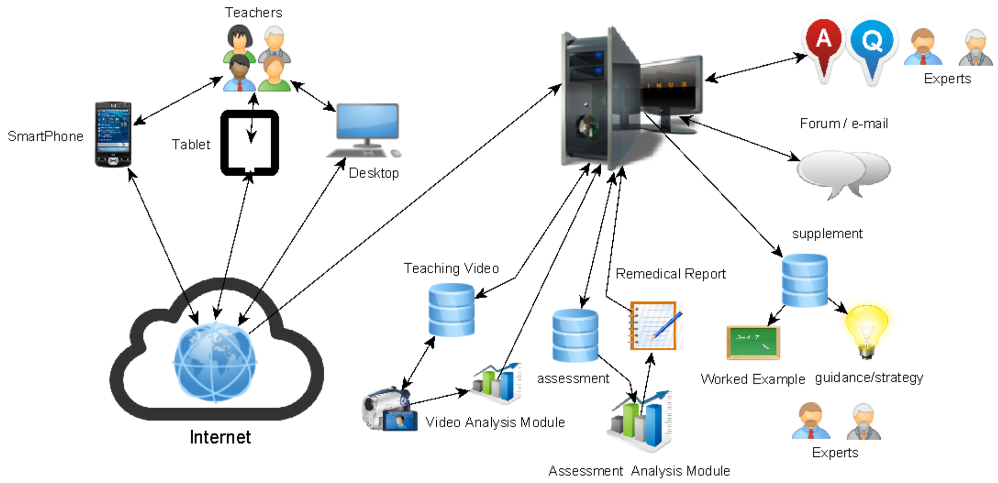

Figure 4: Platform for Teachers' Mathematical Pedagogical Content Knowledge of Remedial Instruction

Results and Discussions

This study was action research which was a two-year (2014-2015) longitudinal survey from 21 schools in Taiwan. In the first year, the participants were fourth-grade teachers. In the second year, their students were fifth grade and their teacher continuously participated in the study. There were totally 227 primary schools participating in this PLC team.

Research procedure

All the teachers must participate in two workshops and one conference each semester. In the activities of workshops and conference, the lesson studies for mathematics instruction were scheduled to improve their MPCK. In the lesson study group, every teacher shared his own experiences, professional strategies and video analysis for mathematics instruction. All the effective resources, strategies were established in the internet platform system for carrying out mathematics instruction.

For each semester, all the students must take mathematics assessments, and such assessments were curriculum-based. The purpose of these mathematics assessments was to detect the students' progress of learning mathematics. There were totally 7 waves of mathematics assessments from 2014 to 2015.

Results

Table 1 depicted the mean score of mathematics assessment from 2014 to 2015. In 2014, these students were fourth-graders, while these students were fifth graders in 2015. It displayed that the mean score increased across each assessment. The statistical test for the mean comparisons of repeated measure showed these existed significant differences. The mean of 2014-3 was higher than the mean of 2014-2; the mean of 2015-2 was higher than the mean of 2015-1; and the mean of 2015-3 was higher than the mean of 2015-2.

As shown in Figure 1, it was the line chart for the mean scores of mathematics assessment from 2014 to 2015. One was concluded that students made progress smoothly.

Table 1: Mean Score of Mathematics Assessment

Year and Assessment	Students	Mean	Statistical Test of Mean Comparisons
2014-1	4-th Grade	69.12	
2014-2	4-th Grade	69.15	
2014-3	4-th Grade	75.40	2014-3 > 2014-2
2015-1	5-th Grade	75.61	2015-2 > 2015-1
2015-2	5-th Grade	76.97	2015-3 > 2015-2
2015-3	5-th Grade	83.69	
2015-4	5-th Grade	84.76	

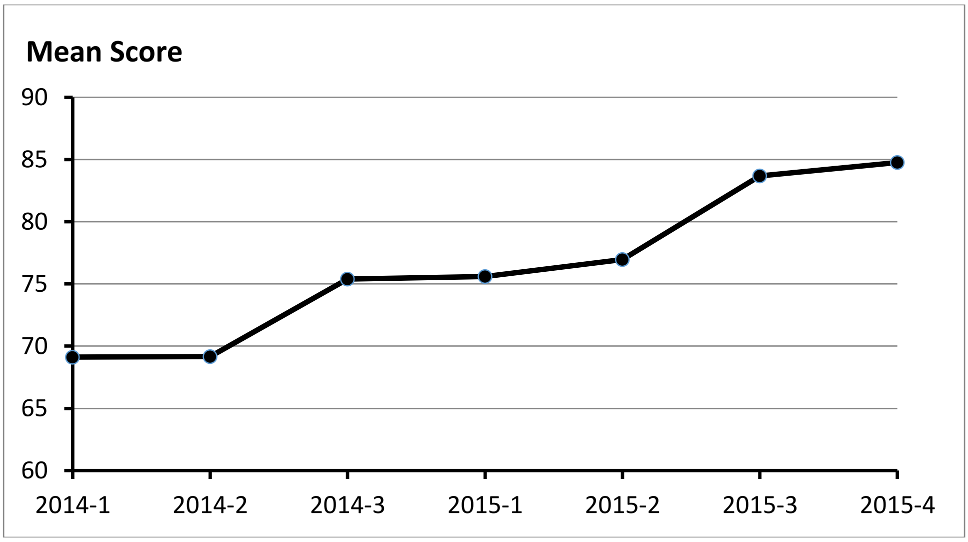

Figure 5: Line Chart for Mean Score of mathematics Assessment

Discussions

The above results and discussions showed the positive effects of this study. The most important findings was that theoretical guidance and effective strategies for remedial mathematics instruction, which were mentioned in this study, were helpful for teachers and students. Integration of worked examples of life mathematics, children's schema of learning mathematics and instructional strategies for mathematics reading comprehension should be an effective path for mathematics instruction.

In addition, some reasons could be also contributed to the effects. One is concluded that establishment of platform system for teachers' MPCK could help teachers and students make progress for mathematics instruction and learning. Moreover, organizations of PLC and lesson study activities could help teachers improve professional knowledge of mathematics instruction so that their students make progress in mathematics learning. Future research could focused on qualitative analysis teachers' MPCK and investigate their teacher-student interactions in mathematics classrooms.

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