DEVELOPMENT OF POP-UP BOOK-BASED EDUCATIONAL APPLICATIONS ON KINEMATICS CONCEPTS WITH FORMATIVE FEEDBACK INTEGRATION

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Abstract. The era of Society 5.0 demands the integration of technology in physics learning to create an effective and student-centered learning process. Kinematics material requires a multi-representation approach, but there is no Pop-up Book-based educational application that combines real-motion animation and formative feedback assessment. This study aims to develop a Pop-up Book-based educational application on kinematics material with multiple-choice questions, informed by formative feedback, using the ADDIE development model (analyze, design, development, implementation, and evaluation). The results showed that the application had a validity level of 76.67% (valid category), effectiveness with an average N-Gain of 0.6 (medium-high category), and practicality with a student response score of 76.3 (positive category). This application is declared valid, effective, and practical for use as a physics learning medium for kinematics material.

Keywords: Applications, Formative Feedback, Kinematics, Pop-up Book**.**

INTRODUCTION

The current Society 5.0 paradigm necessitates profound pedagogical innovations, particularly the integration of advanced digital technology to foster adaptive and student-centered learning environments (Fadhillah et al., 2024. The development of digital technology has brought about significant changes to the world of education, particularly in science subjects like physics. Physics education requires higher-order thinking skills and the ability to solve problems based on abstract concepts (Feri & Zulherman, 2021). However, various studies have shown that many learners still struggle to understand basic physics concepts, particularly in the topic of kinematics (Sutriano, 2021; Nugroho & Rahmawati, 2022). These difficulties are generally caused by the low student engagement in the learning process and the lack of learning media that can connect abstract concepts to real-world phenomena (Rahmadani et al., 2023).

Digital learning media has emerged as a potential solution to bridge the gap between theory and practice. The integration of technology in physics education enables students to interact with content through visualizations and simulations (Utami & Prasetyo, 2023). One increasingly popular approach is the use of interactive media based on mobile learning, designed to encourage active student engagement while providing contextual and personalized learning experiences (Rahmadani & Dewi, 2023). However, most existing digital media remain informational and have not fully facilitated formative feedback as a means of directly diagnosing students' understanding (Affandi & Bakti, 2020).

Formative feedback plays a crucial role in the learning process by helping students identify mistakes, correct their understanding, and improve learning motivation (Hattie & Timperley, 2007). In the context of physics education, formative feedback can serve as a bridge between concept mastery and students' self-reflection on their thinking process (Ole & Gallos, 2023). However, previous research has primarily focused on the use of interactive media or mobile applications without integrating adaptive, real-time formative feedback systems (Fitriyani, 2022; Sholiha et al., 2022).

Based on this review, a research gap exists in the development of physics learning media that is not only interactive but also diagnostic, integrating automated formative feedback. Previous studies

have rarely combined visual interactivity, mobile-based learning, and adaptive formative assessment into a unified learning system.

To address this gap, we developed the "Pop-Up Book-Based Educational Application with Formative Feedback," an interactive learning media that combines three-dimensional pop-up book visualizations with a digital formative feedback system. This application serves not only as a self-learning tool but also as a diagnostic tool for teachers to monitor students' conceptual development.

The novelty of this research lies in the integration of digital pop-up technology with an automatic formative feedback mechanism designed specifically to enhance students' conceptual understanding of physics in an interactive, contextual, and reflective manner. It is expected that this approach will support more meaningful and engaging physics learning, in line with the 21st-century educational goals and the Merdeka Curriculum, which emphasizes self-directed learning and critical thinking competencies.

RESEARCH METHOD

The type of research used in this study is research and development (Costantini et al., 2023). The research was conducted in the even semester of the 2023/2024 academic year with 30 undergraduate students majoring in Physics Education. The development model employed was the ADDIE model, specifically Analysis, Design, Development, Implementation, and Evaluation (Tegeh & Kirna, 2013). Using the ADDIE model in product development is one of the most effective methods currently available (Defina, 2021). The five stages of ADDIE development are illustrated in Figure 1 below.

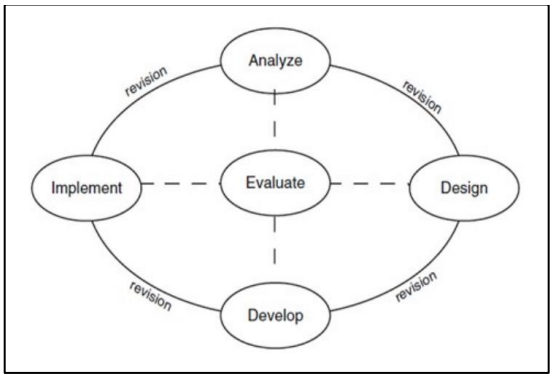

Fig 1. ADDIE Development Model Stages (Cahyadi,2019)

The product developed is an educational application that will undergo three stages of testing: validity testing using validity sheets from subject matter experts and media experts, effectiveness testing through pretest and posttest questions, and practicality testing through student response sheets (Mudjisusatyo et al., 2024). The validity score data obtained is then converted into a percentage using the following equation (Hutabri, 2022).

$$P = \frac{F}{N} \times 100\%$$

The percentage results were then analyzed and converted into predicate statements as shown in Table 1 below.

Table 1. Validity percentage criteria based on expert questionnaires

Percentage (%)	Percentage (%)
80,1% - 100%	Very Valid
60,1% - 80%	Valid

40,1% - 60%	Sufficiently Valid
20,1% - 40%	Less Valid
0,0% - 20%	Not Valid

After being declared valid, the application was tested for effectiveness on a limited basis. The effectiveness test in this study was conducted by measuring student learning outcomes before and after the application was used. The pretest and posttest scores were then analyzed using the N-Gain score, calculated according to the following formula (Selis et al., 2023.

$$N - Gain\ (g) = \frac{S_{Post} - S_{Pre}}{S_{Maks} - S_{Pre}} \times 100\%$$

The results were then analyzed using the Normalized Gaid (g) criteria developed by Sutopo and Waldrip (2014), as shown in Table 2 below.

Table 2. Normalized Gain Criteria

Mean	Criteria
N-gain < 0,25	Low
$0{,}25 \leq \mathtt{N-gain} < 0{,}45$	Lower medium
$0{,}45 \leq \mathtt{N-gain} < 0{,}65$	Upper medium
$\mathtt{N-gain} \geq 0{,}65$	High

The final test was a user practicality test that measured how practical the developed media was. This test was obtained from student responses through a questionnaire that had been distributed. The score data obtained from the Likert scale questionnaire were then analyzed using the following equation (Hutabri, 2022).

$$P\ (\%) = \frac{Score\ obtained}{Maximum\ score} \times 100$$

The percentage results are then categorized into response value categories, as shown in Table 3 below (Putri, 2019).

Table 3. Practicality Categories

Score Range	Criteria
$0\% < p \leq 20\%$	Very Negative
$21\% < p \leq 40\%$	Negative
$41\% < p \leq 60\%$	Moderate
$61\% < p \leq 80\%$	Positive
$80\% < p \leq 100\%$	Very Positive

The evaluation stage is the final stage in each of the four previous stages: analysis, design, development, and implementation. This stage is a stage of improvement based on suggestions and input from the validation team and users regarding media deficiencies. This stage also examines the validity, effectiveness, and practicality of the developed application. The evaluation stage in the ADDIE model assesses whether the developed application is appropriate and can achieve the learning objectives (Tegeh & Kirna, 2013).

RESULT AND ANALYSIS

The development product resulting from this research is an educational application on kinematics based on Pop-Up Books, accompanied by formative feedback questions. The product developed in this study aims to enhance students' conceptual understanding by presenting attractive and contextual multi-representations and helping students identify and correct misconceptions through formative feedback (Aminuddin et al., 2024; Kusairi et al., 2020). Additionally, this product is designed to support interactive and meaningful learning processes while facilitating lecturers in conducting more effective diagnostic assessments of student understanding. The analysis stage was conducted by identifying learning needs through questionnaires and interviews (Tegeh & Kirna, 2013). Based on the questionnaire results, it was found that there was a need for media capable of representing graphs with real motion. This was because many students still had conceptual errors when representing graphs. Additionally, the media used so far is still too monotonous and fails to increase students' interest in learning. Providing exercises based on formative feedback is also necessary, so that students not only complete the exercises but also receive assistance in developing a comprehensive understanding of the concepts. The average results of the questionnaire on student needs related to media obtained data that 78.8% of students (N=30) stated that kinematics material was too complicated and difficult to understand because it used various representations. Furthermore, 85.7% of students (N = 30) agreed that an application should be developed that not only presents material but also provides feedback on each student's answers to practice questions. The interview results generally show that students' cognitive abilities in kinematics are quite good. However, the majority still have difficulty representing graphs, including interpreting the slope of the graph and the area under the curve, as well as connecting two different graphs.

The results of the analysis stage are used as the first step in planning the product to be developed (Tegeh & Kirna, 2013). This initial planning includes determining learning objectives, selecting the type of application to be used, and designing the product concept. The stage of determining learning objectives is based on Core Competencies (CC), Basic Competencies (BC), and Kinematics Material Indicators (Tegeh & Kirna, 2013). Next, the stage of selecting the type of media that suits the needs analysis and characteristics of students, material characteristics, and learning environment characteristics is carried out (Costantini et al., 2023). Based on the analysis results, the selected media is an educational application for kinematics material, featuring pop-up books and accompanied by formative feedback questions. This product was developed using three types of applications: CorelDRAW for designing the initial sketch, Adobe After Effects for animating objects, and Android Studio for designing the application. Additionally, during the design stage, a design plan, script layout, and application layout were also developed. The layout design for the textbook development is shown in Figure 2 below.

Fig 2. Icon and Cover Media Design

In the developed application, students are given two options: material discussion and formative feedback-based exercises. Each discussion (material and exercises) is designed with a pop-up book display. In the material discussion, there will be three main topics, namely, focus on distance and displacement, speed and velocity, and acceleration. Each sub-topic is accompanied by real-motion animations that represent graphs of relationships over time, allowing students to understand the meaning of the graphs through the actual movement of objects. In addition, the discussion focuses only on the central idea of kinematics without lengthy explanations (Bao & Fritchman, 2021; Ding et al., 2024; Xu et al., 2020). This is because the application is not intended as the primary learning medium but as a follow-up to previous learning. The appearance of the material discussion is shown in Figure 3 below.

Fig 3. Design and Layout Sub-Discussion

There will be two levels in the practice questions: Level 1 is intended for solving questions with scaffolding assistance, and Level 2 is for solving questions without assistance. At each level, students' answers will receive feedback that builds their understanding of the concept, rather than directing them to the correct answer. If they are wrong, students will receive the message "don't get stuck," followed by a discussion that corrects their misconceptions. In contrast, they will receive the message "congratulations" and a complete discussion if they are correct. The display of the practice questions is shown in Figure 4 below.

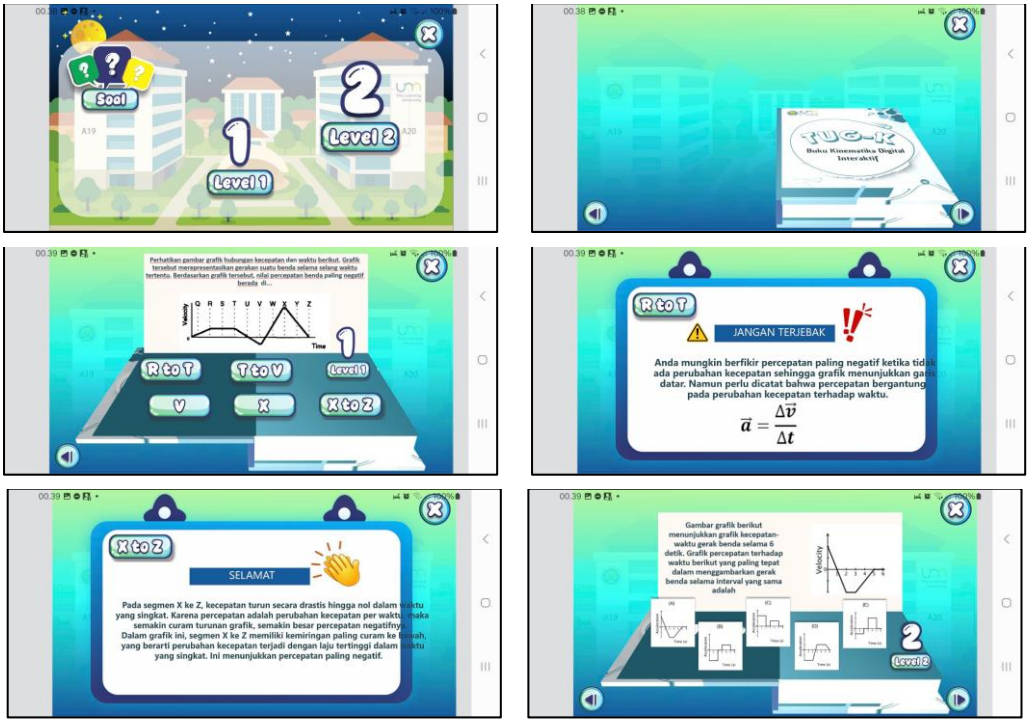

Fig 3. Design and Layout of Sub-Exercises

During the Development stage, validation activities were carried out by two validators, namely an expert validator and a material validator, a physics education lecturer, and learning interventions to measure effectiveness and practicality. The validation stage was carried out by providing a validation sheet with a 5-point scale, namely: score (5) very valid, score (4) valid, score (3) quite valid, score (2) less valid, and score (1) invalid (Hutabri, 2022). The results of the learning media validation are shown in Table 4 below.

Table 4 Validation results of learning media

Aspects	Value V1	Value V2
Content Suitability	78,25	76,75
Language Suitability	74,5	75
Presentation Suitability	73,25	72,5
Graphic Suitability	77,25	78,86
Mean	75.67%	
Criteria	Valid	

Based on the validation results of two validators for the developed media, an average score of 75.67% was obtained, which falls into the 'Valid' category. The assessment covers four aspects: content feasibility, language, presentation, and graphics. Regarding content suitability, each validator scored 78.25% and 76.75%, indicating that the material presented was relevant and aligned with the learning objectives. The language suitability aspect received scores of 74.50% and 75.00%, indicating that the language used was sufficiently communicative and appropriate for the students' developmental level. In terms of presentation, the scores given were 73.25% and 72.50%, indicating that the flow and structure of the media were good but could still be improved. Meanwhile, the graphic suitability aspect received the highest scores of 77.25% and 78.86%, reflecting that the visual appearance of the media was considered attractive, clear, and supportive of the material delivery (Hutabri, 2022). Thus, this media has met the criteria of validity and suitability for learning activities, with minor improvements based on validator input. After the media was validated by two validators and declared valid, the next step was to test the effectiveness of the learning media. This stage was conducted on a limited basis with undergraduate students majoring in Physics Education at Malang State University. This stage was carried out by using the media in the learning process and then giving pretests and posttests to students (N=30) to determine the increase in learning outcomes, so that the developed application's effectiveness level could be determined. The results of the pretest and posttest scores are presented in Table 5 below.

Table 5 Pretest and posttest results

Pre-test Average	Pre-test Average	N-Gain Average	Criteria
60,54	84,21	60	Upper medium

Based on the results in Table 6 using N-Gain, the average pretest score was 60.54, while the average posttest score reached 84.21. This difference in score increase indicates a positive change in students' understanding after participating in the learning process. The calculation of the average N-Gain shows a value of 0.60 or 60%, which is in the upper medium category (Sutopo & Waldrip, 2014). This indicates that the learning process significantly increased conceptual understanding and that the intervention or learning strategy applied was quite effective in improving student learning outcomes. In addition, the provision of real motion animation also helped students understand the interpretation of a graph.

The practicality test was conducted by giving students a questionnaire on their response to the developed application. This test was performed simultaneously with the posttest so that students could assess how the media was used in learning. The results of the practicality test from the students' responses are shown in Table 6 below.

Table. 6 Student practicality results

Aspect	Percentage Per Aspect	Average Percentage	Category
Ease of Use	78	76,3	Positive
Attractiveness	74		
Efficiency	77		

The results of the student response questionnaire for the three aspects obtained an average of 76.3%. The average percentage results of the response aspect were then adjusted to the indicators according to Riduwan (2015). Indicators with an average percentage of 76.3% were in the range of 61%<p≤80%, so it can be concluded that the learning media was categorized as positive (Hutabri, 2022).

Based on these results and discussion, it can be concluded that the learning media developed, namely an educational application for kinematics material based on Pop-Up Books accompanied by formative feedback questions based on smartphones, is valid with a validity score of 75.67% from two expert validators, effective in improving learning outcomes with a N -Gain of 60% or 0.6, placing it in the upper medium category, and received positive responses from users with an average score of 76.3. Therefore, the developed learning media are ready to be implemented on a large scale in the world of education.

CONCLUSION

Based on the data obtained from the research results, it can be concluded that the learning media developed, namely the Pop-up Book-based educational application on kinematics material accompanied by formative feedback assessment, has been declared valid, effective, and practical to use in improving students' understanding of kinematics concepts, especially in graphic representation. The validity of the application reached 76.67%, which is categorized as valid. Its effectiveness, with an average N-Gain value of 0.6, indicates an increase in understanding in the moderate to high category, and the positive response of students with a score of 76.3 indicates a high level of practicality. However, this study still uses limited testing in product development. Therefore, further research is recommended to apply this application on a broader and more diverse scale, such as at various levels of education or different institutions, to test the generalization of its effectiveness and practicality. In addition, developing more interactive application features and personalized feedback can also be a focus to improve learning outcomes and user experience more optimally.

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