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GeoGebra Applet as an Online Learning Media in Solving the Roots of Nonlinear Equations

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ABSTRACT
This research is motivated by the importance of accurately solving nonlinear equations, which have implications for various fields that use linear equations as a problem-solving and modeling tool. Therefore, it is necessary to conduct research into the development of online learning media that can make it easier for students to complete the iteration stages in finding the roots of nonlinear equations. They are considered the right medium to solve this problem. GeoGebra applets are designed and developed according to the students' needs, learning objectives, and methods used in solving the roots of nonlinear equations, and then uploaded to the GeoGebra website for easy access by students. The development of GeoGebra applets aims to assess the feasibility of the developed media based on expert assessments and student response questionnaires. The method used is the research and development model of Borg and Gall. The expert validators are 4 mathematics education lecturers who teach numerical methods courses from 4 universities. Based on the expert assessment, the medium was declared highly valid with a score of 87.92%. Questionnaires were given to 20 students of Mathematics Education at Malikussaleh University in preliminary field testing. Based on the questionnaire, the students' responses in the preliminary field testing were 93.42% in the very good category. Thus, the GeoGebra Applet online learning medium is suitable for further research in Main Field Testing.

Keywords: GeoGebra Applets, Media, Nonlinear, Online Learning, Roots

1. Introduction

The accurate solution of nonlinear equations is essential for the implications of many fields that use linear equations as a problem-solving and modeling tool (Wigati, 2020). The reality is that numerical methods are one of the most difficult courses, according to some students. The students' weaknesses exist in the second indicator of numerical literacy, namely analyzing information presented in the form of graphs, where only 53.65% of the students answered well. (Listiana, Aklimawati, Wulandari, Suandana, et al., 2022). This requires the right learning medium that can accurately, precisely, and efficiently display each stage of completion.

One of the technology-based learning tools that can be used is the GeoGebra application. Some studies using GeoGebra state that it is very helpful in explaining numerical methods for geometrically solving equations in the classroom, allowing students to simulate and manipulate iterative or recursive methods (Martín-Caraballo & Tenorio-Villalón, 2021). GeoGebra can be used to solve problems in the numerical method process (Arceo-Díaz et al., 2020). The GeoGebra applet is a practical and effective tool for training the understanding of mathematical concepts of junior high school students in the material of quadratic equations and functions (Sudarsana et al., 2022). Online GeoGebra makes it easier for students because they do not have to install GeoGebra software (Arifin et al., 2023). The use of GeoGebra-based e-Worksheets can increase student independence in learning (Susanti & Wulandari, 2022). GeoGebra-assisted integral calculus module is classified as effective (Listiana, Aklimawati, Wulandari, & Isfayani, 2022).

The learning medium that can display each iteration step in finding the roots of nonlinear equations is GeoGebra Applets. Thus, researchers are interested in conducting research on the development of GeoGebra applets as online learning media for finding the roots of nonlinear equations.

2. Literature Review and Hypothesis

Media is one of the elements that supports the achievement of effective learning goals (Maqfiro et al., 2020). Information Communication Technology-based learning media can be developed into interactive learning media that can stimulate students to understand learning faster and easier, and be fun because of the interaction between students and images, sounds, colors, videos, and something immediate (Muhtar et al., 2020).

GeoGebra Applets is one of the features in GeoGebra that can be used, modified, and/or developed by educators for dynamic and interactive learning of mathematics (Nisiyatussani et al., 2018). The developed GeoGebra applets include methods for finding solutions to nonlinear equations, namely 1) bisection method, 2) Regula Falsi method, 3) fixed-point iteration method, 4) Newton-Raphson method, and 4) secant method.

The content of the developed product plan consists of 1) GeoGebra Introduction, contains an introduction to GeoGebra, how to use GeoGebra, how to install GeoGebra. 2) GeoGebra Applets, which are divided into 4 applets of methods in finding solutions to nonlinear equations. Each method of nonlinear equations applet contains material, method steps, example problems, graph simulations, and simulation of the steps of each iteration.

3. Research and Methodology

3.1 Data

This research is a development research using the Borg and Gall model. At the preliminary field testing stage, the research was conducted at Malikussaleh University. The data collection technique used was a validation questionnaire which was tested on 4 expert lecturers who taught numerical methods courses. Following the validation of the GeoGebra Applets learning media, an initial field test was conducted with 20 semester 5 mathematics education students to evaluate their response to the learning media.

3.2 Data analysis method.

In the media feasibility analysis,the media validity validation formula calculated by Formula 1

$$V_a = \frac{TS_h}{TS_e} \times 100\% \qquad (1)$$

Va : Expert validation
TSh : Total maximum expected score
TSe : Total empirical score (validation results from validators)

The results of expert validation were then percentageed according to the criteria in the table.

Table 1. Validation Criteria

Validation Criteria	Validation Level
75,01 % - 100,00%	Very valid, or can be used without revision.
50,01 % - 75,00 %	Moderately valid, or can be used with minor revisions.
25, 01 % - 50,00%	Less valid, recommended not to be used because it needs major revision.
01,00 % - 25,00%	Invalid, or should not be used.

Furthermore, to determine the stability and consistency of the validity of the media, use the reliability formula in formula 2.

$$R = \left(1 - \frac{A-B}{A+B}\right) \times 100\% \qquad (2)$$

R = Percent agreement
A = The highest score given by the validator
B = The lowest score given by the validator

To determine media reliability criteria, use the guidelines in Table 2.

Table 2. reliability percentage criteria

Percentage	Criteria
75,01%≤R≤100 %	Very Good
50,01%≤R≤75%	Good
25,01%≤R≤50%	Good enough
0%≤R≤25%	Not good

4. Result and Discussion

The research and development process uses the Borg and Gall model up to the seventh stage, namely research and information gathering, planning, development of preliminary product form, preliminary field testing, main product revision, main field testing, operational product revision, and final product. However, in this article, the research is still in the Preliminary Field Testing stage.

The first stage is research and information gathering. At this stage, the researcher collects information from the GeoGebra website to find out the pre-existing GeoGebra applet. Then an analysis for the development of GeoGebra applets is done. Based on the needs analysis, students need media that can display graphs as well as the completion stages of each iteration stage in solving the roots of nonlinear equations.

The next step is planning. The developed product plan consists of 1) GeoGebra Introduction, contains an introduction to GeoGebra, how to use GeoGebra, how to install GeoGebra. 2) GeoGebra Applets, which are divided into 4 applet methods in finding solutions to nonlinear equations. Each applet method for solving nonlinear equations includes materials, method steps, example problems, graph simulations, and simulations of each iteration's steps.

The next step is *Develop preliminary form of the product.* At this step, media development is carried out to create an initial product. The validation sheet and response questionnaire are also prepared at this stage. The initial product developed is then validated by experts. In this stage, revision followed based on evaluations and input in the form of suggestions from experts to improve the developed media. Validation of GeoGebra applet learning media development products was tested by 4 experts, namely mathematics education lecturers who teach numerical methods courses. The results of validation and reliability based on aspects of expert evaluation are described graphically in

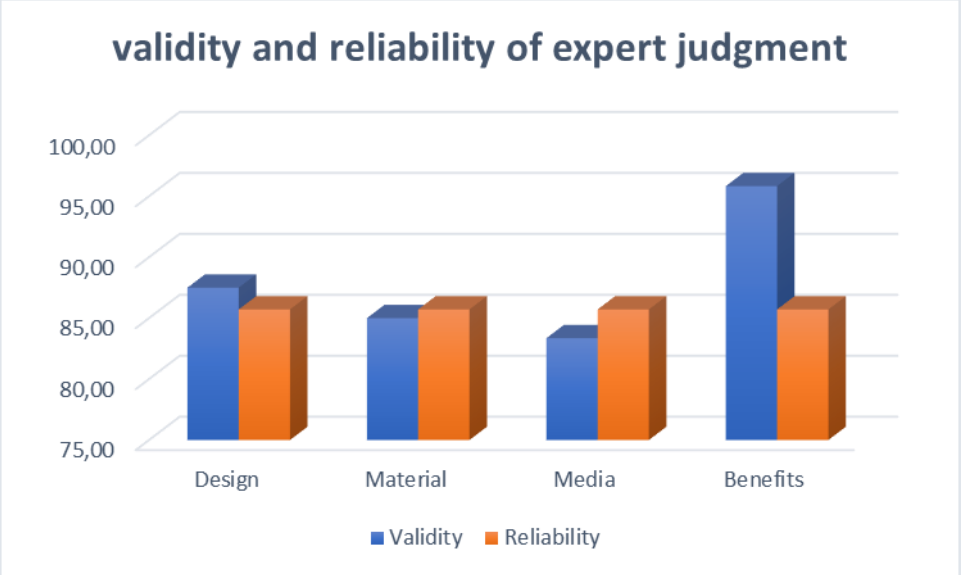


Figure 1. Graph of validity and Reliability Values Based on expert assessment.

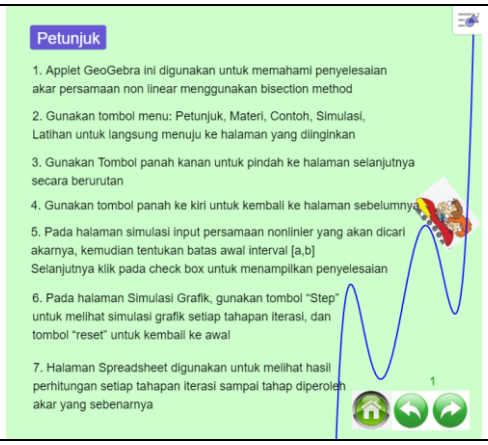
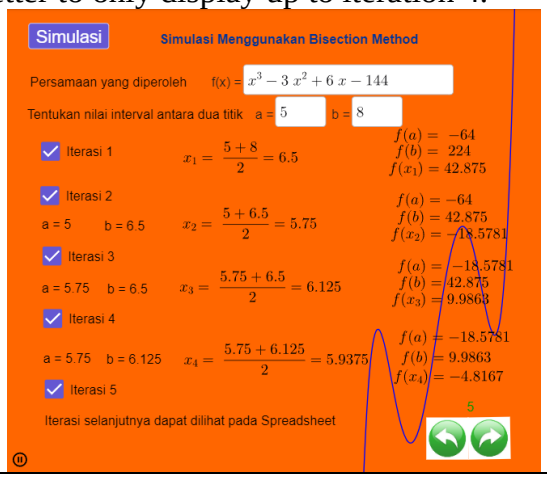
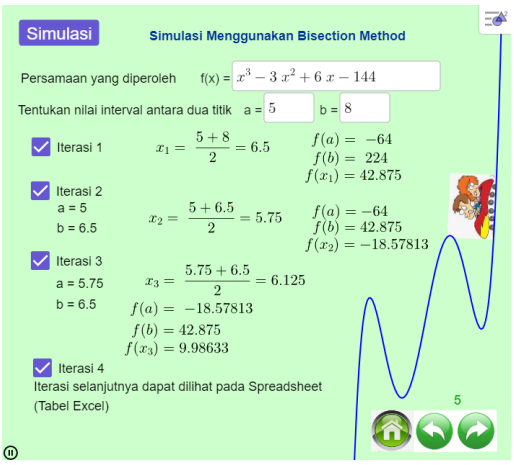
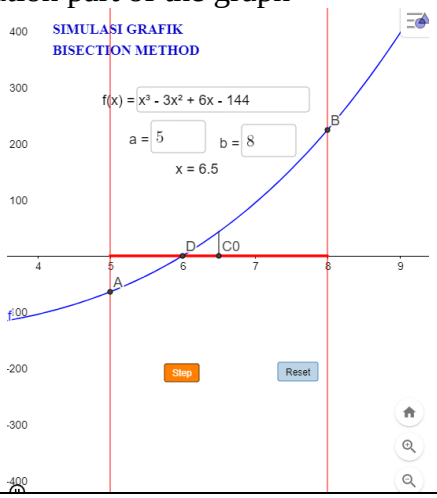
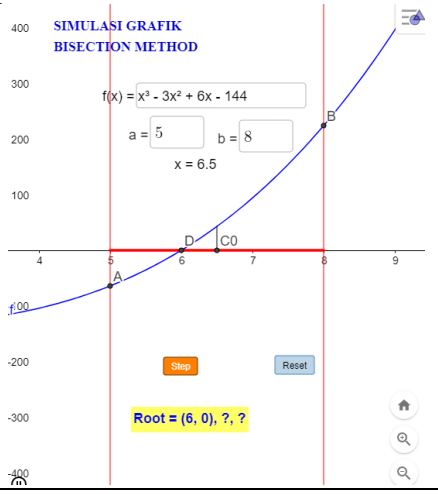
Based on the analysis of the results of the expert evaluation of four aspects, namely design, material, media, and benefit, the value of the design aspect was 87.5%, the value of the material aspect was 85%, the value of the media aspect was 83.35% and the value of the benefit aspect was 95.83%. While the average percentage value of validation with a value of 87.92% is in the very valid category. At this stage, revisions were also made to the suggestions for improvement made by the validators. The following are revisions based on validators' suggestions:

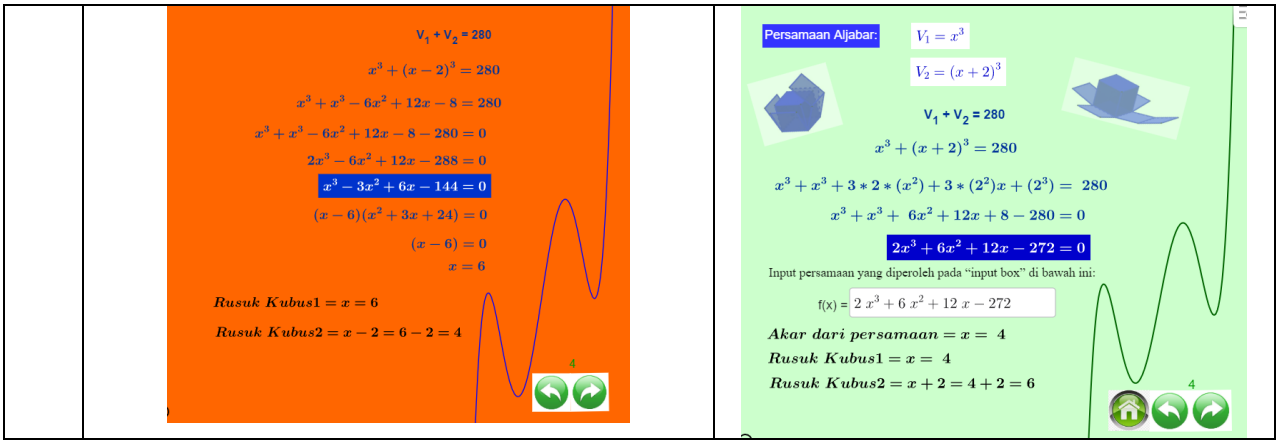
1. Improvements to the initial appearance of the applet
2. Addition of animation using polynomial function graphs
3. Added home button
4. Improvements in the tutorial section.
5. Iteration steps are not clearly visible because they are covered by graphics. Preferably, only up to iteration 4
6. Addition of the actual root value in the graph simulation part.

7. An "input box" for the roots of the quadratic equation so that it is connected to the graph simulation.

Table 3. Revision Based on Expert Assessment

GeoGebra Applet Learning Media Revision		
No.	Before	After
1.	Suggestion: Improved the initial appearance of the applet; colors are too bright. 	Researchers improved the initial appearance of GeoGebra Applet 
2.	Suggestion: Add animations using polynomial function graphs 	Researchers added a moving roller coaster that traverses the graph of a polynomial function. 
3.	Suggestion: Improvements to the instructions section and adding a "Home" button	The researchers improved the sentences in the instructions section and added a "Home" button.

		
4.	Suggestion: Iteration stages are not clearly visible because they are covered by graphs. It is better to only display up to iteration 4. 	The researchers reduced the iteration stage. 
5.	Suggestion: Adding the actual root value to the simulation part of the graph 	The researcher improved the actual root value to the simulation part of the graph. 
6.	Suggestion: Add an "input box" for the roots of the quadratic equation to be linked with the graphing simulation.	The researcher also added an "input box" for the roots of the quadratic equation to link with the graphing simulation.



After revising, the next step is Preliminary Field Testing. Preliminary Field Testing step was carried out by trialling the media with students. Preliminary Field Testing is intended to test the feasibility of media use in learning. The results of the student response questionnaire to the developed media can be seen in the following chart.

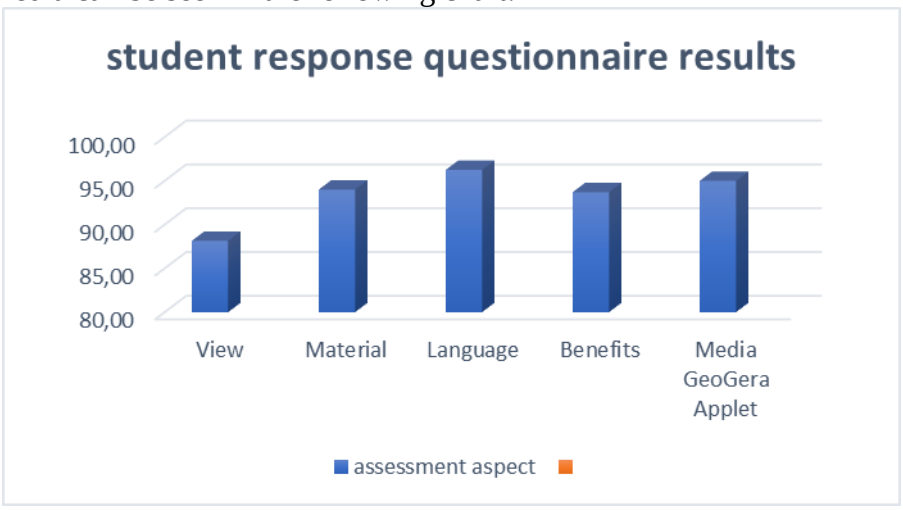


Figure 2. Graph of Student Response Questionnaire Results

Based on the results of the student response questionnaire on 5 aspects of the assessment, 88.15% was obtained for the display aspect, 94% for the material aspect, 96.25% for the language aspect, 93.71% for the benefit aspect, and 95% for the GeoGebra Applet media aspect. So that the average of all aspects obtained was 93.42% with a very good category.

5. Conclusion

Based on expert assessment, the media was declared very valid with Response Questionnaires given to Mathematics Education students at Malikussaleh University in Preliminary Field Testing. Based on the questionnaire, the students' responses in the preliminary field testing were in the very good category. Therefore, GeoGebra Applet online learning media is suitable for further research in Main Field Testing.

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