How Could We Assess the Pedagogical and Professional Competences of Prospective Mathematics Teachers?

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Abstract. Teacher is an important component determining the success of education. In order to improve the quality of teachers, the Indonesian government has established a number of policies such as the Teacher and Lecturer Act of 2005 (UU Guru dan Dosen) and the Government Regulation No. 74/2008 that sets the academic qualification for teacher. Nevertheless, the results of the Competence Test for Teacher (Uji Kompetensi Guru) indicate the low competences of Indonesian teachers. Considering these facts, this study is aimed to develop instruments to assess the competences of prospective mathematics teachers participating in the Professional Education Program for Teacher (PPG). These instruments could provide early indication for improving the quality of teachers. This study employed a research and development approach; in particular the ADDIE model. The phases of this study comprised: (1) analysis phase for identifying the needs and content material; (2) design phase which dealt with constructing the indicators of the instrument; (3) development phase at which the indicators were elaborated into test items; (4) implementation of the prototype of instrument; and (5) evaluation that was aimed to evaluate the quality of the instrument. The subjects of this study were 70 students at Program PPG.

1. Introduction

Students' achievement is heavily influenced by four components that include curriculum content, instructional strategies, instructional resources, and general preparation [1]. The first component refers to the scope of subject content covered in curriculum. The second component correspond the teaching strategies that are used by teachers; whereas the third component refers to resources such textbooks or worksheets that are used in classroom practices. The last component deals with a teacher's preparation before teaching that includes not only technical preparation such as blackboard, but also content preparation. The second and the fourth components clearly belong to teacher's territory. With respect to the second component, several studies shown that teachers' knowledge about and skills on managing instructional activities highly influence students' learning process that consequently will affect students' achievement [2], [3]. These facts indicate the important role of teachers in enhancing students' achievement.

The important role of teachers in education has also highlighted by Indonesian government. In 2005 the Indonesian government released the Teacher and Lecturer Act No. 14/2005 (UU Guru dan Dosen). This act clearly states that teacher is defined as a professional educator whose roles include educating, teaching, guiding, assessing, and evaluating students. This act is supported by the Government Regulation No. 74/2008 about teacher that sets the academic qualification for a teacher. In this regulation the government requires a teacher to hold not only a bachelor degree in education (S1), but also a professional teacher certificate. The teacher professional certificate must be acquired through a professional education program for teacher which is conducted by nationally accredited teacher training

universities (LPTK). Such teacher professional education program – which from now on is called PPG – is designed to prepare graduates of bachelor program to be professional teachers who have four competences, i.e. pedagogical, personality, social, and professional competences. Pedagogical competence refers to teachers' ability to conduct good instructional practices. Personality competence refers to a teacher's position as a role model in terms of attitude, behavior, and also knowledge, whereas social competence corresponds to a teacher's ability to communicate and collaborate. Lastly, the professional competence corresponds to teachers' comprehension of the content of the subject matter.

In addition to the aforementioned competences of teachers, it is worth to consider the aspect of knowledge to be acquired by teachers. According to Shulman [4], there are three main domains of knowledge which are crucial for teachers, i.e. pedagogical knowledge, content knowledge, and pedagogical content knowledge. Pedagogical knowledge refers teachers' knowledge about general pedagogy including knowledge about students' characteristics and knowledge about general aspect of teaching. Teachers' content knowledge is teachers' knowledge about the content of subject matter they teach. This knowledge mostly concern conceptual knowledge, procedural knowledge, and also relations between concepts. Lastly, pedagogical content knowledge covers teachers' knowledge about how to teach a particular subject or topic. Cochran, King, and DeRuiter [5] gave a more detailed description of pedagogical content knowledge. They depicted pedagogical content knowledge as an intersection of knowledge of subject matter, knowledge of pedagogy, knowledge of students, and knowledge of environmental contexts (see Figure 1). According to Prescott, Bausch, and Bruder [6], pedagogical content knowledge plays a crucial role for a good teaching. They argued that teaching requires more than content knowledge of teachers, because teachers do not only deliver content but they also support students' learning. In order to optimally support students' learning process, teachers need to choose and/or design appropriate activities and exercises for students to learn particular concepts, to recognize and analyze students' learning difficulties, and to guide students deal with their difficulties. Connecting Shulman's three domains of knowledge to the four teachers' competences set by Indonesian government, it can be seen that pedagogical knowledge and pedagogical content knowledge are closely related to pedagogical competence, whereas content knowledge is similar to professional competence.
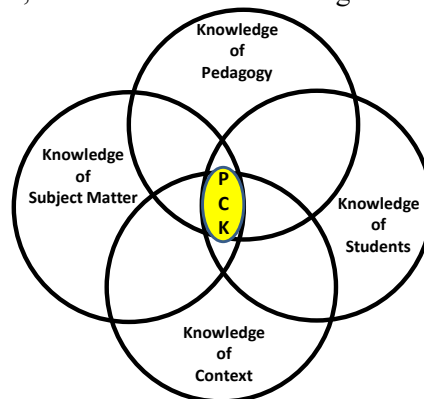

Figure 1. Scheme of pedagogical content knowledge [5]

Despite an increasing attention to improving teachers' competences, the results of Competency Test for Teachers (UKG) are unsatisfactory. For example, the average score for pedagogical and professional competences of 2.430.427 Indonesian teachers in 2015 was only 53.5, which was far below the standard score set by the government, i.e. 75. Furthermore, only 10 out of 34 provinces that had average score above the national average. In addition to the results of UKG, the Indonesian National Assessment Program (INAP) 2015 revealed that teachers who hold professional teacher certificate did not give significant contribution to students' performance (http://puspendik.kemdikbud.go.id/inap-sd/). This finding is quite surprising because it indicates that the competences of professional teachers – i.e. those who hold teacher certificate – might still be questioned. This situation leads to a need to develop an instrument that can be used to assess and accurately predict the competences of prospective teachers who are joining the PPG program. Such instrument can give not only information about the prospective

teachers' competences, but also information on the aspects of PPG that need improvement. Consequently, the present study is aimed to develop an instrument for assessing the competences of prospective teachers; in particular the pedagogical and professional competences.

2. Method

This study was a design research employing the ADDIE (i.e. Analysis – Design – Development – Implementation – Evaluation). Nevertheless, the present study only reported the first three stages of ADDIE model. The reasons for excluding the implementation and evaluation stages was due to the PPG that was just started at the time this study was conducted so that the PPG students were not yet ready for field testing.
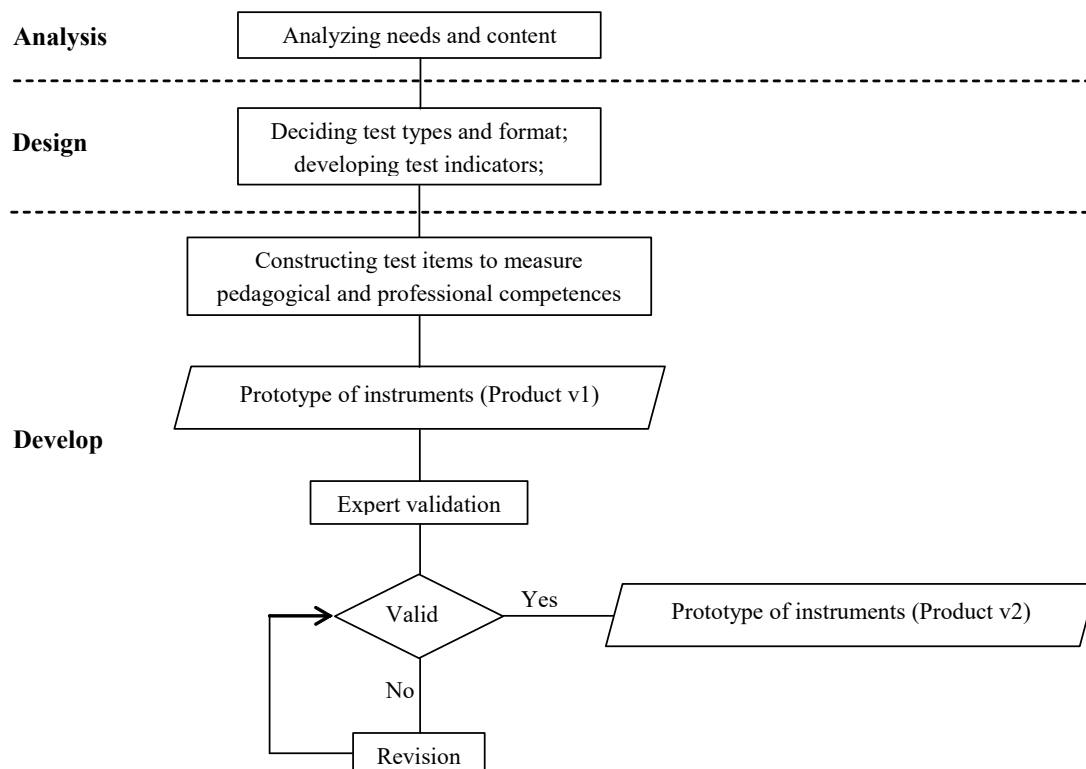
Figure 2. Stages of product development

A more detailed explanation about the analysis, design, and development stages that were performed in the present study was elaborated as follows.

a. Analysis stage

  This stage focused on two main aspects, i.e. needs analysis and content analysis. Needs analysis corresponded with analyzing government regulations concerning the professional education program for teachers (PPG), in particular those which dealt with the graduates' competences. Considering the aims of the study to develop instruments for assessing professional and pedagogical competences of prospective teachers, the content analysis meant not only mathematical content, but also pedagogical content. The mathematical contents were derived from the aspects assessed in the National Written Test for PPG (UTN PPG). This analysis included analyzing the difficulty levels of the items by referring to the Bloom taxonomy.

b. Design stage

  The focus of this stage was to design the product (i.e. instruments or test items) based on the results of analysis stage. In the design stage the researchers decided the types of items, develop the indicators, and the format of test for which we referred to the format that is usually used in UTN PPG and the Competence Test for Teacher (*Uji Kompetensi Guru*).

c. Development stage

The design that was obtained in the design stage was developed into complete instruments. There were two instruments that were developed, i.e. instruments for assessing professional competences and instruments for assessing pedagogical competences. After the instruments were developed, they were validated by experts. The experts' feedback was used to revise the instrument before it was field-tested in the next stage of the study.

All data gathered in the aforementioned three stages were analyzed by using descriptive qualitative approach.

3. Results and discussion

The results of this study cover two areas. The first area is the process of developing the instruments to assess the pedagogical and professional competences for teachers. The second area is the prototype of instruments that have been developed. With respect to this prototype, the present study does not yet try out the prototype in real PPG class. These two areas are described as follows.

3.1. Analysis stage

Two main analyses were performed during the analysis stage, i.e. needs analysis and content analysis. With respect to the needs analysis, government regulations were analyzed in order to identify the standard and expectation set by the government as the main stakeholder in enhancing teachers' competences. This analysis mainly concerned the Regulation of the Minister of National Education number 16/2007 about the standards of academic qualification and competences for teachers (*Permendiknas* No. 16/2007). This regulation explicitly describes four main competences of a teacher, i.e. pedagogical, personality, social, and professional competences. These four competences are specified into teachers' competences at different levels of education including: competences for kindergarten teachers, competences for home class teachers at elementary school, and competences for subject specific teachers at elementary, junior high, senior high, and vocational schools. The students of PPG of Mathematics Education are prospective mathematics teachers for junior high, senior high, and vocational schools; therefore the analysis of government regulation was focused on the competences for subject specific teachers at secondary schools. Among the four teachers' competences described in *Permendiknas* No. 16/2007, the present study limited to the pedagogical and professional competences. The decision to include only these two competences was driven by the conception about the mathematical knowledge for teaching proposed by Hill, Ball, and Schilling [7]. Hill et al. mentioned that the domain for mathematical knowledge for teaching consists of subject matter knowledge and pedagogical content knowledge as shown on Figure 3.
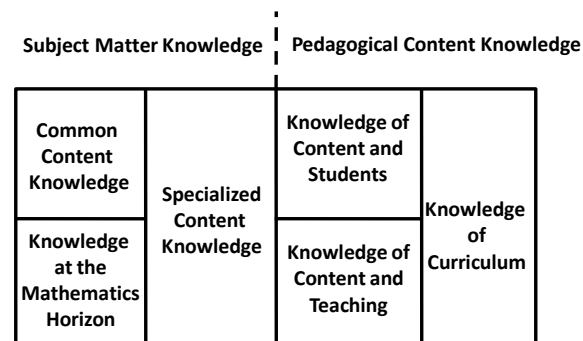
Figure 3. Domain for mathematical knowledge for teaching [7]

The results of analyzing *Permendiknas* No. 16/2007 are a set of sub-competences and their indicators that were considered as crucial to develop instruments to assess pedagogical and professional competences of prospective teachers. These sub-competences and indicators are presented in Table 1.

Table 1. The sub-competences of pedagogical and professional competences [*Permendiknas* No. 16/2007].

Competences	Sub-Competences
Pedagogical competence	Understanding the characteristics of students including physical, moral, social, cultural, emotional, and intellectual aspects.
	Mastering various learning theories and the principles of effective teaching.
	Developing curriculum that is relevant to the subject matter.
	Conducting effective teaching.
	Facilitating the development of students' potential and capability.
	Communicating effectively and empathetically with students.
	Performing assessment for learning and assessment of learning.
	Performing reflective action to improve the quality of teaching and learning process.
Professional competence	Mastering the concepts, structure, and the way of thinking the field of the subject matter.
	Understanding the standard of competences and basic competences of the subject matter.

With respect to content analysis, the present study considered the standard content of the Indonesian curriculum, the content assessed in international studies including the Programme for International Student Assessment (PISA) [8] and Trends in Mathematics and Science Study (TIMSS) [9], and also Permendiknas No. 16/2007. After studying these documents, the present study decided to include five mathematics domains, i.e. numbers and logic, algebra, geometry, and statistics and probability, and calculus.

3.2. Design stage

After taking into account the format of test which are used in the Competence Test for Teacher (*Uji Kompetensi Guru* or UKG) and the National Written Test for PPG (UTN PPG), it was determined to use written test for assessing the pedagogical and professional competences of prospective mathematics teachers. A further consideration into UKG and UTN PPG led the present study to choose multiple-choices as the format of the items. In addition to determining the format of the instruments, the design stage also focused on specifying the outputs of the analysis stage into indicators. The indicators of the pedagogical and professional competences were selected from the indicators described in *Permendiknas* No. 16/2007. Considering the format of the instruments, the criterion for selecting the indicators was the measurability of the indicators by a written test in particular by multiple-choices items. The selected indicators of the pedagogical and professional competences are provided in Table 2.

Table 2. The indicators of pedagogical and professional competences [selected from *Permendiknas* No. 16/2007]

Competences	Indicators
Pedagogical competence:	
Understanding the characteristics of students including physical, moral, social, cultural, emotional, and intellectual aspects.	Identifying students' difficulties in learning the topics covered in the subject matter.
Mastering various learning theories and the principles of effective teaching.	Understanding various learning theories and the principles for learning the topics covered in the subject matter.
	Applying various approaches, strategies, methods, and techniques of teaching that enable students learn in creative ways

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Developing curriculum that is relevant to the subject matter.	Determining the learning objectives of the subject matter.
	Developing learning indicators and instruments for assessment.
Conducting effective teaching.	Using various learning media and resources which are relevant to the characteristics of students and subject matter in order to comprehensively achieve the learning objectives.
Facilitating the development of students' potential and capability.	Providing students with opportunities to develop their potential including creativity
Communicating effectively and empathetically with students.	Communicating effectively and empathetically with students that covers motivating students to actively participate in the learning activities and also responding to students' questions or opinions.
Performing assessment for learning and assessment of learning.	Determining the aspects of learning process and learning outcomes which are crucial to be assessed.
	Determining the assessment procedures.
	Developing instruments to assess learning process and outcomes.
Performing reflective action to improve the quality of teaching and learning process.	Conducting classroom action research to improve the quality of teaching and learning process.
Professional competence:	
Mastering the concepts, structure, and the way of thinking the field of the subject matter.	Applying the concepts of numbers and relations between numbers.
	Applying mathematical logic.
	Applying the concepts of geometry.
	Applying the concepts of statistics and probability.
	Applying pattern, functions, and trigonometry.
	Applying the concepts of algebra, vector, and matrix.
	Applying the concepts of calculus and analytical geometry.
Understanding the standard of competences and basic competences of the subject matter.	Comprehending the standard of competences of the subject matter.
	Comprehending the basic competences of the subject matter.
	Comprehending the learning objectives of the subject matter.

3.3. Development stage

After determining the form and the indicators of the instruments, the development stage was aimed to develop complete instruments. Two sets of instruments were developed in this stage, i.e. instruments for assessing professional competences and instruments for assessing pedagogical competences. Examples of items to assess pedagogical competences of prospective teachers are provided in Table 3, whereas Table 4 shows examples of items to assess professional competence.

Table 3. Examples of items to assess prospective teachers' pedagogical competence

Indicators	Items
Determining the learning objectives of the subject matter	The relevant learning objective for the basic competence " ... *performing the union operation on sets situated in a contextual problem...*" is "*After the learning activities, the students are able to determine ...* "

	A. The number of students in a class B. The number of students who dislike mathematics C. The number of students who like physics only **D. *The number of students who like both mathematics and physics*** E. The number of students who do not like any subject
Using various learning media which are relevant to the characteristics of students and subject matter in order to comprehensively achieve the learning objectives	A proper learning media to help students achieve the indicator "Able to subtract negative integers" is .... A. *Dekak-dekak* **B. *Coins in two colors*** C. Hanoi tower D. Clinometer E. Bridge cards
Determining the assessment procedures	To assess students' achievement on "… *able to solve problem solving situated in real-world contexts*" we need to give students … A. Computational problems B. Routine problems **C. *Non-routine problems*** D. Difficult problems E. Very difficult problems
Identifying students' difficulties in learning the topics covered in the subject matter	A student determined the solution of inequation in the following way: $$\frac{x}{x+3} < \frac{1}{2}$$ $$x + 3 < 2x$$ $$x > 3$$ Based on the student's work, we need to give a remedial on ... A. Understanding a variable B. Understanding a constant *C.* The unequal sign **D. *Division by zero*** E. Algebraic operation
Conducting classroom action research to improve the quality of teaching and learning process	Look at the following cases and determine the most suitable case for a classroom action research… A. A teacher found about 50% of her students did not pass the exam on limit of function. She wants to investigate the possible causes for students' difficulties. B. A teacher just learned that a cooperative teaching was effective for teaching exponential function. He wants to investigate the effectiveness of cooperative teaching in his mathematics class. C. A teacher wants to know whether clinometers made of recycled materials works properly to teach trigonometry. **D. *A teacher found that students' learning activity on the topic trigonometry was passive. She wants to overcome this problem by applying a new learning model.*** E. A teacher wants to know the relation between students' achievement, motivation, and IQ to their decision in choosing concentration in high schools.

Table 4. Examples of items to assess prospective teachers' professional competence

Indicators	Items
Solving problems about equation and inequality	If the equation $t = \frac{x^2+4x+2}{x^2+6x+3}$ has two same roots for $t = a$ and $t = b$, then $a + b = \ldots$ A. $\frac{1}{6}$ B. $\frac{1}{3}$ C. $\frac{7}{6}$ D. 2 E. 7

Solving problems about division of polynomials	The polynomial $f(x)$ has a remainder -2 if it is divided by $x + 1$, remainder 3 if it is divided by $x - 2$. The polynomial $g(x)$ has a remainder 3 if it is divided by $x + 1$ and remainder 2 if it is divided by $x - 2$. If $h(x) = f(x).g(x)$, the remainder of $h(x)$ divided by $x^2 - x - 2$ is … A. $3x - 2$ B. $4x - 2$ C. $3x + 2$ D. $4x + 2$ E. $5x - 2$
Solving problems about discriminant of a quadratic equation	If the roots of $x^2 - (2 + 6a)x + 3a = 0$ are reciprocal, the discriminant of the quadratic equation is … A. $\frac{1}{3}$ B. 3 C. $2\sqrt{3}$ D. 4 E. 12
Solving problems about matrix	Determine the value of p and q to make the matrix $\begin{pmatrix} p - 1 & p + q \\ p - q & p + 1 \end{pmatrix}$ invertible. A. $p \neq 0$ B. $q \neq 0$ C. $pq \neq 0$ D. $p \neq 1$ and $q \neq -1$ **E. $p \neq 1$ and $q \neq 1$**
Solving problems about vector on plane	We are given $\bar{u} = ai - 2j - k$ and $\bar{v} = ai + aj - k$. If the vector $\bar{u}$ is perpendicular to the vector $\bar{v}$, the value of a is… A. -1 B. 0 **C. 1** D. 2 E. 3

4. Conclusion

To conclude, the results of the present study are two sets of instruments, i.e. instrument to assess pedagogical competence and instrument to assess professional competence. The instruments are already in line with the government regulation and theory on teachers' intention of international assessment programs. The coverage of the instrument is supportive towards designing what Prescott and colleagues [6] called as a 'good' mathematics lesson. Nevertheless, we acknowledge a limitation of the present study because a written test might not fully assess prospective teachers' competences because there is a possibility that the prospective teachers respond to the test based only on their knowledge. There are aspects of teachers' competences highly correspond to action and, consequently, requires a performance-based test or a reflective written test; see for example Kenney, Shoffner, and Norris [10]. Therefore, a further study needs to include more comprehensive aspects of teachers' competences.

Acknowledgment

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