Developing mathematics training modules to enhance teachers’ content knowledge

R Sulastri¹, R Johar², M Duskri³, M Ikhsan² and H Meutia¹
¹Serambi Mekkah University, Jl. Unmuha, Batoh, Banda Aceh 23245, Indonesia
²Syiah Kuala University, Jl. Teuku Nyak Arief Darussalam, Banda Aceh 23111, Indonesia
³State Islamic University of Ar-Raniry, Jl. Syeikh Abdul Rauf, Darussalam, Banda Aceh, 23111, Indonesia
E-mail: rini.sulastri@serambimekkah.ac.id

Abstract. Teacher competence test is one way of measuring teachers’ ability in pedagogic and content knowledge. The result of the competency test shows the low category because of teachers’ difficulty in understanding and teaching several topics of mathematics. The purpose of this study was to develop six mathematics-training modules concerning the content knowledge of mathematics teachers satisfying the valid and practical criteria. This research employed the research and development approach of Borg and Gall model in ten phases. However, the development in this research was conducted only up to the eighth phase. The results showed that six mathematics-training modules satisfied the valid and practical criteria. The validity was indicated by the conformity of the materials and concepts for mathematics with teachers’ problems, and the curriculum. The practical criteria were based on the conformity of the implementation of the training modules designed; the efficiency, usefulness, and attractiveness as the modules were designed into several different parts including the instructions and estimation time; and the legibility and the easy to use aspects.

1. Introduction
The Ministry of Education and Culture of Indonesia measures the academic professionalism of teachers administering the teacher competency test (TCT) that is conducted every year. The TCT started in 2012 only for teachers who will participate in the certification and starting from 2015 the TCT is conducted to measure the professionalism of all teachers. The test aims to determine the level of individual teacher competence and map the teachers’ mastery of pedagogical and professional competences. Thus, the TCT focuses on identifying teachers’ weaknesses in the mastery of the pedagogical and professional competencies [1]. The TCT enable a teacher to obtain the information concerning his/her ability, and the results can be a trigger to improve his/her quality as a professional teacher.

Professional competence or content knowledge defined as knowledge of the subject matter or subject that is usually learned or taught [2]. It is further explained that the content includes knowledge of concepts, theories, ideas, the framework of thinking, methods of proof and its evidence, as well as their components [3]. Thus, professional competence is tightly intertwined with the ability of teachers to acquire their subject matter. In other words, pedagogical knowledge in learning is the teachers’ method to teach and construct a mathematical concept following the purpose of learning [4].
Overall, the results of the TCT in 2015 were poor, but there was an increase in 2016. Aceh is one out of 34 provinces in Indonesia showing some changes. Aceh is ranked 23rd nationally in 2016. This showed improvement compared to the previous year being in the last third position [5]. Although, in general, the ranking of Aceh has increased, one of the districts, Pidie district, is still experiencing problems with 86.34% of teachers do not master the subject matter and cannot teach well [6]. The result of this TCT is used as a consideration of policy in the provision of coaching and development programs as well as awards and appreciation for teachers.

The results of the discussion with five mathematics teachers from different junior high school schools in Banda Aceh and the district of Pidie, Aceh, identified that most teachers had performed poorly in the TCT since 2015. One of the reasons is the materials in the pedagogical and professional competence test being too broad so that teachers find it challenging in understanding and solving the mathematics problems. This is in line with some obstacles in the TCT, included the type of problems, the language of the problem being difficult to understand, the advanced content of the question, and the lack of socialization about the implementation of TCT [7,8].

Based on the results of the TCT, the government has conducted various training to improve the quality of teachers related to their ability and learning. Some activities stop at the training phase without following-up on the results of the training. It is, therefore, necessary to continue to follow up the training activities for the short and long-term impact, such as the results of the TCT test in the following year and the final students learning outcomes.

Based on the issues previously mentioned, an effort is required to improve the pedagogical and professional competences of teachers by developing a mentoring model to be applied in the learning process. In developing the model, a module to be used in the training phase is required. Thus, this study is limited to obtaining a valid and practical training module to be used by Junior High School Mathematics teachers to improve their professional competence.

2. Method

This research was development research conducted to obtain a mathematics training module satisfying the valid and practical criteria. The development model used referred to the Borg & Gall model. Development research is oriented to develop and validate the products used in education [9]. The development consists of ten stages: research and information collection, planning, preliminary form of product development, preliminary field testing, main product revision, main field testing, operational product revision, operational field testing, a final product, revision, and dissemination and implementation. However, this research only conducted the first eight phases as this stage has obtained a product meeting the valid and practical criteria following the objectives of the study. The valid product was obtained from the validation carried out by three experts in the field of mathematics content and evaluation, while the practical product was derived from the usefulness and appearance of products used by users.

This research was conducted in Pidie district, Aceh, Indonesia involving ten junior high schools. The school was selected by purposive sampling method, based on the willingness of the school to participate in the study as well as the school level quality (medium or low). Two or three mathematics teachers represented each school.

3. Result and discussion

3.1. Research and information collection

This activity is related to the initial activity including the analysis of mathematics learning materials perceived to be difficult for students and teachers, literature study or review of previous research or reports, and field studies directly related to the products developed. Therefore, the steps taken are determining the subject of the study, the experts as the validator, the place and time of the study, as well as the subject for the pilot study. For the needs analysis, the District Education Department of Pidie, Aceh contributed in releasing the consent, determining the number of schools, teachers and
school supervisors as subjects of the study as well as providing the literature related to the score of Teacher Competency Test (TCT).

Regarding the schools involved, all schools recommended by the Education Department were directly followed up to confirm their involvement in the research and some schools were not willing to participate. Thus, it took about three months to obtain a desired number of schools to be involved. At this stage, we also received the results of TCT from the Education Department as one of consideration in conducting the study. The Education Department was supportive and helpful starting from selecting the school as the objects of the study to inviting the participants to each activity undertaken.

3.2. Planning
The planning conducted consisted of preparation of test items for pedagogical and professional competence in mathematics. This test aimed to determine teachers’ initial ability and examine the materials that were challenging for teachers and difficult to teach to the students. The mathematics test was adapted from the problems of National Exam from the previous years. The problem used was a problem considered difficult and requiring reasoning to examine teachers’ level of mathematics materials and concepts understanding.

At this stage, test and the Focus Group Discussion (FGD) were conducted by involving 45 participants consisting of supervisors, principals, and mathematics teachers, as well as the research team and the expert team of lecturers. The test was administered for three hours for two categories, followed by four hours of FGD located in one of the schools in Pidie district, Aceh. Based on the results of the test and the discussion, six mathematics topics were selected for additional training because they were difficult to be taught to students and difficult to understand by the teachers. Thus, a review of the literature related to the topics and problem identification was conducted, and the problems obtained were also summarized for the planning of training module design.

3.3. Develop preliminary form of product
The activities undertaken were designing the initial product developed namely the training module related to the six mathematics topics selected and considered to be the most challenging. The six topics were Arithmetic sequence and series, Geometry sequence and series, Comparison, Triangle, Plane geometry, and Statistics. Besides, a module validation and an observation guideline were also designed.

There were several stages of designing the training modules included: the introduction discussing the background of training and problems occurred in learning from both teachers and students point of view; aim; general guidance; sources, materials and tools; time; general outline of the activities; and the detail steps of the activity included time spent. The instructions and some notes provided for the facilitator related to the materials and the implementation of the activities were expected to facilitate the facilitator or user in using the module. In addition, there is also a worksheet in the training module that is tailored to the materials (Figure 1).

Revisions were made regarding the content and conformity of the instructions based on the validation results of the modules. Content-related revisions included the misplaced topics such as the Geometry sequence and series located in the Arithmetic sequence and series. Also, there is a problem in the worksheet considered to be less challenging, for example, the Arithmetic sequence problem concerning a sequence of numbers to determine the next term as this types of problem can directly be solved using the formula without a reasoning process.
3.4. Preliminary field testing

Before conducting the pilot study, the second FGD was conducted involving some experts in mathematics, evaluation, and education learning. The experts were limitedly involved in providing feedback to the designed modules. The second FGD results enabled some improvements to the module such as adding contextual questions to assist teachers in solving a problem. Later, a preliminary test was conducted on a limited scale involving three mathematics teachers at one of the junior high schools in Pidie, Aceh. The test results show that most of the contents of the module were correct and appropriate with the mathematics topics, however, more PISA-like problems or problems requiring reasoning were required to be added.

A preliminary test was conducted on a limited scale involving three mathematics teachers in one of the junior high schools in Pidie, Aceh, Indonesia. The test results showed that most of the contents of the module are correct and in line with the mathematical content, however, the reasoning and PISA-like problems (Program of International of Student Assessment) required to be added to the modules.

**Figure 1.** The layout of some revised training module.
3.5. Main product revision
The mathematics training module for six topics was revised based on feedback and suggestions from the preliminary study results. One of the revisions was to add PISA-like questions in the last section of the worksheet for each material. Furthermore, FGD was conducted to refine the developed product involving all research teams including the expert teams and validators to examine the development of the training modules designed. The discussion results suggested that a test should be conducted at the end of the training to determine teachers’ ability to understand and solve PISA-like problems.

3.6. Main field testing
A limited test involving ten mathematics teachers from three secondary schools in Pidie, Aceh, Indonesia for the design of mathematics training module developed was conducted. It aimed to obtain information regarding the application of the product and the level of difficulty experienced by teachers in the trial period. The test results showed that the module was impressive with the challenging and varied problems ranging from the low level to PISA level. This leads the teachers to recall their understanding of the initial concepts related to the topics and solve the high-level questions requiring reasoning.

3.7. Operational product revision
Based on the results of the limited trial, the revision was made to the module by adding the final test of reasoning and PISA level problems. The FGD was conducted by involving the research team to obtain improvements and feedback to the module before the product was expanded. Based on the discussion results, it was agreed to add the tests related to the PISA-like problems at the end of the lesson, as well as correct some typos to obtain a valid and targeted training module. This was a second revision of the modules.

3.8. Operational field test
The revised product was further tested to 25 teachers from ten junior high schools in Pidie, Aceh, Indonesia. The training was conducted for three days involving four lecturers who were expert in the subject matter, mathematics learning, and education evaluation. The activity took place the whole day with different presenter and modules. In addition to product implementation during the training, there were also discussions and interviews with mathematics teachers and school supervisors to obtain the feedback of the training and examine the ability level and understanding of the materials. Most participants provided positive responses of the training because they rarely had the opportunity to participate in the training and they can also learn directly to the experts such as learning geometry material from the expert lecturer of geometry. Also, participants gained new knowledge related Higher Order Thinking Skills (HOTs) and the utilization of the problems. This stage was also conducted to determine the practicality of the module.

The development of the mathematics training modules was only conducted to the stage of obtaining valid and practical modules. The process did involve not only validation but also discussion through FGD involving the expert team, user, and research team. It was aimed to obtain the module designed following the problems faced by the mathematics teacher. These modules dealt with professional competences. According to the Government Regulation Number 74 the Year 2008, professional competencies include the competence for mastering the subject matter in breadth and depth in line with the standard contents of the educational unit program, subject, and/or group of subjects handled. It also covers the relevant scientific concepts and method and technological or relevant artistic that are conceptually coherent with the educational unit program, subjects, and/or groups of subjects handled. Thus, it is crucial to improving the professional competence.

Improving teacher quality is the main priority for the government through its policies. The activities conducted include providing learning resources and manipulative, improving schools’ facilities, as well as teacher training [10]. Teachers can initiate to enhance their professional
competence by reading educational books, writing scientific papers, following the actual news from the media, and participating in the training [11]. In this case, the training should not only focus on the technical training of teaching but also regarding the classroom governance at school, curriculum, and classroom management. Besides, teachers may involve in other activities such as attending a class working group, conducting classroom action research, and actively participating in professional organizations.

This module was developed to assist the government improves the competence of teachers, especially the professional competence. The development of this module satisfied the valid and practical criteria. The validity of the module is used to examine whether the module is adequate and in line with the expected objectives [12]. The analysis of module validation was done by experts including the lecturers and mathematics teachers with several revisions to obtain a valid module. The practicality was indicated by the application of the module during the training. Thus, the module met the needs of the teachers as a user.

4. Conclusion
The development of training modules related to mathematics content knowledge refers to the Borg & Gall development model including ten phases. However, this study was conducted only until the eighth stage as the valid and practical training modules have been obtained. The module considered to be valid based on the mathematics topics and concepts matching both the problems experienced by the mathematics teachers and the applied curriculum. The practical criteria are based on the conformity of the implementation of the training and the designed modules. It is also assessed regarding efficiency, usefulness, and attractiveness, as there are several different sections in the design as well as the instruction and estimated implementation time. Besides, also it is viewed based on the aspect of the legibility of the module and easy to use of the modules. Thus, this module is ready to be used on a large scale to help improve the content knowledge of mathematics teachers.

References
[1] Dinas Pendidikan Kabupaten Pidie 2014 Data Hasil Uji Kompetensi pada 9 Kabupaten Mitra USAID Prioritas Provinsi Aceh untuk Kompetensi Pedagogik dan Profesional
[2] Koehler M J and Mishra P 2009 What is technological pedagogical content knowledge (TPACK)? Contemporary Issues in Technology and Teacher Education 9 60
[3] Shulman L S 1986 Those who understand: knowledge growth in teaching Educational Researcher 15 4
[4] Subramaniam K 2013 Prospective secondary mathematics teachers’ pedagogical knowledge for teaching the estimation of length measurements (Crites 1993). http://doi.org/10.1007/s10857-013-9255-2
[5] Yusuf N Peringkat Uji Kompetensi Guru di Aceh Naik ke Ranking 15 Nasional Serambinews. Kutaraja [Internet] 2018 Agustus 4 [cited 2018 Agustus 4] Available from: http://aceh.tribunnews.com/2018/03/09/peringkat-uchi-kompetensi-guru-di-aceh-naik-ke-ranking-15-nasional
[6] Murthalamuddin Pelatihan Manajemen Sekolah Modul 3 USAID PRIORITAS jenjang SMP/MTs Kabupaten Pidie Dinas Pendidikan Aceh. Banda Aceh 2016 Jan 7 [cited 2016 Jan 7] Available from: http://Disdik.Acehprov.Go.Id/Node/2047
[7] Yuswono L C, Martubi S and Agus B 2014 Profil kompetensi guru SMK teknik kendaraan ringan di daerah istimewa Yogyakarta Prosiding Konvensi Nasional Asosiasi Pendidikan Teknologi dan Kejuruan (APTEKINDO) ke 7 FPTK Universitas Pendidikan Indonesia
[8] Warganegara N S, Berchah P and Hermi Y 2013 Persepsi Guru terhadap Pelaksanaan Uji Kompetensi Guru di SMA Negeri 3 Bandar Lampung Tahun Pelajaran 2012/2013
[9] Jalal F, Samani M, Chang M C, Stevenson R Ragatz A B and Negara S. 2009 Teacher Certification in Indonesia: A Strategy for Teacher Quality Improvement Departemen Pendidikan Nasional Republik Indonesia
[11] Asmarani N 2014 Peningkatan Kompetensi Profesional Guru di Sekolah Dasar *Jurnal Administrasi Pendidikan* **2** 505

[12] Telaumbanua Y N, Sinaga B, Mukhtar M and Surya E 2017 Development of mathematics module based on metacognitive strategy in improving students mathematical problem solving ability at high school *Journal of Education and Practice* **8** 73