Development of algebra test questions based on Bloom’s taxonomy

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Abstract. In Indonesian mathematics textbooks, most of exercise questions for year 8 Algebra are at C1 and C4 levels of taxonomy bloom. Therefore, questions of C5 and C6 level are rarely found. This study aimed at developing Algebra test items for C5 and C6 level of the taxonomy. It employed Plomp’s design research model. However, it is important to highlight that this paper only reports the validation phase of the study which was the analysis of the validity of C5 and C6 Algebra test items. Responses and feedback from four validators were analyzed descriptively and reported in this paper. The findings showed that the items test were valid and standardized at the cognitive level of C5 and C6. According to the feedbacks from validators, we revised the items. Finally, it can be concluded that the items satisfy the criteria of C5 and C6 with a validity score of 4.7. As the items satisfied the valid criteria, it is suggested that these questions can be used to further test their practicalities and effectiveness.

1. Introduction
International assessment such as TIMSS and PISA in 2015 show that Indonesian students’ performances were poor. It is due to Indonesian students were not familiar with high order thinking problems that require students to analyze real-world problems in a mathematics model [1]. The students’ difficulty in answering TIMSS and PISA questions indicates that students’ cognitive levels do not fit with the level of questions. Therefore, they found difficulties in solving the questions.

Another reason for the problem mentioned above is that, in the teaching process, Indonesian students are hardly exposed to problems that relate to a real-world situation. It happens since students are mostly assigned to solve closed-ended questions that have only one solution, which prevents students from finding other possible solutions. Furthermore, most of the test items do not fit to measure students’ competency [2,3]. In the teaching and learning mathematics in secondary schools, cognitive competence plays an important role in enhancing mathematical literacy. Therefore, the quality of test items requires to be aligned with Bloom’s cognitive taxonomy.

In the Indonesian context, textbooks are required to be utilized in teaching and learning process at schools. Most of the problems and exercises in mathematics textbooks are procedural-oriented questions that do not require students’ creative thinking to solve them [4]. Previous studies on textbook analysis showed that Indonesian secondary mathematics textbook mostly present low cognitive level questions, therefore, it needs improvement of the question quality [5,6,7]. For instance, compared to other Asian countries such as China and Saudi Arabia, Indonesian mathematics textbooks have lower quantities of mathematical proofs [8].
It is widely believed that students find mathematics difficult to master, including the topic of algebra. The main difficulty in learning algebra is how to use symbols of mathematics. Algebra emphasizes on the aspect of analysis as well as representation of mathematical concepts and ideas. In the curriculum 2013, Algebra is one of the main competencies that need to be mastered by students. It is essential for the students to master Algebra as the subject is applicable to daily life. For instance, NCTM reveals that Algebra helps students to connect mathematical ideas that are utilized in various fields, either mathematics or other fields [9].

Concerning the condition presented above, the researcher develops the learning instrument using the development model of Plomp and Nieveen [10]. This model consists of three phases: preliminary research, prototyping phase, and assessment phase. However, this paper only focuses on the prototyping phase to determine the validity of the learning instrument.

2. Method
This study adopts Plomp and Nieveen’s model of developmental research. As previously mentioned, this paper reports the prototyping phase. The preliminary stage is divided into 2 stages, namely the analysis and problem questioning phase. The analysis phase is the first step of development research. In the analysis phase, we analyzed textbooks. In this phase, it was found that there is only one problem for the C5 level and there is no question for the C6 level in exercise of algebra. Therefore we need to develop algebra item test for the C5 and C6 levels.

The second phase is prototyping. Thus, in this stage, we developed C5 and C6 questions based on indicators adapted from Bloom’s taxonomy. The items were validated by a panel expert consisting of one lecturer who is an expert on high order thinking tasks as well as three mathematics teachers. It is important to remind the reader that this paper only presents the validation phase of the development of the test items.

We conducted the following steps to establish validity of the questions: (1) Conducting recapitulation of feedbacks from the validators, (2) Determining average scores of validity for each criterion, (3) Counting average scores for each aspect, (4) Counting total of average scores, and (5) Interpreting total of average scores according to the criteria presented in Table 1.

| Criteria            | Average score |
|---------------------|---------------|
| Very Valid          | 4 ≤ Average Score < 5 |
| Valid               | 3 ≤ Average Score < 4 |
| Reasonably Valid    | 2 ≤ Average Score < 3 |
| Not Valid           | 1 ≤ Average Score < 2 |

If the validity scores fall into the criteria of very valid, it can conclude that the algebra test items are qualified to be utilized in the next phase which is the pilot study in the classroom. On the other hand, if the scores fall into the criteria reasonably valid and not valid, we would revise the test items.

3. Results and discussions
As mentioned earlier, this paper reports the prototyping phases of the development of algebra test items. In the phase, we developed algebra test items at C5 and C6 level of taxonomy bloom. The test items then reviewed by experts in order to determine the validity. Table 2 summarizes average scores for each criterion based on feedback from the experts.

The results showed that the test items were valid in terms of quality. Validators’ reviews showed that the questions were aligned with C5 and C6 bloom’s taxonomy in terms of content. The items were also valid in terms of context, competence, and indicators such as: identifying mathematical
statements that were relevant to mathematics problems; developing supporting and contra arguments; using standardized language.

Table 2. Results of validity

| Aspect       | Criteria                                           | Validator | Average of each criterion | Average of each aspect |
|--------------|----------------------------------------------------|-----------|---------------------------|------------------------|
|              | Test items align with the criteria                | V1        | 5                         | 4.8                    |
|              |                                                    | V2        | 5                         |                        |
|              |                                                    | V3        | 5                         |                        |
|              |                                                    | V4        | 4                         |                        |
| Content      | Test items align with C5 and C6 bloom’s cognitive level |           | 5                         | 4.5                    |
|              | The numbering system is clear                      |           | 4                         | 4.6                    |
| Format       | Layout                                             |           | 4                         | 4.8                    |
|              | Font                                               |           | 5                         | 4.9                    |
|              | Language                                           |           | 5                         | 4.5                    |
|              | Structure of sentence                              |           | 4                         | 4.5                    |
|              | Simple guideline and direction                      |           | 5                         |                        |
|              | Communicative language                             |           | 4                         | 4.7                    |
|              | Total of average score                             |           | 5                         | 4.8                    |

The next step was to revise the questions based on validators’ review. We deleted unnecessary questions as well as added some important parts of the test items. Therefore, Table 3 shows the corrections of the test items.

Table 3. Validators’ comments and suggestions

| No. | Validator | Comment and suggestion                        |
|-----|-----------|-----------------------------------------------|
| 1.  | V1        | Revise item 1 and 4                           |
| 2.  | V2        | Revise item 1 since it is not aligned with indicators of C6 |
| 3.  | V3        | The item is appropriate                       |
| 4.  | V4        | The question is in accordance with the cognitive level |

It shows that the validator required revising item 1 and 4. Questions’ guideline and indicator were not appropriate to measure students’ cognitive level, including the ambiguity of language. Therefore, based on the review from the validators, we revised the items. Table 4 shows the corrections for item 1 and 4.

In the first version of the test items, we indicated that question number 1 as a C6 item. However, after the review and correction process, based on the indicator, this question falls into the criteria of the C5 cognitive level.
Before the validation process, as presented in Table 5, we classified item number 2 into the category of C6 cognitive level. However, the validator suggested that item is suitable for C5 cognitive level. This classification is based on language and instruction of the question.

### Table 4. Item 1

| No. | First Edition | Correction | Reasons |
|-----|---------------|-------------|---------|
| 1.  | Item number 1 | C6          | This item requires students to analyze their strategies and solutions as well as students’ decision making in providing the best solution. |
|     | Najwa chooses three positive integer numbers a, b, c. Alifah determines the value of \( \frac{a + b}{c} \), and find that it is 101. Naufal determines the value of \( \frac{b + a}{c} \), and find that it is 68. Dzaky determines the value of \( \frac{a + b}{c} \) and find that it is .... | C5          | Item number 1 There are three positive integer numbers a, b, and c. Alifah uses these numbers to determine the values of \( \frac{a + b}{c} \) and find that it is 101. Furthermore, Naufal uses the number to determine the value of \( \frac{b + a}{c} \) and find that it is 68. In addition, Dzaky determines the value of \( \frac{a + b}{c} \) and find that it is k. What is the value of k? |

### Table 5. Item 2

| No. | First Edition | Correction | Reasons |
|-----|---------------|-------------|---------|
| 2.  | Item number 2 | C6          | This item requires students to analyze their strategies and solutions as well as students’ decision making in providing the best solution. |
|     | 702, 787 and 855 when divided by \( m \) result a positive residual \( r \), whereas 421, 722 and 815 divided by \( n \) leave a residual \( s \), with \( r \neq s \). Please determine \( m + n + r + s \). | C5          | Item number 2 702, 787 and 855 when divided by \( m \) result a positive residual \( r \), whereas 421, 722 and 815 divided by \( n \) leave a residual \( s \), with \( r \neq s \). Please determine \( m + n + r + s \). |

Furthermore, Table 6 presents results of validators’ response to item 3. It shows that the validators agree that it does not require correction of this item in terms of language and cognitive level.
Another correction was for question number 4. As presented in Table 7, the first version of this question had language problems. The validators suggested that language level have to be suitable with the intended cognitive level. In the first version, language and guideline of questions for item 4 were not clear. Therefore, the item required language improvement in to develop an item that is suitable to measure the intended cognitive level.

Table 6. Item 3

| No. | First Edition Cognitive Level | Correction Cognitive Level | Reasons |
|-----|-------------------------------|----------------------------|---------|
| 3   | Item number 3 C6              | Item number 3 C6           | This item provides a problem that requires students to determine a mathematical formula based on provided information and solve the problem by using the formula. |
|     | When a positive integer is divided by 7, the remainder is 2. When it is divided by 8, the remainder is 3 | When a positive integer is divided by 7, the remainder is 2. When it is divided by 8, the remainder is 3 | |
|     | a. Please determine a formula that satisfies the above statement | a. Please determine a formula that satisfies the above statement | |
|     | b. What is the smallest positive integer that satisfies the above statement | b. What is the smallest positive integer that satisfies the above statement | |

Table 7. Item 4

| No. | First Edition Cognitive Level | Correction Cognitive Level | Reasons |
|-----|-------------------------------|----------------------------|---------|
| 4   | Item number 4 C6              | Item number 4 C6           | This item provides a problem that requires students to determine a mathematical formula based on the provided information and to solve the question by using the formula. |
|     | Determine ten numbers that are not formed of a sum of several sequential numbers. For example, 5 = 2 + 3, 6 = 1+2+4. | There are several numbers that are formed of sum of several sequential numbers. For example, 5 = 2 + 3, 6=1+2+3. Determine ten numbers that are not form of the sum of several sequential numbers. | |
This study was conducted based on the previous study that found that there was no question for C5 and C6 cognitive level. On the other hand, according to Sudjana [11], the best proportion is that percentage of C1 and C2 is 30%, C3 and C4 is 40% and C5 and C6 is 40%.

This paper reports the second phase of Ploom’s model of design research that is prototyping phase. Hence, we only report the validation of instruments developed in this study. Several researchers have also reported findings from the prototyping phase of their studies [12,13,14]. Moreover, there are several advantages of C5 and C6 level of test items such as through high order thinking (analysis, evaluation, and creation) student would enhance their knowledge and skills [15]. In addition, students who are familiar with high order thinking questions will have high order thinking skill that supports their academic achievement [16].

However, this study has a limitation since the developed C5 and C6 level test items for algebra topic only involved validity test. Therefore, in the future study, we suggest that the test items are utilized in the classroom to examine their effectiveness.

4. Conclusion
It is concluded that this research has produced valid Algebra test items at C5 and C6 cognitive level for teaching and learning mathematics at Year 7 with validity score was 4.7. Review form expert shows that the test items are appropriate to be piloted in the classroom. Therefore, the piloting step will be the next phase of this study.

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