

Mathematics Teacher Education Program for 21st Century

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Abstract : *The purpose of this study is to analyze the features of intended curriculum for the mathematics teacher education program of the 21st century. This study used the qualitative research methods, case studies and ethnographic study. The data were collected by participant observations, interviews, and documentation. Consequently, the data were analyzed using a qualitative data analysis approach – the component analysis. The results showed that the elements of intended curriculum for the mathematics teacher education program consist of: 1) Knowledge with following sub-categories, 1.1) Pedagogical content knowledge, the school mathematics course, and mathematics learning process, 1.2) Pedagogical knowledge, the teaching profession 1.3) Content knowledge, the collegiate mathematics course, 1.4) General knowledge, the general education courses, and 1.5) Practicum knowledge is the teaching practice course; 2) Skills/Processes; 2.1) Observation skill, concept prediction skill and feedback skill; 2.2) Mathematics learning process such as problem solving, communications, presentations, connections, and proofs and reasoning; 3) Desirable characteristics; 3.1) Collaboration for planning, practice and feedback according to Lesson Study process; 3.2) Open to the opinions and suggestions of others ; 3.3) Understand the products-processes oriented approach; 3.4) Public mind concern through work with others.*

Keywords: mathematics teacher education program, 21st century skills, intended curriculum

Introduction

The differences between the labor demand on the 21st century and 20th century are the abilities of a person, citizens' duty, self-awareness and key elements of knowledge. While the proportion of manual or routine workers tends to decrease, the proportion of workers with expert thinking or complex communication are likely to increase (Lavy & Murnane, 2004). The essential skills for the 21st century such as expert thinking, problem solving, reasoning, analytic thinking, creative thinking, meta cognition and the use of a variety of process to solve the problem can help to prepare the students to thinking, learning, working, problem solving, complex communication and cooperation to work effectively for the rest of their life (Inprasitha, 2011; Kay, 2010, Bellanca & Brandt, 2010, Panich, 2012, Wongtrangan, 2015).

Preparing for the 21st century, several countries have been improving the mathematics curriculum by including the problem solving concept in the course of study. Inprasitha (2011, p.1) concluded that Japan has introduced the problem solving concept into the curriculum since 1951, Singapore in 1992, Brunei and Malaysia. Thailand has entered the problem solving ability as one of the students' competencies according to Basic Education Curriculum B.E. 2011 (Inprasitha, 2014; Ministry of Education, 2001). As a result, the teacher education

is required to prepare the teachers to manage the teaching courses regarding those concepts (Inprasitha, 2013, p. 35).

Nevertheless, both reports from *Tomorrow's teachers: A Report of the Holmes Group* and *A Nation: Prepared: Teachers for the 21st Century* indicated that the teacher education program did not response to a course of education in the 21st century (Brown & Borko, 1992, p. 209). Many countries are facing the challenges in producing and supporting the quality of teachers to improve mathematics teaching effectively (Hiebert, Morris, Berk & Jansen, 2007; Morris, Hiebert & Spitzer, 2009; Park, 2005). There are many problems of the courses from the Faculty of Education especially in the field of science and mathematics, such as adequately content intensity, discouraged professional teaching practices for professional teacher preparing, lack of instruction on student centered as well as insufficient learning process for teacher in the existing teacher education program (Inprasitha, 2006; Wongtrangan, 2014). In addition, the teacher education program did not focus on the problem solving. For example, most of the teacher education programs in Thailand disregarded the significance of problem solving associated with other mathematical learning processes as expected from the basic education core curriculum B.E. 2011 (Inprasitha, 2014, p. 97).

The teacher preparation can help a student teacher to acquire knowledge and required skills in many contexts to teach mathematics effectively (Ball, Thames & Phelps, 2008; Shulman, 1987). In fact, the viewpoints about teaching the mathematical knowledge and skills have been built in accordance with the learning experience of the students in the course (Cooney, 1994; Stigler & Hiebert, 1999) including the professional teacher, characteristics such as morals, ethics, educational values, or interpersonal skills (Chumjit, 2010; Hessong & Weeks, 1987; Inprasitha, 2011; Ministry of Education, 2011; Scriven, 1994; Taylor, 1994; Türk kahraman, 2014). Therefore, the curriculum design of teacher education program requires a deep insight especially in the specific content and essential content for teaching method (Hill, 2010, p. 514).

However, the traditional teacher education program separated the content knowledge from the pedagogical knowledge, thus mathematics studied at the department of mathematics, Faculty of Science. While pedagogy studied at the department of education, Faculty of Education. (Graham, 2006; Inprasitha, 2011; National Research Council [NRC], 2001). The mathematics education programs are either offered under the Faculty of Science or the Faculty of Education. The planning of the curriculum for mathematics teacher education is based on two schools of thoughts. First, to be a competent mathematics teacher, mathematics teacher education program developed by mathematicians is based on a firm belief that one must have an in-depth knowledge of mathematics and some basics in pedagogy is considered adequate to start off the teaching profession. The skill will come later; it is more of on the job skill acquisition. On the other hand, mathematics teacher program developed by educationist tend to emphasize more on the pedagogy, and is developed based on a strong belief that knowledge of pedagogy and of learners is as equally important to knowledge of mathematical content (Graham, 2000; Yunus, Hamzah & Ismail, 2008). Moreover, the teacher education program is required to design to help the student teachers develop their learning abilities from the teaching experience, prepare their opportunities to connect the theory with the practice experience in the classroom and learning from the reflection of the experience (Darling-Hammond & Hamerness, 2005; Darling-Hammond, 2006). As a result, we are interested to study and research the features

of mathematics teacher education program which might be useful for the basic research associated with the development of teacher education program in the future.

Literature Review

The researcher has reviewed the topics relating to the study as follows:

Mathematics Teacher Education Program

Cooney (1994, p. 16) concluded that the mathematics teacher education program should have the following factors in order to encourage efficiency in teaching:

- 1) Encourage the development of mathematical knowledge through teaching with the constructivist perspective;
- 2) Provide the opportunity for student teachers to reflect on their own experiences as mathematics learners;
- 3) Provide the context for students to develop their expertise in identifying and analyzing constraints during class and how to deal with those limitations;
- 4) Provide the context for student teachers to gain experience in the assessment of mathematics understanding for students;
- 5) Provide the opportunity for student teachers to transfer the knowledge about mathematics regarding the strategies that can improve teaching development.

Borko et. al (1992, p.194) reported that the mathematics teacher education program should create students' opportunities to learn subject matter knowledge for develop the conceptual thinking and language, and to connect between representation and application procedures and processes to the other parts.

Bufarsan (2000, p. 23) indicated five main elements of teacher education program responding to the target and standard of the course:

- 1) Knowledge: A rich knowledge content, pedagogy, and technology should be included in the curriculum to prepare future teachers;
- 2) Instruction: Instructional plans using technology and a variety resources should be included in the teacher education program;
- 3) Student diversity: the program should include instructions that meet student cultures and populations, learning styles, and background experiences;
- 4) Professional development: the program should include opportunities to practice professional development;
- 5) Field experience: field experience is needed to learn and practice teaching skills.

The first three components are separated into three parts: knowledge and skills, attitudes and real life in school.

Darling-Hammond, Hammerness, Grossman, Rust & Shulman (2005, pp.394-395) proposed the features of teacher education program as follows:

- 1) The contents of teacher education are the content and connected methods of teaching, including the scope that can help to plan the knowledge of teaching in order to see the relationship between the content and pedagogy linked with practical theory that support the students learning;
- 2) The learning process is a scope for the available curriculum and a tool for many practices to accept the understanding of teacher expression in class;
- 3) The learning context is the scope of teacher learning in the context to develop the practical expertise as the context that covers the entire scope of content and community of practice by sharing the practice management and development based on the knowledge.

Inprasitha (2013, p. 37) mentioned that the key features of the curriculum as: 1) knowledge 2) processes/ skills and 3) desirable characteristics.

From aforementioned, it can be summarized that the expected level of mathematics teacher education program includes: knowledge, skills/processes, and desirable characteristics in which these features are important in the creation and development of the future teacher.

Teachers’ knowledge for 21st Century

In the design of teacher education program, appointing curriculum developers must specify the type and level of knowledge required for the preparation of quality mathematics teachers (Yunus, Hamzah & Ismail, 2008, p. 125). The elements of the teachers’ knowledge have been identified by diverse scholars that teachers cannot teach what they do not know. Therefore, the teacher must have a deep knowledge, not just only the specific mathematics they teach, but also the mathematics that their students are to learn in the future (Fennema & Franke, 1992, p. 147).

Shulman (1986, pp.9-10) identified the elements of knowledge which is the foundation of the teaching consisted of: content knowledge, general teaching knowledge, pedagogical content knowledge, curriculum knowledge, student characteristic knowledge, practical classes knowledge and educational value knowledge. The most influential of the elements of knowledge is the new concept of Pedagogical Content Knowledge. PCK is that special amalgam of content and pedagogy is uniquely the province of teachers, their own special form of professional understanding [...] It goes beyond knowledge of subject matter per se to the dimension of subject matter for teaching. (p.9).

Ball, Themes & Phelps (2008, p. 401) presented the model of knowledge for mathematics teaching as: the general and specific content knowledge and pedagogical content knowledge including content knowledge for students and teaching.

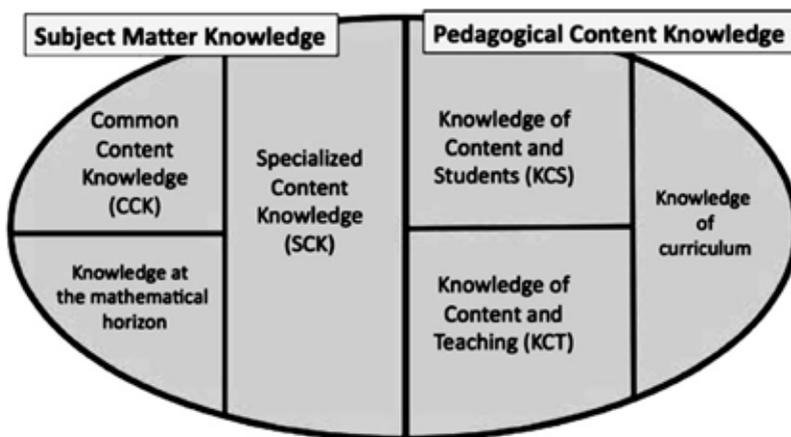


Figure 1. Mathematical knowledge for teaching (Ball et al., 2008)

Skills/Processes for Teachers in 21st Century

Hiebert et al. (2007, pp. 50-58) proposed four important skills in practice of teachers' classrooms:

1) An identification of learning to target is the first skill since ambiguous target results in neglect of learning, the method of learning which connected to the class management and the improvement of teaching method to stimulate effective learning of student in the next lesson;

2) Teaching empirical observation is the evidence gathering skill to fulfill each student target, including; (1) the value of evidence that demonstrates the essential learning of student to evaluate the effectiveness of the instructions; (2) Be aware of the student learning achievement evidences classified by the consistent and inconsistent response of students from them; and (3) Understand how to collect the evidences by identifying the key moments in a lesson that shows the clear evidences of student learning and plan how to collect the evidences from each student by concluding the implementation of useful empirical observations to know what and how;

3) Hypothesis formation of teaching effectiveness is a hypothesis development to link teaching and learning skills by building the forecast methods, such as the questions, activities, and so onto facilitate or inhibit the student learning;

4) Target analysis to improve the teaching is the skills to prepare the information needed to make teaching method decisions based on the evidence gathered. This target aims to clarify the learning goals that include information about whether the students will achieve their goals and create assumptions about teaching methods that facilitate the student learning. The revisions to improve the teaching and learning are from instructions contained in the hypothesis.

Desirable Characteristics of Pre-service Teacher for 21st Century

The development of skills and characteristics of pre-service teachers should be appended in the curriculum rather than as a supplementary course. Banta & Kuh (1998, p.42) stated that the necessary method to improve the quality of the experience of undergraduate students is to joint between inside and outside classroom experience as a part connected between the academic and student development through the value for the student teachers. For example, the values for student teachers in Singapore consist of three items as: student-focused values, values on teacher characteristics and values on professional service and community. Inprasitha (2010, p. 71) presented the core values of student teachers as follows:

1) Building collaboration: emphasis on the community members aware of an identity of each other and provide the value to the members because everyone is important;

2) Public concerns: emphasis on community members to aware of public concerns by realizing the other people in the society rather than ourselves based on the good wills and good intentions;

3) Open-minded attitudes: emphasis on the community members by willing to hear or consider the new ideas either they are criticism or suggestions from community members;

4) Product-Process-oriented Approach: focus on the students to value the work both in the process and the results.

Research methodology

This study used the qualitative research methods such as documentary research, and ethnographic study for the investigation by combining educational context together with

the data gathered by the researchers involved (Freebody, 2003, p. 1). I am studying at mathematics education program of Faculty of Education of Khon Kaen University since 2006. I was teacher assistance in undergraduate student classes from 2006 to 2011 and have participated in every extra activity. I observed how to teach undergraduate classrooms such as problem solving in school mathematics, communication in school mathematics, and so on. In addition to, I observed internship students' classroom and worked with the lecturers every activity.

Data collection

This research collected the data as follows:

1. The author compiled the documents to be used for the data analysis, including mathematics teacher education program for undergraduate students of Faculty of Education, Khon Kaen University and course outline.
2. The author collected the data using in-depth interviews with key informants, including chairman of the curriculum committee, lecturer in mathematics education, mathematics teacher and undergraduate students in the year of 2-5.

Data analysis

The researcher analyzed the documents and information from the target group interview using the component analysis approach to investigate the features of the mathematics teacher education program. Component analysis is good for analyzing the characteristics of the components of each set of the data. The data can be compared and contrasted to make conclusion. (Lincharean, 2012). Consequently, the author discussed each feature with the reference from Ballet (2008), discussing the teachers' knowledge with reference to Hiebert (2007), discussing the teachers' skills and processes and desirable characteristics with the reference to Inprasitha' concepts (2011), finally, the analyzed data were compiled and summarized.

Study results

The author collected the data from the interviews and documents, and then analyzed research data related to the key elements of intended curriculum of the mathematics teacher. The results showed that the mathematics teacher education program of the Faculty of Education, Khon Kaen University consists of the following main components:

1) Knowledge features

The knowledge elements of mathematics teacher education program for undergraduate students of the Faculty of Education, Khon Kaen University include the following courses:

Table 1. The percentage of subjects in the mathematics teacher education program of the Faculty of Education, Khon Kaen University in 2013

Course	Credits	Percentage
Collegiate mathematics	36	21
School mathematics	24	14
Mathematics learning process	21	12

Course	Credits	Percentage
Teaching profession	42	25
Practicum	12	7
General education	36	21
Total	171	100

In addition, the support evidences were gathered from the interview with the chairman of the curriculum committee and curriculum designer.

"...Originally, a major subject was split into three parts: first part at the Faculty of Science 36 units, studying the calculus 1-2 referenced from the diploma program with just 30 units of major subject which is in use now; the other part with 48 units were split in 24 and 24 units because we focus on the problem solving with require process subject such as problem solving, communication; the last part is school mathematics which is not only a generally teaching but also a pedagogy embedded with the content, which is called PCK so in this case called Math PCK"

(The curriculum committee, 8 July2014)

The above evidence revealed that the design of the course in the feature of knowledge consists of the subjects as follows: the content knowledge such as collegiate mathematics courses; the pedagogical content knowledge such as the courses for mathematical learning processes and school mathematics; teaching knowledge such as profession teaching courses and practicum; and general knowledge such as general educational courses.

2) Skills/processes features

The author analyzed the detail of skills/processes using the concept from Hiebert et al. (2007). The analysis from the interview of a chairman of the curriculum committee showed that the necessary skills for the student teachers of the 21st century include:

"... Originally, the students sit and listen to the teachers, so conveying is the performance of common teachers. Poor expression may result in misunderstanding of students. However, if we told the students to solve a problem, they can think when a problem is solved by themselves. The teachers must observe; thus the other important skill is the observation skill...The other associated with the observation is the student anticipation. What the teacher must really observe, they must observe the students' ideas, and teachers can to anticipate students' ideas and difficulties...The students' observation can show that their concepts are not with our anticipation from the reflection. The reflection skill is important for the teacher, which I think as a circle ... I think the important skill competencies are the anticipation skill, observation skill and reflection skill" (The curriculum committee, 8 July2014)

Additionally, the course outlines of problem solving processes in school mathematics and communication processes in school mathematics indicate the teaching guideline focusing on these three skills for students as follows:

- Problem solving collaboration and observation from the problem situations;
- Analysis and discussion about the experience of problem solving to synthesize the problem solving process or solution;
- Anticipation students' ideas from open-end problem solving. (course outlines of problem solving processes in school mathematics, 2013)

From the evidence above, it can be concluded that the mathematics teacher education program of Faculty of Education, Khon Kaen University indicates the guideline to provide the observation skill, student anticipation skill and reflection skill for students. On the part of process, the course curriculum is designed from the concept of National Council of Teacher of Mathematics [NCTM] with the subjects related to the mathematics learning process as the information from the interview.

“...The major subject for this course is the learning process by the concept of NCTM. All the process of mathematics learning is new so it is implemented as a course for undergraduate level. Thus, the process subject includes the problem solving, proof and reasoning, and communication representation connection...”

(curriculum co-designer, 25 October 2015)

The above information shows that the process of the mathematics teacher education program of the Faculty of Education, Khon Kaen University consists of the mathematics learning process subjects. As a result, the students are trained on the learning process from these subjects.

3) Desirable characteristics features

The mathematics teacher education program of the Faculty of Education, Khon Kaen University includes the activities to develop the desirable characteristics of the students from the interview of the chairman of the curriculum committee and teachers regarding desirable characteristics development.

“...I built up a small community such social activity so everyone in the community must work, for example, the children day for the 1st year, math camp for 2nd year and field trip for 3rd year. The team can bring 200 people to any province that they would like, so they need a very hard management by contacting lots of things. For 4th year, they attend the conference and initiate more academic activities such as class observing in Japan or ASEAN or observer the class with Japanese lecturer. Then 5th year, they work with teacher in the school system for 1 year.”

(The curriculum committee, 8 July 2015)

The information from the interview shows that the activities for student development such as children day event, sport day, math camp for youth, mathematics seminar, attending the national and international conferences, observation the class under the research project and teaching practice in school aim to build the social activity for students.

Moreover, there is information of an interview from the chairman of the curriculum committee about the desirable characteristics for the students.

“...To manage the course here, we call it the core values which we are trying to make it happen. The first is to work together in unity... the second, I focus on the open-minded to accept the differences and understand the others ... the third we emphasis on the public mind ... and finally the value is focus on the process and outcome or outcome and process ...”

(The curriculum committee, 8 July 2014)

From the interview with a chairman of the curriculum committee, it can be concluded that the desirable characteristics of the students are: the value of collaboration and unity at work; the value of open-minded to accept the differences in the thought and identity of other people; the value of public mind to work with a good deed; and the value that focus on the process and outcome to understand the work procedure and see through all components in the process to make a good plan with less mistakes. These 4 values are the main approach to develop the desirable characteristics to the students.

From each activity, the participated students have learnt as follows:

“For the process of work on the activities of the branch, first we need to set a meeting between the conference organizers and host ... to divide the roles and responsibilities so the meetings are held between other students on different year during the preparation... after the event, the feedback from the activity is responded to learn good things and things that need to improve ...”

(Undergraduate student3, 12 July2015)

“...I learn the systematic work with plan and expected problem and obstacle to find the solution when the problem actually occurs...”

(Undergraduate student 6, 8 December 2015)

From the data of the interviews and document analysis about the desirable characteristics of the students, the curriculum is suggested that the students each year is responsible for the activity. The students divide roles and responsibilities and set up the meeting to forecast the difficulties and obstacles that might occur from the activities and get the feedback from the students after the event. Additionally, we found the integration of lesson study with the work process to develop the desirable characteristics for the students.

Conclusion and Discussions

The study results show that the curriculum consists of three key features including knowledge, skills and processes and desirable characteristics.

Knowledge

The mathematics teacher education program of the Faculty of Education, Khon Kaen University consists of: 1) Pedagogical content knowledge including school mathematics and mathematics learning process; 2) Pedagogical knowledge including teaching profession; 3) Content knowledge including collegiate mathematics; 4) General knowledge including general education and, 5) Practicum knowledge including teaching practice in school 1-2.

Skills/Processes

The mathematics teacher education program of the Faculty of Education, Khon Kaen University prepares the skills/processes for the students as follows: 1) the curriculum focuses on 3 skills for students: observation skill, anticipation skill and reflection skill, and 2) the curriculum focuses on the mathematical learning processes such as problem solving process, communications process, connection process, proofs and reasoning process, and representations process.

Desirable characteristics

The mathematics teacher education program of the Faculty of Education, Khon Kaen University focus on 1) core values through collaboration by planning, doing and reflecting; 2) the student teachers listen to other people opinions from class and other student development activities; 3) Guide the student teachers to understand the thinking process and outcome and 4) Public mind concerns when they worked together.

As a result, the curriculum should contain the subject of content knowledge, teaching knowledge, general knowledge, practical knowledge and pedagogical content knowledge. According to Park (2005) who analyzed the curriculum of countries group with the top PISA score such as Hong Kong, Taiwan and Korea, he found that the curriculums of those countries contain the subject of pedagogical content knowledge which is a significant knowledge for the teachers. For the skills/process, observation skill, student concept prediction skill and feedback are the main focus. The processes are emphasized on the mathematics learning process of students to manage the class to associate with student learning. Hiebert et al. (2007) stated that the key teachers' competencies including the skills to set the objective of lessons, observe the student concept and get the reflection to improve their teaching. The desirable characteristics of the students are focused on the core values by the process of Lesson Study.

Therefore, teacher educators should recognize to design mathematics teacher education program especially the features of the program. In addition to, implementing the program should carefully design. In the future I will be study of the how to implement the mathematics teacher education program of the Faculty of Education, Khon Kaen University which focus on the four of core values.

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