

GEOGEBRA APPLICATION BASED TUTORIAL MATERIALS TO IMPROVE SPATIAL MATHEMATICS ABILITIES IN VOCATIONAL HIGH SCHOOLS

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ABSTRACT

Spatial ability is crucial to solving mathematical problems. GeoGebra is one of the mathematics software systems widely used as an effective teaching media that is also reported to be effective to improve students' spatial ability. This study aims to develop GeoGebra-based tutorial materials to increase students' mathematical spatial abilities at Vocational High Schools. This study involved 21 vocational high school students of the Accounting and Finance department. This study used the ADDIE Model (Analyze, Design, Develop, Implement, Evaluate). Research data were collected with a Pretest, a Posttest, students' response questionnaires, and expert assessments. The findings proved an increase in students' mathematical spatial abilities after the use of GeoGebra-based tutorial material indicated by the validity assessed by two media experts and two material experts with a percentage of 90.13%, the practicality of the students' limited test reaching a percentage of 83.24%, the effectiveness of the students' learning completeness reaching a percentage of 82.22% and the practicality testing in the field trials reaching a percentage of 80.49%. The effectiveness of students' learning completeness also achieved a percentage of 79.46%. The results of the gain normality test revealed that 19 students obtained high improvement and 2 students obtained low improvement. The total gain normality reached 0.9 indicating that the improvement was significant.

Keywords: GeoGebra, spatial mathematics, tutorial

INTRODUCTION

The role of technology is not only growing rapidly in the field of communication but it also has an impact on education. Technological developments that dominate in the field of education include the use of Technology, Information, and Communication (ICT) facilities to support the teaching and learning process in schools. Therefore, the ability of teachers in the field of ICT is essential to support the learning process [1].

The application of ICT in abstract mathematics learning is also increasing. In mathematics, to understand mathematical concepts, representation is required. Sabirin [2] explained that representation is a tool to find solutions to mathematical problems, which can be in the form of words, writings, pictures, tables, graphs, concrete objects, mathematical symbols, and others. In describing numbers, symbols, graphs, or tables as a tool to solve

problems, it must be clear and correct, to get the right final result. The representation made available by ICT-based teaching media allows students to explore mathematical concepts.

GeoGebra is one of the mathematics software systems that can serve as effective teaching media in mathematics. It is free and offers a variety of helpful features to be used in the teaching-learning process thus improving students' performance. Nurdin et al. [3] reported that Geogebra-based learning video is effective as a learning medium to improve students' ability to understand mathematical concepts. Sugiarni et al. [4] also concluded that Problem Based Learning with Geogebra assistance runs effectively and is conducive. The results of students' responses in learning geometry with the Geogebra-assisted problem-based learning model generally produced a positive impression. In addition, Nur'aini et al. [5] stated that describing and mathematically calculating geometry can be easily performed using the GeoGebra application.

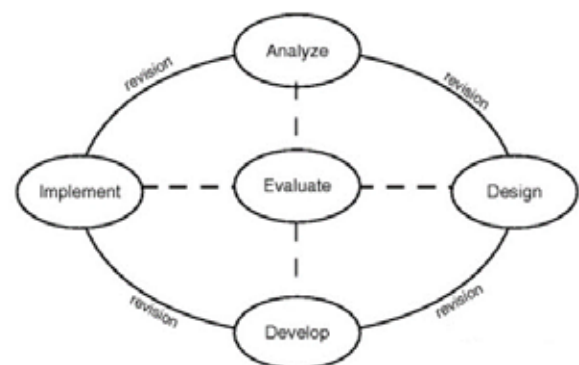
Furthermore, GeoGebra was also reported to be advantageous to improving students' spatial ability [6]–[11]. Spatial ability is crucial to solving mathematical problems. In mathematics, spatial reasoning is a fundamental skill. Learning mathematics is a challenging and active system of interconnected components that primarily rely on spatial thinking rather than quantitative or numerical notions [12]. In describing graphics, students are required to have the ability to present problems or data in graphical form, this ability is called mathematical spatial ability. There is a significant influence on visual-spatial intelligence and numerical abilities together on mathematics learning achievement [13].

However, the initial observations in mathematics lessons in a State Vocational High School, SMK N 2 Madiun revealed that most students were not able to draw the graph correctly. This was indicated by the students' incorrect use of line equations in finding coordinate locations. This had an impact on students' final results and their learning achievement. Currently, the mathematics teachers directly describe an example of solving a linear graph method program. Usually, on the graph of the completion of a linear program, there is more than one line, if all the lines are drawn through a PowerPoint slide, students will find it difficult to understand the graphic presentation. In this problem, a media that contains elements of motion (depicting graphics) and sound elements (explanations) is required. Video or tutorial material is a medium that covers both elements, so it is very suitable to be used as a learning medium for the linear graph method program material. Setyansah & Lusiana [14] explained that in tutorial media, students try to solve problems with directions from lecturers through tutorial materials broadcasted through the website using cellphones that web-based MatLab tutorials are categorized as quite dominant. Making graphics in visual literacy lessons required effective visuals with resources that provide a brief guide to graphic design tools including hardware,

software, books, and web resources following exposure [15]. Ratnasari et al. [16] showed that the routine practice of teachers without technology can be a barrier to technology-based learning. Supported by Mutia [17] who suggested that alternative solutions to students' learning difficulties are: (a) using computer applications (Powerpoint, Ms. Word with SmartArt Graphic) and software such as Cabri Geometry, The Geometer's Sketchpad (GSP), Geometry Expert, Logo, Geogebra, and Winger. The GeoGebra application is effective in overcoming students' difficulties, and an instructional medium is required to facilitate students' learning due to the teacher's limits in teaching. Therefore, the objective of this study is to develop GeoGebra application-based tutorial materials to improve spatial mathematics abilities in vocational high schools.

METHOD

This study was a research and development study by applying the ADDIE model. This model consists of 5 development stages, namely analyze, design, develop, implement and evaluate. The research development steps are described in Figure 1 [11]. This study involved 21 students of the Finance and Accounting department in class X AKL-4 SMK Negeri 2 Madiun.



In the design stage, a storyboard was created to be used as a guideline for product development. In the developing stage, the draft of the materials was compiled. The content of

the GeoGebra-based tutorial material was an explanation of the concept of a linear graph method program and steps to draw a graph, an introduction to some GeoGebra icons, and the steps for solving linear program problems using GeoGebra. In the implementation stage, the tutorial materials were evaluated by media experts and material experts by filling in the assessment instrument. In the evaluation stage, improvements to tutorial materials were carried out based on the results of the assessment results from the material experts and media experts.

The data collection methods used in this study consisted of instruments for experts' judgment. This study involved four experts as the validator. To find out the overall percentage, it was used a Likert scale. To calculate the results of the experts' evaluation, this study used the following formula [18].

$$\text{Validation} = \frac{\text{Tse}}{\text{TSh}} \quad (1)$$

Information:

Tse = Total empirical score
(the result of expert judgment)

TSh = Maximum total score

The calculation process in the GeoGebra tutorial media was declared valid (good/acceptable) if the combined validity results show more than 70% results. A pretest and posttest were administrated before and after before and after the tutorial materials were presented. Pretest and Posttest were performed online via a google form. The results of students' learning completeness individually were calculated with the following [19].

$$\text{KB} = \frac{\text{T}}{\text{Tt}} \times 100\% \quad (2)$$

Information:

KB = Completeness of learning

T = Total score obtained by students

Tt = Total score

Individually, students are considered to have completed learning if the proportion of correct answers is 65% or above, and a class is said to be classically complete if 85% of the students have completed learning. The data obtained from the research were analyzed with an n-gain test to determine that there was an increase between the pretest and posttest. The increase was calculated with a normalized N-Gain formula using the pretest and posttest score as follows. The results of the N-Gain calculation are then interpreted using classification adopted from Meltzer as described in Table 1 [20].

$$g = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}} \quad (3)$$

Table 1. Gain Normality Score Criteria

Gain Normalized (g)	Improvement Criteria
$g < 0.3$	Low
$0.3 \leq g \leq 0.7$	Moderate
$g > 0.7$	High

A questionnaire was used to evaluate the students' responses to the developed tutorial materials using the Guttman Scale. The following formula was used to figure out what proportion of students responded [19]. The students' responses were classified based on the criteria listed in Table 2.

$$\text{Percentage} = \frac{\text{A}}{\text{B}} \times 100\% \quad (4)$$

Information:

A = Total score from data collection

B = total maximum score

Table 2. Students' Response Criteria

Percentage	Criteria
75% to 100%	Very High
50% to 74,99%	High
25% to 49,99%	Moderate
0% to 24,99%	Low

Data were collected from student response questionnaires to examine the practicality of the GeoGebra tutorial media. The form of students' response questionnaires used a Likert

scale and a checklist method. The Likert scale is used to measure people's attitudes, opinions, and perceptions [21]. GeoGebra tutorial media meets the criteria of practicality if more than 70% of students classically give a positive response [22]. However, if it is less than 70%, the researcher must make improvements to the GeoGebra tutorial media based on the suggestions from the students.

RESULTS AND DISCUSSION

The materials selected in this study were the materials of linear equation systems. The product was developed to meet the needs in the field. The teacher always repeats the material presented in online meetings. The objectives were formulated according to indicators of the system of linear equations and sequences, among others: mathematical modeling; area delineation; presents the calculation results; determines the set of solutions.

In the design stage, the researchers compiled a media validation sheet, students' response questionnaires, and learning outcomes tests, media selection, and initial design of learning devices. The displays of GeoGebra tutorial media is illustrated in Figure 2, Figure 3, and Figure 4.



Figure 2. Initial Display

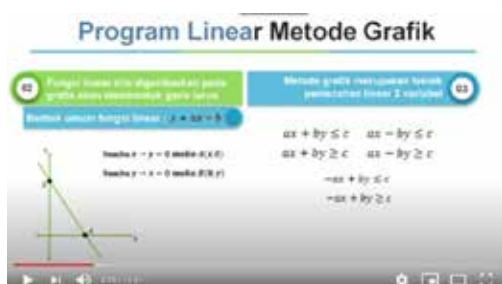


Figure 3. Display of Material Explanation

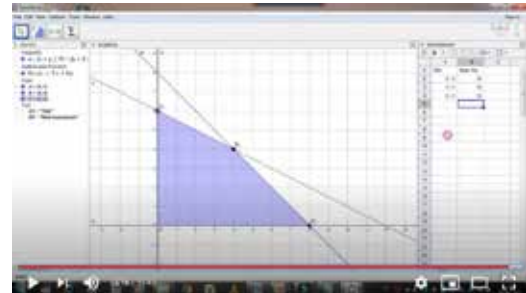


Figure 4. Display of Analysis Results

The validity of GeoGebra-based tutorial materials, in this study, the final percentage of 4 experts consisting of 2 media experts and 2 material experts shows 90.13%, so it is in the very feasible category. The results of the feasibility assessment are presented in Table 3.

Table 3. Feasibility Assessment by Experts

Expert	Score Obtained	Score Maximum
Media	57	72
Theory	80	80
Total	137	152
Percentage	90.13 %	

A limited trial was carried out by students of class X AKL-4 SMK Negeri 2 Madiun who participated in the trial and was limited to 11 students. The trial results were limited to the questionnaire aspect of the student's response. responsibility to get a practicality percentage of 83.24%. While student learning outcomes in limited trials while participating in learning using GeoGebra tutorial media were obtained by giving a learning outcome test with an average score of 72.50 so that it was declared that they met the percentage of completeness. 82.22%. This shows that the GeoGebra tutorial media can be said to be effective.

A field trial was conducted by 21 students of class X AKL-4 SMK Negeri 2 Madiun. The results of field trials on the aspects of students' responses obtained a practicality percentage of 80.49%. Meanwhile, students' learning outcomes in field trials while participating in learning using GeoGebra tutorial media were obtained by providing a learning outcome test with a percentage of student learning completeness of 79.46%. This indicated that

GeoGebra tutorial materials were considered to be very effective.

If learning outcomes after using GeoGebra-based tutorial material were higher than learning outcomes before utilizing it, the mathematical spatial ability was classified as increasing. The gain normalcy test revealed that two students met the criteria for moderate improvement and 19 students fulfilled the criteria for significant improvement. As for the normality of the total gain, the result was 0.9 in the high category. This was supported by research by Ardian & Munadi [23] who reported there was an interaction between strategies learning with spatial abilities in its effect on creativity. Yuliardi & Casnan [24] also found that there was a positive correlation between spatial abilities and mathematical communication skills and asynchronous communication with tutorial media provides indirect communication.

Based on the results of the evaluation, the Geo Gebra-based tutorial materials were an appropriate learning medium for learning mathematics, especially in linear equation systems with the graphic method, because it meets the expected criteria of validity, practicality, and effectiveness. It can provide students with examples of graphic images to help the students understand the concept of drawing graphics. Thus, it helps the students to draw graphs correctly and produce the right solution.

This was in relation to the usage of technology, smartphone use, online security, and the positive impact of technology [25]. Moreover, the teachers can do more simulation studies following examples to improve their programming skills [26]. Specifically, logical reasoning has a stronger association with spatial abilities than numerical or arithmetic abilities with spatial abilities [27]. GeoGebra-based learning also increases students' motivation [28] which encourages students' engagement in the learning process.

CONCLUSION

Based on the results of product assessment and evaluation, the developed GeoGebra application-based tutorial materials obtained the validation of 90.13%. The practicality level assessed from students' questionnaire responses to limited trials was 83.24%, which indicated that students' responses to tutorial-based learning media using the GeoGebra application could be considered to be high. While the average score obtained from students' questionnaire responses in the field trial was 80.49% which was also included in the high category. Whereas in the field trial, the average score of the learning outcomes test was 79.46%. It can also help students enhance their spatial abilities by using the teaching material-based GeoGebra application that was produced. This was based on the results of the pretest score that was improved in the posttest after the usage of media. This suggested that teachers' support of students' spatial abilities through the production of instructional media is essential.

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