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ARITMATIKA: An innovative application to enhance higher order thinking skills in students through problem-based learning

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Abstract
The objective of this research is to develop "ARITMATIKA" an innovative application designed to support students' Higher Order Thinking Skills (HOTS) through Problem-Based Learning. The research methodology employed is based on the general Plomp educational problem-solving model, encompassing three of its five phases: the initial investigation phase, the design phase, and the realization phase. This use of three out of the five phases is due to the preliminary nature of this research. The findings indicate that ARITMATIKA is suitable for use in enhancing learning outcomes in the Introduction to Geometry course.

Keywords: *Application, HOTS, Problem-Based Learning, Quality Education.*

Abstrak
Tujuan dari penelitian ini adalah untuk mengembangkan "ARITMATIKA", sebuah aplikasi inovatif yang dirancang untuk mendukung keterampilan berpikir tingkat tinggi (HOTS) mahasiswa melalui Pembelajaran Berbasis Masalah (PBL). Metodologi penelitian yang digunakan didasarkan pada model pemecahan masalah pendidikan umum Plomp, yang mencakup tiga dari lima fasenya: fase penyelidikan awal, fase desain, dan fase realisasi. Penggunaan tiga dari lima fase ini disebabkan karena penelitian ini merupakan preliminary research. Hasil temuan menunjukkan bahwa ARITMATIKA layak digunakan dalam meningkatkan hasil belajar pada mata kuliah Pengantar Geometri.

Kata kunci: *Aplikasi, HOTS, Pembelajaran Berbasis Masalah, Pendidikan Berkualitas*

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INTRODUCTION

Competition in the 5.0 era demands proficiency and sensitivity to rapid changes (Yuliani et al., 2022). One way to enhance this sensitivity is by improving Higher Order Thinking Skills (HOTS). Therefore, HOTS are essential skills that students must possess (Mailani et al., 2022). Moreover, HOTS is also a topic of concern in the field of higher education (Ningrum et al., 2022; Utami et al., 2024). HOTS encompass complex thinking processes, including critical analysis and the creation of problem-solving solutions (Budiarta et al., 2018). HOTS also involve students' abilities to integrate ideas and facts to analyze, evaluate, and create (Annuuru et al., 2017). In Bloom's Taxonomy, HOTS are classified as skills ranging from C4 to C6 (Tanujaya et al., 2017). The Cognitive Taxonomy of HOTS is presented in Figure 1.

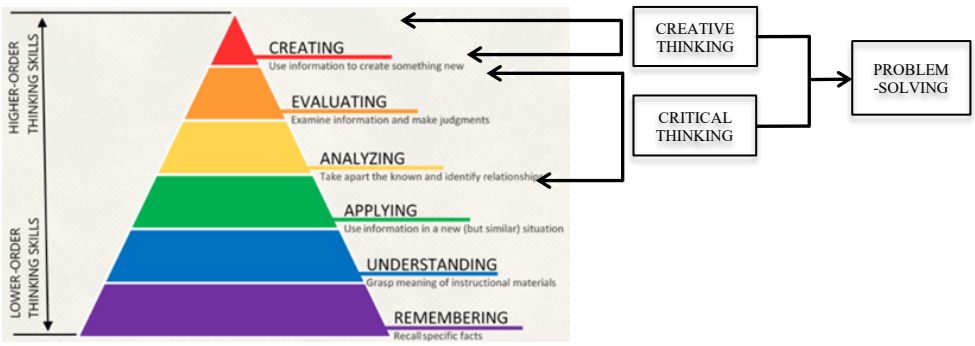

Figure 1. Cognitive Taxonomy of HOTS (Saraswati & Agustika, 2020)

Based on Figure 1, problem-solving ability is one of the skills encompassed by HOTS. However, in practice, students' problem-solving abilities remain low (Sriwahyuni & Maryati, 2022). This low proficiency in mathematical problem-solving is partly due to ineffective mathematics instruction (Chen et al., 2019; Szabo et al., 2020; Arofah & Noordyana, 2021).

Research by Herman et al. demonstrates that HOTS can be enhanced through Problem-Based Learning (PBL) (Herman et al., 2022). Additionally, Setiawan's research indicates that student engagement increases when teachers implement PBL, which in turn enhances HOTS (Setiawan et al., 2012). PBL also improves students' HOTS at the analysis stage (Riadi & Retnawati, 2014). To optimize PBL in this digital era, digital elements need to be incorporated to engage students in learning. One approach is through the use of innovative applications related to geometric concepts.

Therefore, the proposed solution in this research is the development of ARITMATIKA, an innovative application for the Introduction to Geometry course implemented through PBL. The specific objective of this research is to develop "ARITMATIKA" (Aplikasi Inovatif untuk Mendukung HOTS Mahasiswa melalui Pembelajaran Berbasis Masalah). The urgency of this research lies in the importance of innovation in education in the 5.0 era to support students' HOTS, enabling them to be competitive upon graduation.

METHOD

This research is a development study focusing on first-year university students taking the Introduction to Geometry course. The study follows the general problem-solving model of education by Plomp, consisting of three of the five phases: initial investigation, design, and realization, as presented in Table 2.1.

Table 2.1 Research Phases

Research Phases	Activities
Phase 1: Initial Investigation	1. Pre-Planning: Conceptualizing the application through problem-based learning. 2. Reviewing Theories: Examining theories related to Android-based applications and problem-based learning. 3. Identifying Geometry Sub-Topics: Organizing the learning objectives by identifying sub-topics in geometry. 4. Identifying the Learning Environment: Assessing the classroom facilities, YouTube, and LMS (Learning Management Systems) as learning resources.
Phase 2: Design	1. Developing a Theoretical Framework: Establishing the theoretical foundation for "ARITMATIKA" in problem-based learning, covering theories related to Android applications and problem-based learning models. 2. Developing "ARITMATIKA": Creating the application content. 3. Determining the Content of "ARITMATIKA": Establishing the specific content for "ARITMATIKA".
Phase 3: Realization	1. Drafting "ARITMATIKA": Compiling a draft for the entire geometry material. 2. Conducting Validation: Performing validation procedures. 3. Analysis and Revision: Analyzing feedback and revising the draft to finalize the "ARITMATIKA" prototype.

RESULTS AND DISCUSSION

The results of development research with three of the five stages of the Plomp model are presented as follows.

Initial Investigation Phase

Several activities were undertaken in this phase:

a. Pre-Planning Activities: It was identified that the current problem-based learning approach remains largely direct and requires enhancement in effectiveness through the incorporation of digital technology advancements. One proposed solution is the development of a learning application designed to integrate both synchronous and asynchronous learning modes.
b. Theoretical Study on ARITMATIKA: The theoretical framework included digital technology, specifically Android, and problem-based learning. The Android platform was selected to provide interactive applications that support the learning process, while problem-based learning aims to present real-world problems to stimulate critical thinking.

c. Material Identification: The content for the Introduction to Geometry course for first-semester students in UM's Bachelor of Mathematics Education program was identified to include five chapters: relationships of lines and angles, parallel lines, triangles, quadrilaterals, and similar triangles.
d. Learning Environment Identification: The learning environment for the Undergraduate Mathematics Education Study Program employs a blended learning approach using Learning Management System (LMS) Moodle for online instruction, complemented by face-to-face sessions over 16 meetings.

Design Phase

Several activities were undertaken in this phase:

a. Theoretical Foundations: The design phase involved establishing the theoretical underpinnings for the Android learning application and the problem-based learning model. The application leverages technology to support the learning process and was developed using Microsoft PowerPoint, converted to HTML5 via iSpring Suite 11, and further converted into an application using Web2APK Builder. The problem-based learning model focuses on stimulating students' critical thinking, particularly in tackling Higher Order Thinking Skills (HOTS) problems.
b. Development of Learning Tools: Problem-based learning tools were developed with the following syntax: orienting students to problems, organizing students to learn, guiding individual and group investigations, developing and presenting results, and analyzing and evaluating the problem-solving process. These tools were designed for 16 meetings, incorporating virtual synchronous, collaborative asynchronous, and independent learning sessions. The application is utilized during independent asynchronous sessions, providing interactive media access to support individual learning.
c. Content of ARITMATIKA: The content structure of the ARITMATIKA application is illustrated in Figure 1.

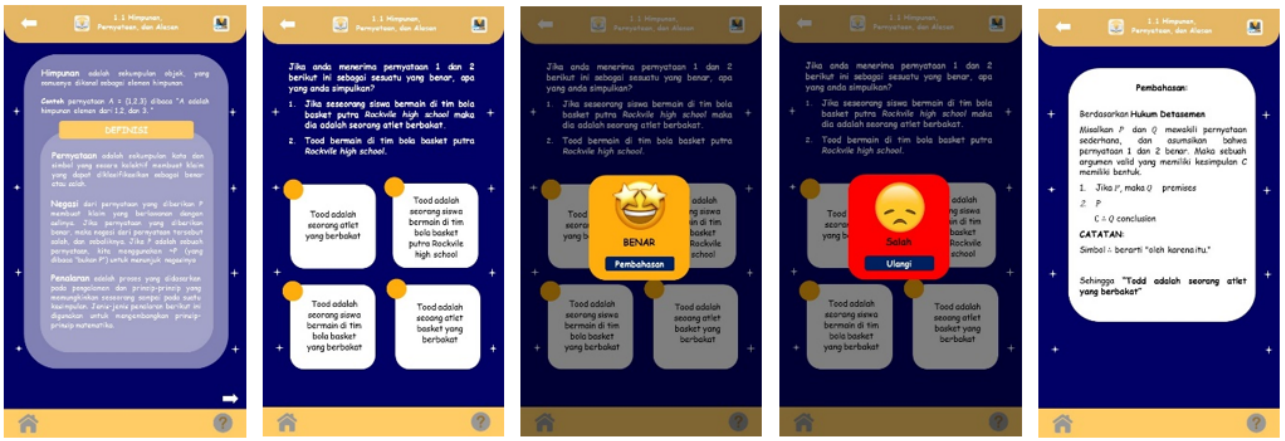

Figure 1. Display of some content in ARITMATIKA

ARITMATIKA contains introductory geometry material, example questions, practice questions, and feedback on the practice questions given.

Realization Phase

Several activities were undertaken in this phase:

a. Drafting ARITMATIKA: The ARITMATIKA draft includes several menus: material, practice questions, problem-solving worksheets, and developer identity. The material menu presents sub-chapters of the geometry introduction succinctly, along with example problems. The practice questions menu features four questions representing each sub-chapter. The problem-solving worksheet menu, presented in flipbook format, is integrated into the application, though students must submit their work through direct contact with the instructor. The developer identity menu contains the developer's name and photograph.
b. The validity testing process was conducted on both the media (product) and the material of the ARITMATIKA application. The objective of the media validity testing was to measure the level of validity of the developed media, ensuring its suitability for user implementation. Material validity testing aimed to assess the validity and appropriateness of the material contained within the media.

Media Expert Validation Results

The media validation test was conducted by two media experts, covering five main aspects: media usage, integration, balance, appearance, and design and linguistic aspects. The results of the media validity test are as follows:

$$\text{Validity Percentage} = \frac{\Sigma x}{\Sigma x_i} \times 100\% = \frac{69}{88} \times 100\% = 78.4\%.$$

Based on the calculations, the percentage of feasibility for media validity testing by media experts is 78.4%, indicating that the media is valid as it falls within the range of 60% to 80%.

Material Expert Validation Results

The material validation test was conducted by two experts in geometry, focusing on two main aspects of introductory geometry material: content appropriateness and language. The results of the material validity test are as follows:

$$\text{Validity Percentage} = \frac{\Sigma x}{\Sigma x_i} \times 100\% = \frac{41}{52} \times 100\% = 78.8\%.$$

According to the calculations, the percentage of feasibility for material validity testing by experts is 78.8%, indicating that the material is valid as it falls within the range of 60% to 80%.

c. Several views of the ARITMATIKA prototype.

(a) (b) (c) (d) (e)

Figure 2 Displays of (a) splash screen, (b) homepage, (c) FAQ, (d) developer identity, and (e) help

The ARITMATIKA display begins with the appearance of the splash screen. Then the user will be directed to select a menu as shown in Figure 2(b). The application is also equipped with instructions for using the application as FAQ (Frequently Asked Questions), the identity of the application developer, and help as seen in Figure 2.

(a) (b) (c) (d) (e)

Figure 3 Displays of introductory material for geometry (a)&(b), example questions (c), and practice questions and the feedback (d)&(e)

As a step to improve students' high-level thinking abilities, the application includes various materials related to introductory geometry, material in the form of material descriptions, enrichment videos, examples of enrichment questions, practice questions, and feedback on the questions given. Several displays of introductory geometry material can be seen in Figure 3.

The research results indicate that ARITMATIKA is suitable for student use, based on feedback from material expert validators and media experts. This suitability arises from ARITMATIKA's role as a learning medium in the form of an application, featuring comprehensive support for the Introduction to Geometry course, utilizing Higher Order Thinking Skills (HOTS) through problem-based learning. The application includes complete materials aligned with the identified curriculum, example questions, practice questions for each sub-topic, and worksheets employing a problem-based learning model. Additionally, the application facilitates independent asynchronous learning while promoting collaborative and participatory interactions between lecturers and students.

Previous research supports these findings. Kartika et al. (2023) concluded that applications in geometry courses are effective learning media, and Tristanti & Iffah (2022) found that Android-based learning media, such as those developed with Smart Apps Creator, can enhance students' evidentiary abilities. These studies align with the goals of our research.

The development of ARITMATIKA can be guided by the suggestions from both media and material validators. In the media aspect, the validators recommended customizing icons and buttons in the application to better suit their functions. For instance, clearly labeling the "Next" and "Previous" buttons would facilitate easier navigation for first-time users. Additionally, standardizing graphic elements such as font size and type across the application can enhance its professional appearance and reading comfort. The validators also suggested incorporating more interactive features, such as drag-and-drop functionality for practicing geometric drawings or augmented reality features for visualizing shapes in three-dimensional space.

For the introductory geometry material, the development should include more in-depth explanations, particularly regarding the practical applications of geometric theory in everyday life and other scientific fields. This aligns with the problem-based learning approach used in the development of the ARITMATIKA application. Including a glossary would help users understand specific geometric terminology. Finally, the validators recommended providing a wider variety of practice questions with varying levels of difficulty to cater to different learning needs.

CONCLUSION

In conclusion, by following the stages of the Plomp model—including the initial investigation phase, design phase, and realization phase—it was determined that ARITMATIKA is well-suited to support the Introduction to Geometry course, employing HOTS through problem-based learning for students. This suitability arises from ARITMATIKA's role as a learning medium in the form of an application, featuring comprehensive support for the Introduction to Geometry course, utilizing Higher Order Thinking Skills (HOTS) through problem-based learning. Furthermore, problem-based learning tools in ARITMATIKA were developed with the following syntax: orienting students to problems, organizing students to learn, guiding individual and group investigations, developing and presenting results, and analyzing and evaluating the problem-solving process. The percentage of feasibility for media validity testing by media experts and validity testing by material expert indicating that the media is valid of both areas.

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