Development of student worksheets assisted by GeoGebra application in improving higher-order thinking ability in mathematics learning

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Abstract. This research was motivated by the low thinking level of SMK Mega Link Majene students in solving higher-order thinking problems and inadequate math teachers using mathematics applications in the learning process. This study aims to develop student worksheets assisted by the GeoGebra application to develop higher-order thinking skills. This research is Research and Development (RnD) using the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation). The participants were 27 eleventh-grade students of SMK Mega Link Majene. The instruments were tests, student activity observation sheets, teacher implementation sheets, and questionnaires. The student worksheets should meet the characteristic of helping students develop higher-order thinking skills—analyzing, evaluating, and creating. The results showed that the student worksheets were in the valid category. The worksheets also fulfilled the practicality category: the learning implementation was well-executed, and met the effectiveness categories: (1) the students’ high-level thinking ability in mathematics on average was in the high category; (2) student activity was in the very active category; and (3) student responses to the student worksheets assisted by the GeoGebra application obtained a very positive response. The findings implied that the development of student worksheets assisted by the GeoGebra application met the valid, practical, and effective criteria.

1. Introduction
Higher-order thinking skills (HOTS) are one of the abilities students need to face the global world's challenges. This will support the student’s ability to complete the Program for International Student Assessment (PISA) test [1]. The PISA results for Indonesia in 2018 have been announced by the Organization for Economic Co-operation and Development (OECD). The PISA aims to evaluate the education system by measuring students’ performance in secondary education, especially in three main areas, namely mathematics, science, and literacy. The PISA 2018 results from the OECD Head of Early Childhood and Schools involved 12,098 students from 399 schools in several Indonesia regions considered representative. In the PISA 2018, Indonesia obtained math and science scores below the OECD average of 489. Indonesia's PISA score for mathematics ranged from 379, and science was at 396. Simultaneously, China and Singapore ranked high for math scores with 591 and 569, respectively. The PISA results in 2018 was an early alarm for a shift in Indonesia’s paradigm of education for mathematics competence, where 71 percent was still below the minimum competency.
One way to foster students’ HOTS in learning mathematics is to develop learning instruments, including student worksheets, which contain HOTS questions. It is in line with research stating that it is essential for students to practice higher-order thinking skills using standardized mathematics problems, such as PISA, TIMMS (Trends in International Mathematics and Science Study), or HOTS questions [2]. Moreover, there is a significant difference in the science process and HOTS between students taught using problem solving-based physics student worksheets and conventional student worksheet [3]. Simultaneously, research in developing student worksheets based on open-ended questions was proven to have a potential effect on students’ mathematics learning outcomes [4]. According to [5] and [6], a student worksheet is a learning resource and learning media that can help students and teachers create effective interactions in the learning process. It is aligned with research stating that the student worksheet contains brief descriptions of the material and questions arranged step by step in an orderly and systematic manner. In the learning activities, students must understand the lesson they get [7]. The benefits of student worksheet are (1) engaging students in the learning process, (2) helping to develop concepts, (3) training students in finding and developing process skills, (4) as guidelines for educators and students in carrying out the mathematics learning process, (5) helping students obtain notes about the lesson studied through the learning activities and (6) adding information about the concepts learned through systematic learning activities.

Mathematics is a lesson that must be understood, not only memorized. To help students understand mathematics, teaching mathematics can be accompanied by learning media, such as the GeoGebra application. The use of student worksheets assisted by GeoGebra applications is an alternative expected to improve students' HOTS. According to [8], GeoGebra is a software that can visualize mathematical objects quickly, accurately, and efficiently. This is in line with the research findings revealing that the GeoGebra application immensely helped mathematics teacher professional development forum or Musyawarah Guru Mata Pelajaran (MGMP) of SMK Majene Regency [9].

The revised Bloom's taxonomy has two different thinking processes, namely higher-order thinking skills (HOTS) and lower-order thinking skills (LOTS) [10]. Lower-order thinking skills involve the ability to remember (C1), understand (C2), and apply (C3), while higher-order thinking skills involve analysis and synthesis (C4), evaluate (C5), and create or creativity (C6). Figure 1 illustrates the HOTS-LOTS of Bloom's taxonomy pyramid.

Figure 1. HOTS - LOTS Bloom’s taxonomy.
Moreover, indicators measuring higher-order thinking skills \[11\] are presented in Table 1 below.

| No. | Indicator | Description |
|-----|-----------|-------------|
| 1.  | Analyze  | 1.1 Analyze the incoming information and divide or structure the data into smaller parts to identify patterns or relationships. |
|     |           | 1.2 Recognize and differentiate the causes and effects of a complex scenario. |
|     |           | 1.3 Identify/formulate questions. |
| 2.  | Evaluate | 2.1 Provide an assessment of solutions, ideas, and methodologies using suitable criteria or existing standards to ascertain their value of effectiveness or usefulness. |
|     |           | 2.2 Make hypotheses, criticize, and examination. |
|     |           | 2.3 Accept or reject a statement based on predetermined criteria. |
| 3.  | Create   | 3.1 Generalize an idea or way of looking at something. |
|     |           | 3.2 Design a way to solve the problem. |
|     |           | 3.3 Organize elements or parts into new structures that have never existed before. |

2. Methods
This type of research is developmental research (Research and Development) with the ADDIE model to produce student worksheets as valid, practical, and efficient products. The ADDIE development model, developed by Branch \[12\], is a product-based development model with development steps consisting of five stages: analyzing, designing, developing, implementing, and evaluating. This model was used to produce student worksheets with the GeoGebra application, aiming to improve the higher-order thinking skills of students of SMK Mega Link Majene.

The participants were eleventh-grade computer and network engineering or Teknik Komputer dan Jaringan (TKJ) students of SMK Mega Link Majene of the academic year 2020/2021. The research instruments were: (1) student worksheet validation sheets; (2) student worksheet, used to collect data on students’ higher-order thinking skills; (3) teacher observation sheets, used to observe the management of learning; (3) student observation sheets, used to monitor students’ activities; and (4) questionnaire, used to get students’ response upon the worksheet and GeoGebra usage.

Quantitative data in the form of learning tests were analyzed with descriptive statistics. Meanwhile, qualitative data were directed to answer the question: “How is the process and results of developing student worksheets assisted by the GeoGebra application to improve students’ higher-order thinking skills in mathematics learning, including the criteria of validity, practicality, and effectiveness?”

2.1. Data analysis on the validity of student worksheets
Based on the results of the validation sheet of two validators or experts (learning design experts and material content experts), the average value of V from V1 (first validator) and V2 (second validator) were calculated. The criteria used were: (1) V values for each aspect of the student worksheet, observation sheet for the ability to manage learning, observation sheet for student activities in learning, and questionnaire for student responses to the learning instruments were at least in the category of "Valid Enough"; and (2) V values for all aspects reached the minimum category of "Valid." If this is not the case, then it is necessary to revise the worksheet based on the validators' suggestions or look back at the lacking aspects. It is then re-validated and analyzed until the minimum V value is in the “Valid” category.

2.2. Data analysis on the practicality of student worksheets
To assess the teacher's activities in the learning process, we observed several aspects, including (1) the teacher opens lessons and convey basic competencies, learning objectives, and media that will be used in learning, (2) the teacher presents information using student worksheet with GeoGebra stones, (3) the
teacher asks students to open the GeoGebra application on their computers, (4) the teacher guides students to complete GeoGebra student worksheets, (5) the teacher directs students to ask questions they have not understood, (6) the teacher selects students to present their works on the worksheet and asks other students to respond, (7) the teacher directs students to draw conclusions based on the student worksheet they have completed, (8) the teacher asks students to submit their worksheets, (9) the teacher delivers material to discuss in the next meeting, and (10) the teacher closes the lesson.

Qualitative analysis of the teaching observation describes the teacher's teaching ability. The average score for the lesson implementation was determined at each meeting. The criteria used are at least in the "High" category.

2.3. Data analysis on the effectiveness of student worksheets

Analysis of the effectiveness of the student worksheets includes three components: (1) student learning outcomes, in which the score criteria was set at least 70; (2) student response data should meet the following requirement: at least 50% of students who respond positively to at least 70% of the number of questions or items existing in each aspect; and (3) student activity, in which the criteria used are the value of student activity at least in the "Active" category.

3. Results and Discussion

3.1. The results of expert validation on student worksheets

Expert assessments of (1) student worksheet, (2) learning implementation plan, (3) learning outcomes test, (4) teacher implementation observation sheets, (5) student activity observation sheets, and (6) student response questionnaires, and (7) the GeoGebra application based on: format, language, content, illustrations, benefits/uses and instructions contained in the validation sheet instrument. The data from the expert's assessment are summarized in table 2 below.

| Source                                | Average | Criteria |
|---------------------------------------|---------|----------|
| Student worksheet                     | 4.22    | Valid    |
| Learning implementation plan          | 4.22    | Valid    |
| Higher-order thinking skills          | 4.42    | Valid    |
| Teacher compliance observation sheet  | 4.10    | Valid    |
| Observation sheet of student activities in learning | 4.14  | Valid    |
| Questionnaire student responses to learning | 4.32 | Valid    |
| GeoGebra application                  | 4.22    | Valid    |

Based on table 2, on average, the experts' validation results are considered in the "Valid" category. This means that the development of student worksheets assisted by the GeoGebra application is feasible to test.

3.2. Description of the test results of the student worksheet assisted by the GeoGebra application

After the first draft was revised based on the validation results, the revised version was called Draft 2. Draft 2 was tested on 27 eleventh-grade students of SMK Mega Link Majene. The learning was carried out by following the covid-19 health protocol, and only five to six eleventh-grade students were allowed to get in the computer laboratory room. Before the students came into the classroom, it was sprayed with disinfectant. Then, the students' body temperature was measured using a thermograph, and they were also required to wash their hands, use a mask and face shield, and maintain a distance from each other. The trials of using student worksheets with the GeoGebra application are depicted in figure 2.
Figure 2. Testing the use of worksheet with GeoGebra application.

The analysis results on the trials of using student worksheets assisted by the GeoGebra application can be seen in Table 3 below.

Table 3. Statistical analysis of trials on eleventh-grade students of SMK Mega Link Majene.

| Statistic                              | Value          |
|----------------------------------------|----------------|
| The average higher-order thinking skills test | 61.5 | 84.65 |
| Median                                 | 65 | 90.50 |
| Mode                                   | 70 | 96 |
| Maximum value                          | 78 | 100 |
| Minimum value                          | 35 | 45 |
| Standard deviation                     | 11.79 | 13.94 |

Meanwhile, the analysis results on students' higher-order thinking skills are presented in Table 4 below.

Table 4. Data analysis results of higher-order thinking skills.

| Indicator            | Percentage | Category   |
|----------------------|------------|------------|
| Analyze (C4)         | 80%        | Moderate   |
| Evaluating (C5)      | 75%        | Moderate   |
| Creative (C6)        | 55%        | Low        |

Table 4 shows that the indicators of analyzing (C4) and evaluating (C5) are in the medium category. Creating (C6) is still in the low category. This finding is in line with a study stating that it is necessary to provide mathematics problems based on HOTS to improve students' higher-order thinking skills [2]. Furthermore, the completion score can be seen in Table 5 below.

Table 5. Description of completion score based on tests of higher-order thinking skills.

| Score          | Category       | Acquisition of Test Scores |
|----------------|----------------|----------------------------|
|                |                | Frequency | Percentage |
| 70 ≤ score ≤100| Completed      | 23        | 85.19 %    |
| 0 ≤ score < 70 | Not complete   | 4         | 14.81 %    |
| Jumlah         |                | 27        | 100 %      |
Table 5 illustrates that the completion score classically meets the mastery standard of at least 80%. This finding is aligned with the study, revealing that student worksheets have a potential effect on mathematics learning outcomes [4].

3.3. Practicality

The observations on implementing the learning instruments in the trials obtained the average percentage of 80%, regarded as the "High" category. This means that the student worksheet assisted by the GeoGebra application can practically be used in mathematics learning. This finding accords with research stating that a practical student worksheet is used to improve science process skills and higher-order thinking skills [3].

3.4. Effectiveness

Based on the observations in the three fields, the effectiveness criteria were met, namely: (1) the higher-order thinking ability test met classical completeness, that was, 85.19% of the 80% standard; (2) student activities were in the “very active” category with the percentage of 85%; and (3) students gave a very positive response, with the percentage of 85%. This result agrees with the research findings, pointing out that student worksheets effectively engage students and develop skills and the ability to find mathematics [5].

4. Conclusion

Based on the study results, it is concluded that the student worksheets assisted with the GeoGebra application as developmental research products were able to improve students' higher-order thinking skills in mathematics. This research implies that student worksheets assisted with the GeoGebra application gain valid, effective, and practical criteria. Besides, this study developed student worksheets specifically on a system of equations and linear inequalities of two variables. Therefore, the development of student worksheets assisted by GeoGebra applications in other topics to improve students' higher-order thinking skills was necessary.

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