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Developing a GeoGebra-Assisted Web-Based Learning Module for Analytical Geometry in a STEM Context

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Abstract

In modern education, incorporating technology is crucial for enhancing learning experiences and ensuring equal access to education. By integrating technology, educators can create interactive and immersive learning environments that boost student engagement and motivation. This research aims to describe the development process and results of a GeoGebra-assisted, web-based module for analytical geometry within a STEM context. The research follows the ADDIE model, which includes five stages: analysis, design, development, implementation, and evaluation. Data collection methods include questionnaires, documentation, and literature reviews. Feasibility validation assesses the module's face and content validity, focusing on content, language, and appearance. Data analysis utilizes a Likert scale to assess the validity of the module's aspect categories. The results indicate that the web-based module was developed in accordance with each stage of the ADDIE model. Expert feasibility tests show that the module demonstrates good validity in terms of content, language, and appearance.

Keywords*; Analytical Geometry; STEM Context; Web-Based Learning Module*

Abstrak

Dalam pendidikan modern, mengintegrasikan teknologi sangat penting untuk meningkatkan pengalaman belajar dan memastikan akses pendidikan yang merata. Dengan mengintegrasikan teknologi, pendidik dapat menciptakan lingkungan belajar yang interaktif dan imersif yang meningkatkan keterlibatan dan motivasi siswa. Penelitian ini bertujuan untuk mendeskripsikan proses dan hasil pengembangan modul berbasis website berbantuan geogebra untuk geometri analitik pada konteks STEM. Penelitian ini merupakan penelitian pengembangan menggunakan model ADDIE yang terdiri dari 5 tahap yaitu analisis, desain, development, implementation, dan evaluation. Teknik pengumpulan data menggunakan angket, dokumentasi, literatur review. Validasi kelayakan dilakukan untuk mengetahui validitas muka dan isi pada modul berbasis website ini yang meliputi validitas konten, bahasa, dan tampilan. Analisis data menggunakan skala likert untuk mengetahui kelayakan aspek kategori. Hasil penelitian menunjukkan bahwa modul berbasis website telah dihasilkan berdasarkan tahapan setiap proses model pengembangan ADDIE dan berdasarkan uji kelayakan oleh para ahli, validitas dari modul berbasis website ini adalah baik dalam hal konten, bahasa, dan penampilan.

Kata Kunci: Geometri Analitik; Konteks STEM; Web-Based Learning Module

Introduction

In the learning process, technology integration plays a crucial role as a tool to facilitate learning and assist educators in delivering knowledge and material. This integration can enhance engagement and interaction of students in the learning process and facilitate personalized learning experiences (Eden, 2024). With the advancement of technology, the utilization of technology in the learning process has become common among educators. One common use of technology in education is through educational websites, which are essential tools for students to learn and enhance their academic performance (Shana, 2004).

The integration of web-based learning into the educational process significantly enhances educators' ability to convey material to students. Recent research suggests that using web-based platforms, especially multilingual ones, can foster students' learning autonomy and cultivate a positive attitude towards mathematics (Pichon, 2024). By providing interactive and personalized resources, web-based platforms cater to diverse learning styles and paces, making complex mathematical concepts more accessible and comprehensible (Smith, 2023). For example, in analytical geometry topic, the concept is considered difficult and disliked by students. This is due to various factors, one of which is the lack of engagement, leading to a decrease in students' interest in learning concepts.

To attract students' interest in learning analytical geometry, educators need to use engaging approaches, such as the Science, Technology, Engineering, and Mathematics (STEM) approach. A recent article emphasizes that STEM education can significantly enhance student engagement in the classroom. By integrating science, technology, engineering, and mathematics, STEM programs provide hands-on, real-world applications that captivate students' interest and foster active participation (Doe, 2023). Through the STEM approach, students are trained to handle problems and learn new things, produce creative solutions, become self-reliant, think logically, and become technologically literate. Such an approach is expected to increase students' interest in learning mathematical concepts such as analytical geometry.

Based on the above explanation, the author aims to develop a GeoGebra-assisted web-based learning module in a STEM context. This module is expected to facilitate students in finding learning references and, with rapid technological development, enable students to learn anytime and anywhere through the website, which can be accessed via their mobile phones or laptops.

Method

This research is a research and development study utilizing the ADDIE model, the most widely known and used systematic learning design framework, encompassing analysis, design, development, implementation, and evaluation. However, the implementation and evaluation stages will be discussed in a separate article. Consequently, this article focuses exclusively on the analysis, design, and development stages, including the results of validity tests conducted by three experts.

ADDIE model is chosen due to this model is structured with a sequence of systematic activities aimed at addressing learning issues related to educational resources, ensuring they align with the needs and characteristics of the students (widyastuti, 2019). Moreover, this model is also considered essential in the development of educational and training programs (Hannum, 2005; Muruganantham; 2015). Three experts in this study are two learning design experts and one learning media expert. Data collection methods include questionnaires, documentation, and literature reviews. Data were analyzed by descriptive qualitative and descriptive quantitative.

According to the phases of web-based module development, In the analysis phase, three main activities were carried out: analysis of the content of analytical geometry, media analysis, and task analysis within a STEM context. During the design phase, the first step was to select the material to be presented, choose the media, design the STEM-related problems to be featured, and design the initial layout of the website along with the necessary menus.

The development phase involved the initial development of the website using an open-source Content Management System, WordPress. Additionally, STEM problems were systematically presented in the project modules, and worksheets created in GeoGebra were linked to the website. After the initial product was completed, the web-based module was validated and revised.

Validation sheets were used to measure the product's validity, with validation performed by three experts. Three categories were measured: content, language, and appearance. Those categories were adapted by author from Muchlis (2021) and the aspects measured within each category are presented in the table below.

Table 1. Module Validation Category

Category	Measured Aspect
Content	Suitability of material to competencies and indicators Extent to which material meets student needs Presence of assessment tools Accuracy of Reality in STEM clarity of content and instructions Tasks according to project-based criteria
Language	Adherence to Indonesian Language Standards (PUEBI) Use of clear and concise sentences Consistent use of standardized terminology Clarity of Information Provided Communicative Language Style Readability and Attractiveness of Language Style
Appearance	Systematic and Interesting Module Structure Systematic order of material Clarity of Pictures and Diagrams Effectiveness of GeoGebra Applet Organized and appealing layout of sub-modules

The questionnaire used a Likert scale with 4 scale options. The validation data were then analyzed using the average validation aspect score based on the calculation steps for the total average score by Hobri (2010), with the total average score for all aspects being:

$$\mathrm{V_a} = \frac{\sum_{i=1}^{n} \mathrm{A_i}}{\mathrm{n}}$$

V_a = average total score for all aspects

A_i = average score for aspect-i

n = numbers of aspect

Next, V_a or the average total score is adjusted according to the validity criteria by Hobri (2010) as follows:

$1 \leq V_a < 2$: Not Valid

$2 \leq V_a < 3$: low Validity

$3 \leq V_a < 4$: Valid

$V_a = 4$: Strong Validity

Results

The results of this research describe the development stages based on the ADDIE model, limited to Analyze, Design, and Develop. In the analysis stage, the process begins with identifying problems within the material to be discussed and exploring alternative solutions. This analysis stage also includes material analysis, technology analysis, STEM context analysis, and student characteristics analysis. Based on this analysis, the main topics selected for the module are coordinate systems, lines in planes, and space. Additionally, the STEM context to be used is the environmental context, specifically the creation and use of eco-enzymes on campus. This context was chosen because it aligns with students' experiences and is expected to enhance their motivation and engagement in completing project tasks.

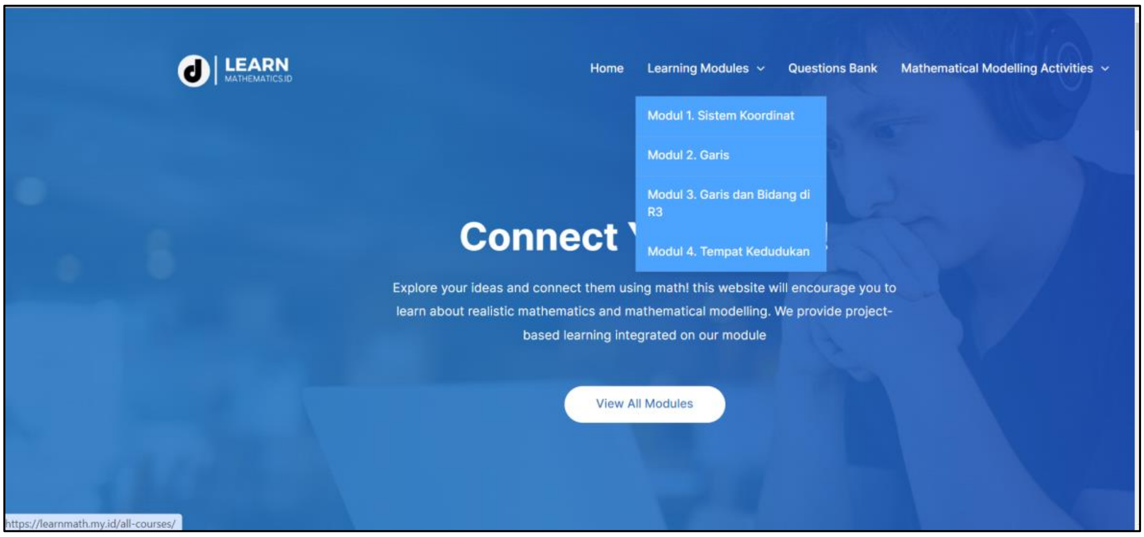

Figure 1. Initial Appearance Of The Website-Based Module

In the design stage, the mathematical content is first identified and organized on the website along with the applets to be developed in GeoGebra. The analytical geometry material used is based on the arrangement found in a book authored by one of the researchers. After formulating the mathematical content, interactive content is planned for display on the module's web page. The GeoGebra applets embedded on the website require students to log in or enter their name without logging into a GeoGebra account.

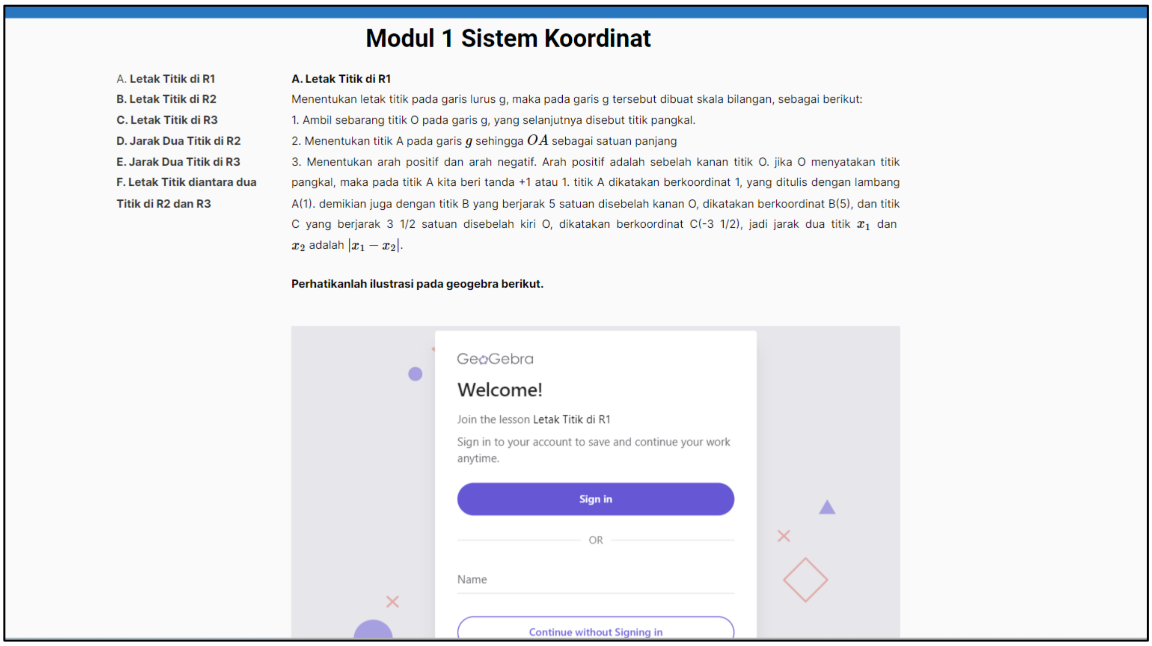

Figure 2. Geogebra Worksheets Embedded on Website Pages

In the development stage, project tasks are created with attention to the criteria for project-based tasks, focusing on mathematical modeling tasks. The context used in these tasks employs a STEM approach with eco-enzymes as the subject matter. The project tasks include understanding the production of eco-enzymes, harvesting eco-enzymes, and their use or application as a water purifier in a lake. This context was chosen because the research subjects had taken environmental courses, and the eco-enzyme topic integrates science, technology, engineering, and mathematics (STEM). In the science discipline, students learn how to produce eco-enzymes, understand the necessary materials, and their role in creating eco-enzyme solutions, including their application as cleaners. In mathematics, students apply analytical geometry concepts to determine effective methods for using eco-enzymes as water cleaners, such as for lake water purification. In the engineering and technology aspects, students design the process of making and using eco-enzymes with tools like MS Excel, GeoGebra, or a graphing calculator.

Figure 3. Project Assignments with a STEM Context

In the mathematical modelling or project-based task, Students can use the geogebra worksheet and the project manual (guidebook) on the website (Figure 3). Geogebra worksheet is a worksheet that corresponds to online project assignments on the Geogebra website portal. This worksheet consists of production process, harvesting process, and application of ecoenzyme for lake water purifier (see Figure 5).

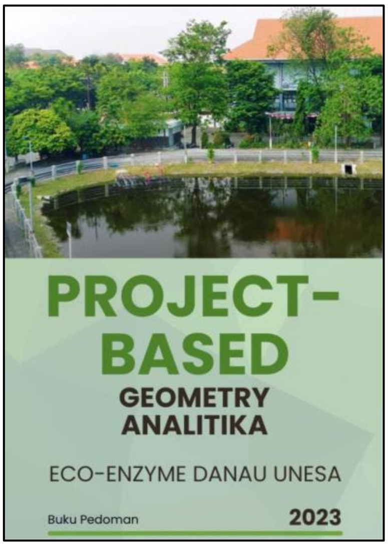

Figure 4. Project Manual

Meanwhile, the project assignment manual contains basic information regarding eco-enzymes, their production process and their applications in various aspects. With these two things, it is hoped that students can work on their projects more systematically, directed and effectively.

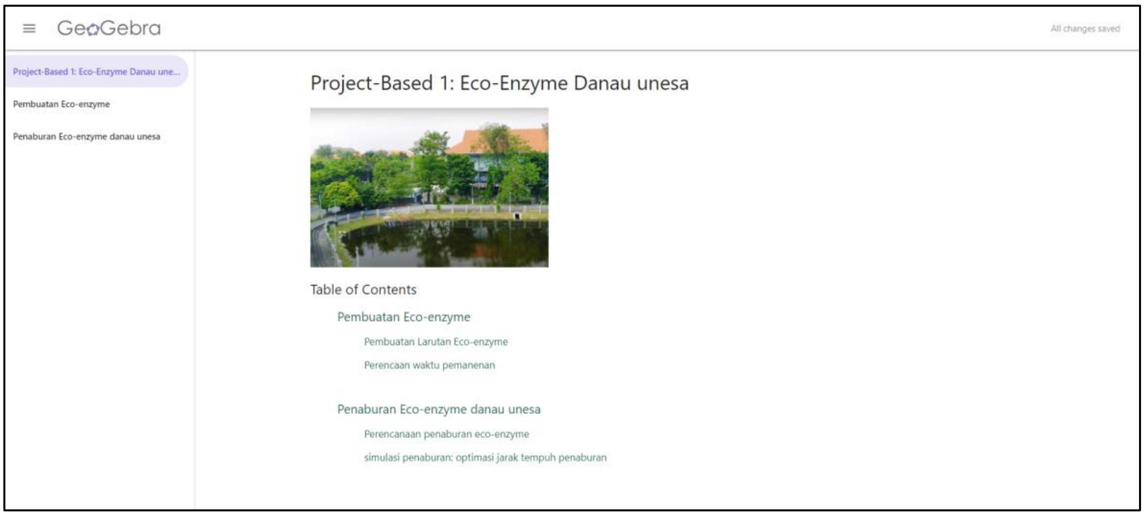

Figure 5. Geogebra Worksheet

Based on validation results from three experts, the content category received an average aspect score of 3.39, placing it in the valid category. The language category scored an average of 3.33, also in the valid category, while the appearance category had an average score of 3.13, maintaining its validity. Despite this overall validation, three aspects received the lowest scores: 1) the existence of an assessment tool, 2) a systematic and attractive module structure, and 3) the effectiveness of the GeoGebra applet. Considering the average category score, the module is deemed valid with a V_a score of 3.29. The validators provided several recommendations, including adjusting image and font sizes, adding videos to GeoGebra worksheets, and enhancing the website's appearance. Following these suggestions, the web-based module has been improved and revised according to the feedback from the three validators.

Discussion

The integration of GeoGebra in the web-based learning module for Analytical Geometry significantly enhances the interactive and dynamic nature of the learning process. GeoGebra, being a powerful tool for visualizing mathematical concepts, allows students to manipulate and explore geometric shapes and their properties in real-time. This interactivity is crucial for developing a deeper understanding of analytical geometry, as students can experiment with different parameters and immediately observe the outcomes. Research supports the effectiveness of dynamic geometry software in improving students' spatial reasoning and conceptual understanding (Hohenwarter & Lavicza, 2007; Jiang & McClintock, 2000).

Incorporating a STEM (Science, Technology, Engineering, and Mathematics) context into the learning module addresses the interdisciplinary nature of modern education. Analytical Geometry serves as a foundational element that intersects various STEM fields. By framing geometry problems within real-world STEM scenarios, students can see the relevance of their learning and are more likely to engage with the material. For instance, problems involving geometric shapes in engineering design or coordinate systems in physics can provide practical applications of theoretical concepts. This contextualization is supported by the educational framework proposed by Bybee (2010), which emphasizes the importance of real-world applications in STEM education.

The web-based module, coupled with GeoGebra's interactive capabilities, also positively impacts student engagement and motivation. The interactive nature of the software makes learning more enjoyable and less abstract. Students are more likely to stay engaged when they can actively participate in the learning process rather than passively receiving information. Furthermore, the immediate feedback provided by GeoGebra helps to keep students motivated by allowing them to quickly assess their understanding and correct mistakes. Studies have shown that interactive and immediate feedback mechanisms in educational technology significantly enhance learning outcomes (Shute, 2008).

Future research could explore the long-term impact of using GeoGebra-assisted web-based modules on students' performance in analytical geometry and their overall STEM proficiency. Additionally, investigating the effectiveness of similar modules in other areas of mathematics and science could provide valuable insights. Another area of interest could be the development of adaptive learning systems that use data analytics to personalize the learning experience for each student, further enhancing the efficacy of web-based educational tools.

Conclusion

The development of a GeoGebra-assisted web-based learning module for Analytical Geometry in a STEM context offers a promising approach to enhancing mathematics education. By leveraging the interactive and dynamic capabilities of GeoGebra, contextualizing learning within real-world STEM applications, and ensuring accessibility and engagement, such modules can significantly improve students' understanding and appreciation of analytical geometry. However, careful consideration of the associated challenges and continuous improvement based on feedback and research are essential for maximizing their potential.

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