Open-ended mathematics module to improve students’ higher order thinking skill

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Abstract. Higher order thinking skill (HOTS) is a more complex thinking skill using cognitive domains in C4 (analyzing), C5 (evaluating), and C6 (creating). This study aims to develop an initial mathematical module based on a valid prototype of open-ended mathematics module to help students to improve HOTS on the material of linear equation system in two variables. An open-ended approach is one of the learning approaches that can be used to increase HOTS students. This type of study was research and development (R&D). There are three stages of development research, namely (1) preliminary study consisting of 3 steps, namely initial research, analysis of the needs, and literature study, (2) product development consisting of three steps namely planning, initial product development, product testing and revision, (3) product efficacy testing, which is the stage of comparing modules developed with existing products. This research was conducted on the eighth-grade students of a public junior high school in Surakarta. The results obtained from this study was the average results of each initial module validation by media experts, material experts, and language experts are 3.27, 3.21, and 3.77. The product prototype is valid so it can be used to measure students’ HOTS.

1. Introduction
Students' thinking skills affect learning ability, speed, and effectiveness so that thinking skills are linked to the learning process [1]. Mathematics as a science is very important to learn by students because it can develop a high order thinking skill (analysis, evaluating, and creating) [2, 3]. Mathematics is integrated in one field of education so that it can encourage students to think by connecting with one another or as a whole so that thinking skills are needed in solving mathematical problems [4]. Cognitive abilities in the revised of Bloom’s taxonomy are divided into two, namely lower order thinking skill (LOTS) and higher order thinking skill (HOTS). This is in line with the opinion by Abosalem [5], dividing thinking skills into high level skills and low level skills can make it easier for educators to help low category students before students turn to higher thinking skills.

The division of thinking skills also develops activities that can be carried out by high category students and places the students at the appropriate level [5]. Lower skills require an application and routine steps [6], while HOTS encourages students to be able to interpret, analyze, or manipulate existing information [7]. HOTS directs students to manipulate information through the existing knowledge in order to be able to find answers in new problems [8]. There are six cognitive levels in the revision of Bloom's taxonomy, namely remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6) [9]. Among them, the skills of analyzing (C4), evaluating (C5), and creating (C6) are HOTS, while remembering (C1), understanding (C2), and applying (C3) are LOTS [9]. HOTS occurs when students have the skills to analyze data or
information that students will then process to be presented in different forms [10]. Students who have these skills show excellent performance in comparing, differentiating, organizing, classifying, and identifying causes and effects from a perspective [10]. HOTS indicators are based on the revised Bloom’s taxonomy. They are: (1) analyzing consisting of differentiating, organizing, and attributing, (2) evaluating consists of checking and critiquing, and (3) creating consisting of generating, planning, and producing [9]. This study used six HOTS indicators, namely differentiating, attributing, checking, critiquing, planning, and producing.

In general, students' mistakes in solving mathematical problems are conceptual errors, principle errors, or operating errors [11, 12]. The stages carried out by students in completing mathematical questions can give clues to the extent of students' thinking skills. Students still make many mistakes in solving mathematical problems [11, 12]. For example, research conducted by Mirna [11], shows that at 67.80% of students have not been able to work on one question related to concept definition. Errors that occur in 67.80% of students cannot write the information provided, write what is asked, operate the computation, draw up a plan, and look for other possibilities on the problem. These errors are related to HOTS. HOTS can improve student performance and reduce student weakness [13]. Therefore, HOTS is needed to help students interpret, analyze, manipulate information, evaluate, and create concepts based on existing experience.

Students’ errors also occur because students are given material with formulas and so on but students have not been able to apply and analyze the formula [14]. In Indonesia, 2013 curriculum books are available both as guidelines for teachers and students. But the learning process in schools still uses textbooks that are marketed because students are considered to be less able to learn to use these student books. The textbook used is still a lot of using routine problems so that it is less able to encourage HOTS students. This is also supported by research conducted by Mutmainah [15] that one of the factors causing the low mathematical ability of students is the lack of teaching materials that meet the needs of students. So, educators need to provide learning media that can support HOTS students.

The teacher is one of the subject educators who play a role in developing students' thinking abilities [14]. Therefore, teachers need to make innovations to support learning so that they can encourage and improve HOTS students.

One of the materials that are effective, efficient and give priority to the independence of the student is learning materials in the form of modules [16]. Teachers can develop modules that can help the learning process with the aim of increasing HOTS students. In addition to paying attention to learning media, teachers can also use learning approaches to support the modules developed. One learning approach that can be used is an open-ended approach. Open-ended help students to develop their potential and are free to put their thoughts into the given problem [17]. There is a potential effect on students' mathematical abilities by giving open problems or open questions [18]. By using open-ended problems, the basic concepts can be explored, so the students do not only recall certain facts but almost all possible facts to solve the problems [19].

Several studies related to HOTS have been conducted by Apino and Retnawati and Heong at al [20, 21] with the conclusion that HOTS of students is still low. Based on the above description and previous research, the purpose of this research was producing an initial mathematical module based on an open-ended approach to improve student HOTS which is valid.

2. Method
This type of study was Research and Development (R&D). This research is producing and developing a mathematical module based on an open-ended approach to improve HOTS students. The subjects of the trial in this research were grade eighth-grade students of a public junior high school in Surakarta. The procedure of development research refers to the stages of development research according to Budiyono [22] which has been modified by researchers. Figure 1 shows a flow chart of the development research process.
Figure 1 shows that the research method consists of several stages, namely (1) the stage of the preliminary study, (2) the stage of product development, and (3) the stage of product efficacy testing. The stage of the preliminary study consisting of initial research, analysis of the needs, and literature study. Initial research and needs analysis were carried out simultaneously. Data retrieval is done through interviews and initial tests. Initial tests were conducted by giving HOTS tests on the material in linear equation system in two variables to determine students’ HOTS abilities. The second stage is the stage of product development which consists of planning, developing the initial module, and testing and revising the module. This research was limited to the stage of product development namely on developing the initial module. Researchers make theoretical product planning, then theoretical products are developed into initial modules (prototypes). The researcher also made instruments in the form of assessment sheets for media experts, material experts, and language experts who were used to assess the initial module.

The results of the validation obtained from the expert assessment sheet, both media experts, material experts, and language experts in the form of qualitative data so that before being analyzed must be converted into quantitative data rules. The initial module (prototype) in this study is said to be valid if the results obtained from the module assessment score analysis show that the initial module developed is included in the criteria of good or very good or is in the range $2.50 \leq \bar{x} \leq 4$.

### 3. Result and Discussion

The results of this study are mathematical modules based on open-ended approach to improve student HOTS is valid. In this study, the results and discussion contained a description of the preliminary study and product development stages. The stage of product development was limited to the planning and developing the initial module.

#### 3.1. The stage of the preliminary study

The preliminary research consisting of initial research, analysis of the needs, and literature study.
3.1.1. Initial research

Interviews were conducted with several teachers. The aim is to find out what students needed in the learning process, how the learning process took place, the learning model or approach used, the textbooks used, student enthusiasm when learning, and what problems are encountered during learning. The result interviews are learning using books provided by the government or marketed textbooks, students are less active in asking questions and opinions in class. Students memorize more formulas than understanding formulas or concepts.

The researcher also gave HOTS tests to determine the initial ability of HOTS students. Six essay questions given to 77 students, obtained the reliability of 0.7415. The average score of the HOTS indicator is 1.1837 and the standard deviation is 0.2421. It was found that HOTS of students SMP was still low. The results of the initial research are that the indicator of differentiating and the indicator of checking include the medium category, the indicator of attributing is the high category, while the indicator of critiquing, an indicator of planning, and indicator of producing include low categories.

3.1.2. Analysis of the needs

Analysis of the needs aims to find out what the teacher or student needs in the learning process to support HOTS. As explained earlier, analysis of the needs was conducted at the same time as the initial research.

Students find it difficult to understand printed books from the government or textbooks that are marketed so that students are passive and difficult to learn independently. The learning process at school is usually fixated on books, students are less active or still centered on the teacher, the learning method used lectures, giving homework assignments, and assessments of students are not based on the task completion process [23]. Students' ability to solve HOTS questions for linear equation system in two variables material in the form of everyday problems or open-ended problems is still in the low category. Students are not active in learning so learning is still teacher-centered.

Based on some of the things found, students and teachers need teaching materials that are easily understood and can be used independently by students. In this case, the researcher developed a module. Module development aims to help students learn independently, to increase learning enthusiasm and improve student learning outcomes [24].

This study developed an initial module based on the open-ended approach to improve students' HOTS. The initial module is a prototype that was developed based on theoretical products but has not been validated by experts. The initial module design is then validated by experts.

3.1.3. Literature study

Then a literature study is conducted to examine the things that are the focus of the study. The literature study stage is carried out to obtain information about module theory, HOTS, open-ended approach, and linear equation system in two variables material. This information can be obtained through books, journals, and other sources.

The results of the literature study on the module are the characteristics of the module, the function and purpose of the module, the module preparation procedure, and the module framework. Mathematical modules based on the open-ended approach are teaching materials in the form of print media in the field of mathematics that are arranged systematically by involving real and open problems to guide students to gain experience or new knowledge that can be useful in understanding mathematical concepts. HOTS is a skill at a higher level, to distinguish ideas or facts and use these facts to get other knowledge to get solutions to the questions or problems presented [25]. The material in the initial module was developed based on the 2013 curriculum, namely Basic Competency 3.5: explaining linear equation system in two variables and their solutions related to contextual problems and Basic Competency 4.5: solving problems related to linear equation system in two variables.
3.2. The stage of product development
The next stage is the stage of product development which consists of planning, developing the initial module (prototype making), and testing and revising the module. This research was limited to the developing of the initial module.

3.2.1. Planning
Planning stage, namely planning what products and what kind is developed by the needs of students on learning activities. The purpose of this development is to obtain module that can improve students’ HOTS, which is a mathematical module based on an open-ended Approach that is valid, practical and effective. Display modules attractive and interactive. Initial modules are equipped with the characteristics of the open-ended approach. This module is used by grade VIII of students of junior high schools in Surakarta. The researcher made an expert assessment sheet, teacher response questionnaire, student response questionnaire, and HOTS questions. The discussion this time is limited to the validity of the module based on the results of the assessment of experts.

3.2.2. Developing the initial module (prototype making)
Initial product design development in the form of theoretical planning that will be produced is called the theoretical product [22]. The theoretical product in this study is a module developed in A4 size (21 × 29.7 cm), sentence structure follows the rules of the General Guidelines for Indonesian Spelling, and the Subject Object Predicate, 57 pages thick, font size 12, font types are Times New Roman and Cooper Black. The developed module consists of three parts, namely the beginning, the core, and the end. Then develop theoretical products into prototypes or initial modules.

The prototype module that was made is a ready-made module but it cannot be tested yet. So that validation is done to the experts before being trialed in the field. The prototype product was validated by three experts namely material experts, media experts, and language experts. The initial part of the module consists of a cover, preface, table of contents, and glossary. The table of contents view and glossary are not presented. The table of contents contains a module frame with page numbers. Each part of the module is indicated by a page number. The glossary contains the understanding of foreign terms or words. The module cover is shown in Figure 2.

![Figure 2. Cover](image)

The cover consists of the title of the module, the name of the author, the target audience of the odd semester VIII grade students, some illustrations or graphs that represent the module discussion, and there is a 2013 curriculum logo. The title of the module is linear equation system in two variables. At the bottom right of the cover, there is a biodata of the module owner in the form of name, class, and school name. The next part of the preface is shown in Figure 3.
The preface contains information about the role of the module in learning, thanks to those who have helped in the process of making the module, and a brief overview of the discussion in the module. Next is the core part. The core part consists of the introduction and learning activities. At the core part, the characteristics included in the open-ended approach are to present open problems or everyday problems, then there are instructions for students to find patterns to construct their problems, there is room in the module to display student answers in many ways, and students are given the opportunity to present the findings either written on the module or presented to the class. The introduction includes a description of the module, basic competencies and indicators achievement of competence, instructions for using the module, and a concept map. Learning activities contain module material, student worksheets, evaluation of learning activities, summaries, and competency tests. In the introduction, a display of a concept map will be presented, while learning activities will display material and student worksheets. The concept map display is shown in Figure 4.
The concept map contains a description of the order of linear equation system in two variables material and linear equation system in two variables sub-materials. Then the module material display is shown in Figure 5.

Figure 5. Module material

Modul materials contain learning objectives, elaboration of linear equation system in two variables material supported by examples or activities, and sub-material conclusions. Figure 6 shows the appearance of the student worksheet.

Figure 6. Student worksheet
To strengthen the understanding of the concepts/knowledge/principles of knowledge learned, this module provides individual and group student worksheets. Student worksheets contain a problem and then there are instructions to solve so students can learn independently and be able to understand the subject matter. The end contains the answer key and bibliography. For display, the answer key can be seen in Figure 7.

![Image of answer key](image_url)

Figure 7. Answer key

The answer key contains the answers to the evaluation questions on each learning activity and answers to the competency test. This answer key is equipped with an assessment score.

3.3. Result of initial module validation
The initial module developed are arranged sequentially according to the stages of development from the beginning, core, and end sections. The initial module is developed from theoretical products according to results in preliminary stages and planning. The initial module is equipped with various images or illustrations that can attract students to actively learn to use the module. This initial module was arranged based on the characteristics of the open-ended approach to be able to improve HOTS. The initial module can be used if it is valid. The module is validated by experts.

The experts consisted of 3 experts namely media experts, material experts, and language experts. Media expert is Anggit Prabowo, M.Pd. from the Mathematics Education Study Program at Universitas Ahmad Dahlan Yogyakarta. Material expert is Drs. Edi Prajitno, M.Pd. from the Mathematics Education Study Program at Universitas Ahmad Dahlan Yogyakarta. Language expert is
Sugeng Supriyono, S.S., M.Pd. from the Indonesian Language Study Program at Universitas Respati Yogyakarta. Validation is carried out using instruments of validation sheet containing assessment sheet is in the form of a checklist that uses a Likert Scale with a scale of 4 that has been reviewed by the lecturer. After the initial module is said to be valid based on the results of the experts' validation, the initial module can be tested. However, this paper is limited to discussing the validity of the initial module or limited to the development of the initial module. Suggestions and comments from experts are summarized in Table 1.

| Suggestions and comments                                      | Follow-up                                      |
|--------------------------------------------------------------|------------------------------------------------|
| There is an incorrect mathematical symbol                    | Fix mathematical symbol                        |
| Concept maps do not correspond to systematic module material  | Customize the concept map with the module material |
| Some number of errors in the material or tests in the module | Correct numbers in the material or tests in the module |
| The cover image illustration does not match the material     | Adjust the illustration of the image on the cover with the material |
| Writing cut in the dividing line                             | Improve writing so that it doesn't get cut off |
| Incorrect size of writing                                    | Equate the size of the writing                 |
| Inconsistent in the use of a word                            | Use a word consistently                        |
| Use of sentences that do not fit the language standard       | Change the sentence to match the standard       |

After the researchers revised the initial module according to the advice of the experts, then it was validated again. Table 2 shows the results of the initial module validation calculations by experts.

| Assessors                        | Total score | Average score | Category    |
|----------------------------------|-------------|---------------|-------------|
| Anggit Prabowo, M.Pd.            | 72          | 3.27          | Very Good   |
| Drs. Edi Prajitno, M.Pd.         | 90          | 3.21          | Good        |
| Sugeng Supriyono, S.S., M.Pd.    | 49          | 3.77          | Very good   |

Module validity shows harmony, meaningfulness, and usefulness of conclusions that have been made. The higher the product validity, the better the conclusions are drawn, and the better the significance of the usability index [26].

4. Conclusion
This research is only limited to the product development stage, namely the development of prototype modules or initial modules. The initial module design has been developed based on the results of preliminary studies, namely data obtained in initial research, analysis of the needs, and literature studies. The initial module is structured based on an open-ended approach to improve students' HOTS. The initial module consists of three parts, namely the beginning, the core, and the end part. The average validation result of all validators was 3.42 meaning that the module meets the criteria very good. Therefore, this module is valid and feasible to be used as a reference for teaching materials in the learning process. In line with Yuni and Thohiri [26], this module is arranged systematically so that users can understand the material easily. To develop this module, the researcher will continue the product trial stage (limited scale test and wide-scale test), and the product efficacy testing stage. The mathematics module based on the open-ended approach is expected to be able to improve students' students' HOTS.
Acknowledgment
We thank the experts who have been willing to become the validators of this research module. Thanks a lot to all committee of AD INTERCOMME 2019 has assessed our writing.

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