Validation of prototype instruments for implementing higher order thinking learning using the IMPROVE method

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Abstract. Indonesian education, as stated in the National Curriculum of 2013, aims to develop higher order thinking skills (HOTS). HOTS are thinking processes that involve higher cognitive level of Bloom's Taxonomy, namely analysis, evaluation and creation. This study aimed to produce a valid, practical and effective prototype of HOTS learning using IMPROVE method. This study employed the Research and Development approach using ADDIE model (Analysis, Design, Development, Implementation and Evaluation). Initial stage of the development of the prototype was carried out by analysing, designing, developing and revising the instrument. Next activity was the validation of the prototype instrument by experts. Based on the validator’s opinion, it was indicated that the prototype of higher order thinking learning using IMPROVE method was valid and practical. It was concluded that the prototype was ready to be piloted at schools to examine its practicality and effectiveness.

1. Introduction
Indonesian education, in the National Curriculum of 2013, aims to develop critical and creative thinking skills, both skills are higher order thinking skills (HOTS). HOTS are thinking processes involving the higher cognitive level of Bloom's Taxonomy, namely analysis, evaluation and creation. The domain of cognitive processes belonging to HOTS is the domain of analysis, evaluation and creation [1]. Analysis is the ability to identify problems systematically, evaluation is the ability to provide reasons for the answers provided, and creation is the ability to design and formulate word problems into a mathematical model to solve the problem.

HOTS is more than simple memorizing or understanding, instead it involves various cognitive processes such as creating, generating ideas, exploring consequences, reviewing, monitoring progress and so on [2]. HOTS tends to involve complex problems having many solutions [3].

Higher order thinking is a thinking process that requires students to use brilliant ideas to apply previously learned knowledge. Thus, this ability supports students to think critically, creatively and reflectively. Students are often confused when they face a complex problem because their teachers do not usually give higher order thinking problems. Most schools tend to emphasize lower order thinking skills in their teaching and learning. The consequence of this habit is that students forget easily and have poor learning outcomes [4]. This is in line with the 2011 Trends in International Mathematics and Science Study (TIMSS) and the 2012 Program for International Student Assessment (PISA) survey that Indonesian students have poor achievement in the international mathematics contests presenting non-routine problems [5]. Furthermore, it is revealed that Indonesian students are poorly ranked in the
TIMSS in terms of understanding complex information, theory, analysis and problem solving, using procedures in problem solving, and investigating [6].

The factors that cause Indonesian learners to incorrectly solve high order thinking problems are being less meticulous in solving the problems, poor initial mathematics ability, ineffective learning, and lack of understanding of the problems [7]. This condition indicates that our educational condition is still not encouraging HOTS. Students’ thinking ability in solving mathematical problems is mainly at the lower order thinking. This is actually the root of the problems that needs to be addressed, like a chronic disease that needs to be immediately treated. This means students’ higher order thinking skills, especially in solving mathematics problems, need to be developed. Students need to be equipped with higher order thinking skills, namely the ability to remember more relevant concepts to a problem and to present alternative solutions before choosing the most appropriate one. In addition, the ability to systematically compile facts in the problems by forming patterns and relationships leads to students being able to simplify complex information using a correct model to solve the problem [8].

One of the promising methods for developing HOTS is the IMPROVE method. IMPROVE is an acronym of Introducing new concept, Metacognitive questioning, Practicing, Reviewing and Reducing difficulties, Obtaining mastery, Verification, and Enrichment. This method develops HOTS by metacognition questions and peers interaction. The metacognition questions are built in four stages of the problem solving process, namely: orientation and problem identification, organization, treatment, and evaluation [9].

The metacognition questions include comprehension questions, strategic questions, connection questions, and reflection questions [10]. It is reported that the average score of the cooperative learning group undergone the metacognitive exercise is significantly higher than the cooperative group without the exercise and groups of individuals undergone the metacognitive exercises on the students’ mathematical representation skills [11].

It is expected that the metacognitive questions, one of the important components in IMPROVE method, can develop students’ HOTS. Therefore, it is necessary to develop a learning of HOTS using the IMPROVE method to produce valid, practical and effective products.

2. Method
Based on the previously mentioned background and conceptual model, the research questions were presented as follows: 1) What were the processes to develop a valid HOTS learning for senior high school students using IMPROVE method? 2) What were the results of the development of a valid HOTS learning for senior high school students using IMPROVE method?

This study employed an R & D Approach based on the ADDIE development model[12], which involved analysis, design, development, implementation and evaluation. The first year of this study focused on assessing the validity of the developed products based on the initial stages of development (analysis, design and development). The analysis phase began with analyzing of the school curriculum, user needs analysis (teacher), and students’ characteristics to obtain information on whether HOTS learning model with IMPROVE method for targeted senior high schools was needed. The second stage was design: determining the basic idea or the design of HOTS learning based on the cognitive orientation, organization and elaboration pattern using the IMPROVE method. The third stage was development which involved the validation of experts and revision.

This research was conducted at three high schools in Banda Aceh. The subject of this pilot study were nine mathematics teachers from the three schools. Initial data collection was done in three stages: (1) Analysis stage, which was also called pre-planning. In this stage, the instruments needed were the curriculum analysis sheet, teacher’s need analysis sheet, and student characteristic analysis sheet. (2) Design stage, the activity undertaken was designing the prototype based on the needs analysis conducted in the first stage. This stage was a systematic process of designing a prototype by setting subject matter and learning objectives, designing lesson plan (LP), discussion worksheet (DW), assignment worksheet (AW), assessment tools and guidelines for using the IMPROVE methods in learning. The instrument required in this stage was the validation sheet. Next, the preparation of lesson
plan started with determining the components of lesson plan such as basic competence, indicators of competence achievement, linkages between subject matter, indicators of competence achievement and time, as well as linkages between scientific approach, IMPROVE method, settings, communicative language. (3) Development was the stage of products realization. In this stage, learning/prototypes consisting of LP, DW, AW, assessment tools as well as the guidelines for using the IMPROVE methods in learning were developed. The products were then consulted with the partner teachers and subsequently validated by two expert lecturers, and two teachers (excluding partner teachers). The validation aimed to determine the quality of the products/prototypes. The validation process was carried out until the developed products were declared feasible to be used in the learning process. The quality of the products were based on the aspect of validity which was obtained at this stage.

There were six instruments involved in this initial stage study, namely: curriculum analysis sheet, requirement analysis sheet, student characteristic analysis sheets, LP validation sheets, DW & AW validation sheets, evaluation tools and guidelines for using the IMPROVE method, and feedback sheet of experts and teachers. Data obtained from the analysis and design stages was then analysed descriptively, while data analysis from the development stage was aimed to examine the validity of the products. To investigate the feasibility of these products, formative evaluation was required at each phase of development, including the phase of expert validation and revision.

Expert validation was aimed to examine one aspect of the products development quality. It was done by expert lecturers and teachers. The validators’ recommendations were necessary to examine the feasibility of the products based on the indicators proposed by Nieveen: 1) at least three out of the four experts (validators) stated that the HOT'S learning prototype using the IMPROVE method was based on a strong theoretical basis, and 2) at least three out of the four experts stated that the components of the products were consistently related [13]. Furthermore, product revision phase I (prototype), for field trial in the second year of this research was carried out after the products had been declared to be feasible by the experts.

3. Results
This section is reported in three parts. Part 1 is the analysis stage, part 2 is the design stage, and part 3 is the development stage.

3.1. Analysis stage
This research was started by administering a questionnaire concerning the curriculum, the needs of teachers, and the characteristics of the students to the nine partner teachers. The results were then analyzed and it was revealed that the students were required to have HOTS even though the teachers did not design topics related to HOT due to lack of literature and lack of understanding of the skills. The teachers expected that the learning model to solve non-routine problems could be used easily with clear steps to encourage students to be more active in order to achieve expected learning goals. Materials needed to be developed were for the topics of algebra, probability, geometry, and trigonometry.

Based on the teachers’ needs analysis on the learning model needed to improve students’ thinking skills, the teachers mentioned that one of the problems in their school today was limited number of books and teaching materials, especially books containing HOTS. In addition, the teachers have never attended training on designing HOTS problems and how to teach them. Thus, they needed additional teaching materials related to HOTS.

Further analysis was carried out to analyze the students' characteristics including mathematics skills and attitudes towards mathematics learning, especially towards HOTS problems. The teachers mentioned that the students were less enthusiastic when they were provided with non-routine problems. The students tended to only listen to what the teacher said. They did not build their understanding of a concept independently. Usually only few students were active in solving the problems given by the teacher. Most of the students were silent or talked among themselves and in the
end they could not solve HOTS problems. Based on the three analysis, it could be concluded that the teachers needed a learning model to promote students' HOTS using the IMPROVE method.

3.2. Design stage
After the analysis phase had been completed, the next stage was to create the design based on the results of previous analysis. The activities undertaken at this stage were designing LP, guidelines for using the IMPROVE method, DW, AW and its evaluation, and the instruments.

At this stage we designed nine LP together with the DW, AW, training and evaluation tools for nine meetings. LP I, II and III focused on algebra and probability; LP IV, V and VI discussed about geometry; LP VII, VIII and IX discussed about trigonometry.

3.3. Development stage
This stage involved the development of HOTS learning (product) and the validation of the instrument. The developed products included LP, DW, AW, exercises and evaluation tool. The learning was developed with regards to the principles and structure of the preparation of LP, DW, AW and its tools by paying attention to eleven criteria/indicators (see Table 1, 2 & 3). The development result was called the prototype 1 design.

The initial product (prototype 1) was then consulted with the partner teachers and some feedbacks were obtained. Validation was done by the validators after the revision to examine the quality of the products. The validation process, which was content validity, was conducted by two expert lecturers (material experts), and two teachers (not from partner teachers). The validation results from these experts were used as a reference to revise and refine the prototype. In tables 1, 2, and 3 below, we can see the prototype validation result.

**Table 1.** The validation results of lesson plan (LP).

| No | Aspect          | Criteria/Indicators                                      | Validators | Mean |
|----|-----------------|---------------------------------------------------------|------------|------|
|    |                 |                                                         | 1  2  3  4 |      |
| 1  | Contents        | Basic competences (KD) & Competence Achievement Indicators (CAI) | 4  4  5  4 | 4.25 |
|    |                 | Conformity of subject matter, CAI and time              | 4  4  3  5 | 4.0  |
|    |                 | Conformity of Scientific Approach and the IMPROVE Method| 4  5  4  5 | 4.5  |
| 2  | Format          | Setting                                                | 4  5  5  5 | 4.8  |
| 3  | Language        | Communicative                                          | 5  3  5  5 | 4.5  |
|    |                 | Average validator                                      | 4.2  4.2  4.6  4.6 | 4.4  |

**Table 2.** Validation results of DW, AW and exercises.

| No | Criteria/Indicators      | Validators | Mean |
|----|--------------------------|------------|------|
|    |                          | 1  2  3  4 |      |
| 1  | Content Eligibility      | 4  3  4  4 | 3.75 |
| 2  | Presentation Eligibility | 3  4  4  4 | 3.75 |
| 3  | Language Eligibility     | 4  4  4  4 | 4.0  |
| 4  | Graphic Eligibility      | 4  5  4  5 | 4.5  |
|    | Average validator        | 3.75  4  4  4.25 | 4.0  |
Table 3. Validation results of the evaluation tool.

| Aspect of problems | Criteria/Indicators                  | Validators | Mean |
|--------------------|--------------------------------------|------------|------|
|                    |                                      | 1  2  3  4 |      |
| Construction       | Problem in accordance with solution  | 4  5  4  4 | 4.25 |
|                    | demands                              |            |      |
|                    | Rubrics                              | 4  3  4  4 | 3.75 |
| Language           | Communicative problems               | 5  5  5  4 | 4.75 |
|                    | Average validator                    | 4.25  4.25  4.5  4 | 4.25 |

The results of the instrument validity presented in tables 1, 2 and 3 show that the validity of the prototype fell in the valid criteria with the average score of 4.22.

4. Discussion
The procedures undertook in developing the prototype to produce a qualified product started from the analysis stage, analyzing the curriculum, teachers needs and characteristics of students, followed by designing the prototype and the validation as well as revision.

4.1. Analysis stage
In the analysis stage, it was found that the HOTS learning using IMPROVE method was important to be implemented. In this stage, it was also revealed that HOTS learning using the IMPROVE method was never done before or it was limited to C4 level with group discussion method. The Directorate of High School Development said that there were three criteria of teaching materials: (1) the availability of materials according to curriculum demands, meaning that the development of learning materials must be in accordance with the curriculum, (2) characteristics of the target, meaning that the developed learning should be tailored to the characteristics of students as target, covering the social, cultural, geographical and developmental stages of students, (3) the development of learning should be able to solve problems or difficulties in learning [14]. Thus, the prototype that has been developed in this study could satisfy the three criteria of teaching materials.

4.2. Design stage
The activity undertook at this stage was the selection of initial formats and HOTS learning. Some of the difficulties encountered in this stage included the lack of teaching materials consisting HOTS problems; it was difficult to distinguish the problems in the cognitive domain of C4, C5 and C6; and it was difficult to find references concerning the IMPROVE method. Nevertheless, the design of this HOTS learning could be designed well with solid teamwork.

4.3. Development stage
The development stage was the products/prototypes realization. A product based on the framework from the design stage was developed. The products/prototypes were LP, DW, AW, exercise, and evaluation tools as well as learning guidance of the IMPROVE method. These products met the valid criteria based on the result of lecturers and teachers’ assessment. Although they had achieved good classification, as shown in tables 1, 2 dan 3, the material distribution aspect had a low score compared to the other aspects. In order to develop the lesson plans better, the feedbacks given by the assessor was adjusted in the material distribution to the allocated learning time. Meanwhile, based on the validation sheet, the average score was 4.22, this indicated that the prototypes met both criteria: based on a strong theoretical basis and had consistently interrelated components. This is in accordance with the indicators of validity analysis developed by Nieveen. Such studies have been conducted by Leiris et al. about “validation of indicators for implementing an adaptive platform for MOOCs”. The score of
the internal consistency, which was statistically evaluated using Cronbach’s alpha, was greater than 0.8, indicating good internal consistency [15].

5. Conclusion

The HOTS learning was developed based on ADDIE theory consisting of five stages, namely Analysis, Design, Development, Implementation and Evaluation. For this year, the process of developing the prototype was conducted in the first three stages of ADDIE model, they were: (a) the stage of analysis, determining the information and needs of the HOTS learning. In this stage, data on the curriculum description used in the schools, teacher needs analysis and characteristic analysis of students. (b) The design stage, obtaining overview of the prototype to be designed based on the needs analysis conducted in the first stage. This stage begins by designing LP, DW, AW, evaluation tools, guidelines of the IMPROVE method, and validation sheets for feedbacks of the designs; (c) The development stage, developing prototypes in the design phase, based on the validation results from the experts to be tested at the partner schools. Based on the development process of three stages of the ADDIE model, it was concluded that the prototype of HOTS learning using the IMPROVE method was valid and practical.

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