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Challenge-Based Learning in Probability: Developing Digital Teaching Materials for High School Students

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Abstract: This study aims to develop digital teaching materials on probability using the Challenge-Based Learning (CBL) model that meets the criteria of being valid, practical, and potentially effective. This is motivated by the low level of difficulty students face in understanding abstract probability material and the lack of interesting and effective learning resources. The development of these teaching materials is expected to provide an innovative solution to overcome the limitations of existing learning resources, particularly in mathematics learning, such as those related to probability. The research used a Research and Development (R&D) approach following the ADDIE model, which includes five stages: analysis, design, development, implementation, and evaluation. Instruments used included expert validation questionnaires, student learning outcome tests, and student response questionnaires. This research trial was conducted on class X students of SMA Negeri 4 Palembang. Data were analyzed both descriptively and quantitatively to assess the quality and impact of the developed materials. The validation results show that the digital teaching materials fall into the "highly valid" category with an average score of 88.66%. The practicality assessment based on student response questionnaires obtained an average score of 89.67% and was categorized as "highly practical". Data collection on learning outcomes was conducted through pretest and posttest learning assessments. Data analysis included normality tests, N-Gain tests to determine the extent of learning improvement, and paired t-tests to determine the significance of differences. The t-test results yielded a Sig. (2-tailed) value of 0.000 less than 0.05, indicating a significant difference between the pretest and posttest scores. The N-Gain test yielded a value of 0.77, categorized as high. The developed product not only meets quantitative criteria but also contributes pedagogically by increasing students' active engagement in the learning process. The integration of the CBL model and digital media enhances students' motivation, participation, and understanding of abstract mathematical concepts. By utilizing Flip PDF software, teaching materials are converted into interactive e-book formats that are more engaging and accessible. This product is worthy of broader application in mathematics education at the high school level.

Keywords: digital teaching materials, challenge-based learning, flip PDF professional, probability.

▪ INTRODUCTION

Mathematics is a subject that is studied and taught at every level of education (Jimenez et al., 2023). However, to this day, mathematics is still perceived as a difficult and intimidating subject. This perception has led to low student motivation in understanding mathematical concepts (Schukajlow et al., 2023). Therefore, as teachers, we must be able to motivate students and change their mindset to create an enjoyable mathematics learning experience (Desmet et al., 2023). This is in line with the opinion of Aulia et al. (2024), which shows that the learning media used significantly influences motivation and learning effectiveness. The mathematics learning process is continuous and meaningful. To create meaningful mathematics learning, it is necessary to involve

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the students' surrounding environment to make it easier for them to understand the mathematical concepts being studied and apply them in their daily lives (Bolstad, 2023).

The rapid development of technology in recent years has brought significant changes to various aspects of life, including education (Statti & Torres, 2020). Technology-based education leads to learning methods that utilize the latest technology to support learning activities (Ahmad et al., 2023). Technological advancements have shifted the focus of learning from conventional methods to digital learning to improve the quality of the learning process (Ahamed & Azmari, 2025). In line with the views of Lumbantoroun & Anggresta (2023), several factors can influence the quality of education, including the availability of learning facilities, effective time management, and the utilization of learning media or educational tools.

In the context of 21st-century education, one of the learning tools used is digital teaching materials (Sari & Atmojo, 2021). Digital teaching materials are various types of learning tools presented in digital form and accessible through electronic devices such as computers, tablets, or smartphones to support the learning and teaching process (Mella et al., 2022). By utilizing digital instructional materials technology, not only is the material presented more engagingly, but it also makes access easier for students. This aligns with the view of Moreira et al. (2023), who state that the development of digital instructional materials aligns with advancements and innovations in the field of education, as well as the demands of the current digital era.

One of the mathematical topics that students often find difficult to understand is probability. A needs analysis based on a literature review revealed that some students struggled to learn probability due to a lack of understanding of the concept, resulting in lower learning outcomes (Zainudin et al., 2021). Interview results at the school also showed that digital teaching materials (electronic) have never been used in the mathematics learning process. The learning resources used are teacher manuals and printed books. As for learning media such as PowerPoint, they are also rarely used. According to Ndruru (2022), the absence of teaching materials developed by teachers at the school has led to students being less interested and motivated in learning probability concepts. This reinforces the need for the development of more contextual and interactive digital teaching materials to help students understand probability concepts more deeply.

To overcome these problems, it is necessary to use digital teaching materials that employ effective learning models or approaches. One such model is Challenge-Based Learning. According to Caballero et al. (2024), Challenge-Based Learning (CBL) is a problem-based learning model that starts with everyday problems, which are then turned into challenges that students must discuss and solve. This Challenge-Based Learning model promotes the learning process and active student engagement (Rosário & Raimundo, 2024).

Several studies also support the importance of implementing CBL in 21st-century learning, especially in relation to low student motivation and difficulties in understanding probability material. According to Gallagher & Savage (2020), CBL not only encourages student engagement through the presentation of meaningful real-world challenges but also facilitates student involvement in the learning process. These challenges spark curiosity about the learning process and ultimately increase students' motivation to understand the material more deeply.

This is also in line with the opinion of Leijon et al. (2022), who suggest that its application can increase learning motivation and strengthen the development of 21st-century skills, such as collaboration, critical thinking, and communication, which are essential in solving mathematical problems, including those related to probability. In the context of mathematics education, the use of digital learning media can enhance students' understanding of probability-related material (Brnic et al., 2024). These findings provide a solid theoretical foundation for the development of CBL-based digital instructional materials in this study, as they demonstrate that a learning design focused on real-world contexts and challenge-based approaches will be effective in addressing such issues.

In developing CBL-based digital teaching materials, software support is needed that can accommodate interactivity and content flexibility. One such software is Flip PDF Professional, which enables the conversion of PDF materials into interactive flipbook formats with additional supporting media such as videos, images, and audio (Setyawan & Faqih, 2023). The advantages of Flip PDF Professional include its user-friendly interface for beginners and the ability to publish the final product for offline use (Janah et al., 2022). By leveraging mathematics learning technology with digital instructional materials, education becomes engaging, effective, and adaptable to the current needs of students (Buchori et al., 2024; Yuan et al., 2021).

In this study, the application of CBL focused on the development of interactive digital teaching materials for probability, representing a significant innovation in this area. Probability was chosen because it is an abstract concept that is often difficult for students to understand when taught using conventional methods. Through the integration of CBL and interactive e-book-based digital teaching materials, students not only learn the theoretical concepts of probability but also connect them to real-world contextual situations. This approach promotes a more balanced cognitive, affective, and social engagement among students. The novelty of this research lies in the application of the CBL model, which is still rarely applied in mathematics education, particularly in probability material, and its integration with digital media designed to support active, collaborative, and meaningful learning. Thus, the developed product is not only pedagogically relevant but also adaptive to the demands of 21st-century education.

Previous studies have examined the use of technology in mathematics learning, including the development of digital teaching materials aimed at improving student effectiveness and engagement (Sari & Atmojo, 2021; Mella et al., 2022). However, most of these studies still use conventional approaches, and few have integrated the Challenge-Based Learning (CBL) model, especially in probability material. Additionally, the use of Flip PDF Professional as a medium for developing digital teaching materials in the context of mathematics learning has not been extensively researched. This indicates a research gap in the development of CBL-based digital teaching materials supported by technology to enhance student motivation and understanding.

Therefore, based on the need for innovation in mathematics learning, especially in probability material, the researcher is interested in conducting research on the development of digital teaching materials on probability using the challenge-based learning model and Flip PDF Professional software. Based on the background description, the research questions in this study are as follows:

1. How to develop valid digital teaching materials on probability based on Challenge-Based Learning for high school students?.
2. How to develop practical digital teaching materials on probability based on Challenge-Based Learning for high school students?.
3. What is the potential effect of the product resulting from the development of digital teaching materials on probability based on Challenge-Based Learning for high school students?.

▪ METHOD

Participants

The subjects in this students of X SMAN 4 Palembang. The subjects were selected using purposive sampling, taking into account availability, accessibility, and relevance to the research topic. The data also came from 44 students of class X.

This research site was chosen because it has implemented an independent curriculum that emphasizes differentiated learning, which is in line with the characteristics of the learning model used in the study. In addition, the school also has learning facilities that support the integration of technology in the classroom, allowing access to digital devices that are highly relevant for implementing digital teaching materials. This makes it easier for researchers to test the practicality and potential effects of the approach.

Research Design and Procedures

This research is a research and development study aimed at producing digital teaching materials based on challenge-based learning on probability for high school students. The development model used in this study is the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation (Spatioti et al., 2022). The analysis stage involved identifying learning needs, analyzing the curriculum, and examining student characteristics and difficulties that students often encounter when understanding probability material. In addition, an analysis was conducted on the availability and limitations of existing learning resources. The information from this stage formed the basis for designing digital teaching materials that were tailored to student needs and learning objectives.

At this stage of the design process, the structure of the digital teaching materials was designed based on CBL syntax. The planning included learning objectives, digital design formats, and the creation of relevant assessment instruments. The flow was also designed to support active student engagement. The development stage involves creating digital teaching materials in accordance with the specified design. The materials are developed in e-book format using Flip PDF software. The product was then validated by experts in the field of learning media. Suggestions and feedback from validators were used to revise the teaching materials before they were tested.

During the implementation stage, digital teaching materials are tested through preliminary and final tests of learning activities designed based on learning objectives. Potential effects are identified through the analysis of learning outcome data collected from preliminary and final tests administered after learning activities.

The evaluation stage involved assessing the development and implementation process through validator feedback and observations during the learning process. The evaluation was conducted by analyzing student learning outcomes data both descriptively

and quantitatively using N-Gain tests and paired sample t-tests. This was interpreted as an indication of the potential effect of digital teaching materials on student understanding.

Instruments

Data collection in this study utilized several instruments developed in accordance with the research objectives, namely to measure the validity, practicality, and potential effects of the developed digital teaching materials. An expert validation sheet was used to assess the validity of the digital teaching materials from the aspects of content appropriateness, presentation design, language, and suitability for the application of the challenge-based learning model. Validation was conducted by three validators, who are experts in mathematics education development and qualified mathematics teachers with experience teaching probability-related content. The indicators on the validation sheet include:

Table 1. The indicators on the validation sheet include

No	Aspect	Indicator
1	Content Feasibility Aspect	Material suitability
		Material currency
		Encouraging curiosity
2	Presentation Feasibility Aspect	Display design
		Presentation techniques
		Presentation support
		Learning presentation
3	Language Suitability Aspecy	Compliance with language rules
		Communicative
		Dialogic and learning
		Suitability for student development

To assess the practicality of the digital instructional materials, a student response questionnaire was used. The questionnaire included statements related to the presentation, content delivery, benefits, and alignment with the challenge-based learning model. Indicators of student response questionnaires, including:

Table 2. Student response questionnaire indicators

No	Aspek	Indicator
1	Appearance	Clarity of text
		Clarity of images
		Attractiveness of images
		Relevance of images to the material
2	Presentation of Material	Presentation of material
		Ease of understanding the material
		Accuracy of presentation of material
		Clarity of sentences
		Clarity of terms
		Relevance of examples to the material
3	Benefits	Ease of learning
		Interest in using teaching materials
		Increased motivation to learn

4	Challenge-Based Learning Model	Engage stage
		Investigate stage
		Act stage

Additionally, to determine the potential effect of using digital teaching materials on student learning outcomes, a learning outcome test instrument was used. The test was designed in essay form to measure students' understanding of probability-related material. The test was administered after students completed learning using digital teaching materials based on the challenge-based learning model. Test results were analyzed to assess student learning outcomes and learning achievement based on the established minimum passing criterion of 75.

The test questions were developed based on the competency achievement indicators in the probability material. Before being used in the pilot test, the instrument was first validated by two expert lecturers and one mathematics teacher who had experience in developing and assessing assessments. The validation was conducted to assess the suitability of the content of the questions with the indicators, the clarity of the language, and its relevance. The results of the analysis are used to revise or replace questions that are not appropriate, so that an instrument suitable for use in research is obtained.

The learning outcome test instrument used in this study consisted of open-ended questions designed to measure the understanding of probability concepts among in-class X high school students. This study aimed to evaluate the potential impact of using Challenge-Based Learning (CBL)- based digital teaching materials on student learning outcomes.

The indicators of conceptual understanding, measured through test questions, include explaining the probability of a simple event and a compound event, calculating probability based on the number of events and the sample space, determining the expected frequency of an event, and analyzing the relationship between two independent and mutually exclusive events. Questions are classified based on Bloom's revised taxonomy cognitive levels, ranging from level C2 (understanding) to C3 (applying), C4 (analyzing), and C6 (creating).

To maintain scoring reliability, a descriptive assessment rubric was also used, which contains detailed assessment criteria for each question item. Scoring was carried out by two independent assessors to ensure objectivity and consistency of scores. If there was a significant difference in scores between the two assessors, a discussion was held to reach a final agreement.

Data Analysis

The data analysis technique used in this study was quantitative descriptive. Quantitative descriptive methods were used in analyzing the results of questionnaires and tests to obtain the validity, practicality, and potential effects of the product that had been created.

Validity Analysis

To determine whether the developed product is valid or feasible, the results of the assessment conducted by the validators can be used. The research instrument used by the researcher is a questionnaire. The scores from each expert validator are averaged and converted into percentages. The validity percentage is then categorized into specific

evaluation criteria: 85–100% falls under the "highly valid" category, 70–85% under the 'valid' category, 55–70% under the "sufficiently valid" category, 40–55% under the "less valid" category, and 0–40% under the "invalid" category (Lusiana & Kesumawati, 2024).

Practicality Analysis

The practicality of the product is analyzed based on the results of the student response questionnaire. The total score from all student responses is calculated and averaged, which is then converted into a percentage. These percentages are categorized into assessment criteria, namely 85-100% falls into the very practical category, 70-85% falls into the practical category, 55-70% falls into the fairly practical category, 40-55% falls into the less practical category, and 0-40% falls into the impractical category (Lusiana & Kesumawati, 2024).

Potential Effects

To measure the potential effect of using digital teaching materials on student learning outcomes, pretest and posttest results were obtained. Data analysis in this study was conducted to determine the potential effect on improving student learning outcomes. The potential effects were measured using the N-Gain test and the paired t-test. The N-Gain values obtained were then categorized into assessment criteria: $g \geq 0.70$ (High), $0.30 \leq g < 0.70$ (Moderate), and $g < 0.30$ (Low). A paired t-test was conducted to determine whether there was a significant difference between the pretest and posttest scores, assuming the data were normally distributed. The criteria for the paired t-test are as follows: sig. (2-tailed) less than or equal to 0.005 indicates a significant difference, while sig. (2-tailed) greater than 0.05 indicates no significant difference. The final results of the analysis will serve as the basis for drawing conclusions regarding the potential effects of the digital instructional material development product.

▪ RESULT AND DISSCUSSION

Research produced a digital teaching material product on probability based on challenge-based learning for in-class X students. This product was first validated by expert validators and subsequently tested through three phases: individual testing, small-scale testing, and field testing. The results of product development are as follows:

In the first stage, the engagement stage, students are introduced to contextual problems that are close to their daily lives, for example, in the form of situations involving the probability of events in games, decision-making, or random events. The challenge is explicitly formulated in the form of provocative questions that spark curiosity, such as "How does probability influence decisions in uncertain situations?" Based on observations and student responses, this challenge successfully captured the attention of most students. They showed enthusiasm in expressing their initial assumptions and relating the challenge to their personal experiences. This indicates that the Engage stage was quite successful in triggering students' affective engagement.

In the investigate stage, students are encouraged to explore and learn more about the concept of probability. The teaching materials provide various digital resources. Students are given the freedom to choose which resources they want to use first. Based on observation data and student comments, they demonstrate varied patterns of independent exploration, with some choosing to read the material while others immediately attempt the exercises. This reflects that digital teaching materials can

facilitate personalized learning. At this stage, students also begin to build conceptual understanding and prepare data as a foundation for tackling challenges in the next stage.

The final stage is the act, where students are asked to complete the initial challenge by developing solutions based on data and mathematical reasoning. The students' solutions take the form of problem-solving based on the challenge context. From the students' work, it was found that most were able to connect their solutions to information from the Investigate stage and construct logical arguments. Although there was variation in the depth of their answers, this process demonstrated that students were not merely "answering questions" but also learning to present solutions in their own way. This is a strong indicator that CBL, through this digital instructional material, is capable of fostering more effective thinking.

Analysis

The first stage that the researcher conducted in developing a digital teaching material product was analysis. There were several stages carried out in this stage, namely needs analysis, curriculum analysis, characteristic analysis, an technology usage analysis

Needs Analysis

In this analysis, the researcher identified the needs of students, including the learning resources used, learning media, and issues arising during the learning process at SMAN 4 Palembang. The needs analysis was conducted by interviewing one of the mathematics teachers at the school. From the interview results, it was found that there had never been any use of digital (electronic) teaching materials in the learning process for mathematics. The learning resources used were printed books and teachers' manuals. Additionally, learning media such as PowerPoint were rarely used. The use of limited or unvaried learning media can lead to a lack of enthusiasm and boredom in the learning process. The researcher's analysis also identified problems, specifically students' difficulty in understanding probability material due to their lack of understanding of the concepts presented in the material (Zainudin et al., 2021). Additionally, the lack of teaching materials has led to students being uninterested or unmotivated to learn mathematics related to probability (Ndruru, 2022).

Curriculum Analysis

Based on the analysis results, the curriculum used in schools is the Merdeka curriculum. This analysis refers to the learning outcomes of the Merdeka curriculum for phase E of Class X.

Characteristics Analysis

The results of the analysis of student characteristics indicate that students continue to struggle with understanding probability material, as it is relatively challenging and requires logical reasoning. In addition, students are also more interested in mathematics learning that uses digital media.

Technology Use Analysis

The results of the analysis of technology use, conducted through interviews with the researcher and one of the mathematics teachers at the high school, revealed that the

school supports the use of technology by allowing students to bring their mobile phones to school.

Design

At this stage, the researcher began developing digital teaching materials in accordance with the learning model and materials used. The researcher also began compiling the instruments to be used in the development of the digital teaching materials.

The storyboard design contains the display structure of digital teaching materials. Each section contains learning components, including the cover, Introduction, Table of Contents, Learning Outcomes and Objectives, Concept Map, Learning Activity 1, Learning Activity 2, Glossary, and Bibliography. The media validation section was designed to assess the quality of teaching materials, including content, presentation, visual appearance, and usefulness. Each aspect was assessed by experts using a 1-4 Likert scale. The assessment results form the basis for revisions during the development stage.

The initial prototype design of the media was created using Canva, a web-based graphic design application that allows for the flexible combination of text, images, icons, and educational illustrations. Once the entire page design was complete, the file was converted into an interactive e-book using Flip PDF Professional. This application enables content to be displayed in a flipbook format, a digital book that features realistic page-turning effects. This digital teaching material is designed to be accessible both offline and online through various devices, including laptops, tablets, and smartphones. With a flipbook format and attractive visuals from Canva, this teaching material is expected to increase student motivation and make learning enjoyable and meaningful.

The process of creating these digital teaching materials utilized the challenge-based learning model, incorporating a previously created storyboard. The digital teaching materials include a front cover, main page, Learning Activity 1, Learning Activity 2, Glossary, and Bibliography. The front cover of the teaching materials features an image, a large title related to the subject matter and learning model used, the identity of the creators, including their names and supervising lecturers, class, level, university logo, and Merdeka Curriculum logo. The results of the design are presented in Figures 1-5.

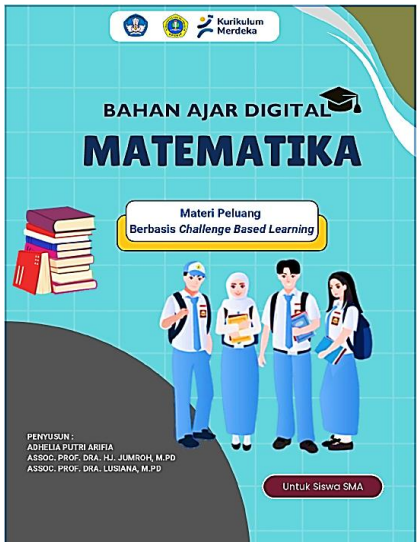

Figure 1. Front cover

Figure 2. View of the foreword and table of contents pages

Figure 3. View of the learning outcomes, learning objectives, and instructions for use pages

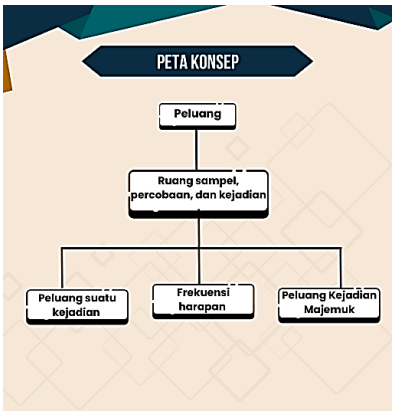

Figure 4. View of the concept map page

Figure 5. View of the learning activities page

The development of student learning activity sections in teaching materials using the challenge-based learning model. These learning activity sections include learning objectives, material descriptions, and the stages of the challenge-based learning model. The stages in challenge-based learning are the Engage stage, the Investigate stage, and the Act stage.

The developed digital teaching material consists of 28 pages that utilize the challenge-based learning model and probability material. Flip PDF Professional software was used to convert the digital teaching materials into an electronic book. The design of

the stages is the result of a storyboard that was created beforehand. At this stage, the instruments were developed to assess the validity and practicality of the digital teaching materials that had been created.

In the engage stage, the teacher acts as a facilitator who sparks students' curiosity through big ideas taken from everyday life. Then, the challenge was linked to the experience of online learning. At this stage, students were also asked to formulate questions from these big ideas. This activity was designed to foster initial engagement and establish connections between everyday life and mathematical concepts.

After understanding the challenges in the investigate stage, students were directed to explore solutions using digital teaching materials. Students learned digital teaching materials equipped with interactive readings, learning materials, and practice questions. Activities include reading basic concepts of probability, understanding challenges, and answering guiding questions. Teachers guided the exploration process, assisted students when they encountered difficulties, and facilitated discussions among students to reinforce their conceptual understanding. This process encourages cognitive engagement as students independently access information sources and analyze materials relevant to the challenges they face.

In the Act stage, students have already developed solutions to the challenges given at the beginning of the meeting. The solutions were written in the form of narrative explanations. Some students also presented their work in front of the class, supported by visual aids from digital teaching materials. The teacher acted as evaluator and facilitator in the learning process, providing formative feedback to strengthen students' logical thinking. Additionally, students were given an individual assessment to assess their understanding of the learned concepts.

Development

At this stage, researchers continued from the design stage that had been previously created. The media was developed in the form of an interactive e-book using Flip PDF Professional software, which allows the integration of various multimedia elements. Flip PDF Professional was chosen because it is compatible with various devices (laptops, tablets, and mobile phones) and features an intuitive interface that is easy to use for both teachers and students.

The digital teaching materials that have been developed produce prototype 1. Then, the digital teaching materials are first validated by validators through a questionnaire provided by the researchers. The validation of the teaching materials is conducted to obtain feedback or suggestions from the validators for improvements to the digital teaching materials before they are tested on students. After validation, the digital teaching materials are tested individually (one-to-one) to identify any errors or mistakes. Subsequently, a small-scale test (involving a small group) is conducted to assess the practicality of the digital teaching materials that have been developed. The validation questionnaire is used to obtain the assessments of the three validators on the developed product, covering several aspects, including content suitability, presentation design, and the CBL learning model.

Based on the validation results, the average assessment score for validator 1 was 87.64%, validator 2 obtained an average of 83.52%, and validator 3 obtained an average of 88.82%. Meanwhile, the average assessment score for the three validators was 88.66%.

Therefore, the validated digital teaching materials meet the criteria for being highly valid. The high validation scores indicate that the developed digital teaching materials have met the expected standards for content and presentation. The "highly valid" category, with an average score of 88.66%, indicates that overall, the teaching materials are aligned with learning objectives, conceptually accurate, and suitable for the characteristics of high school students. The validation questionnaire is the result of a filling or an assessment carried out by validators. The validators provide scores, input, or comments through the questionnaire, which are then analyzed to determine the level of validity of the product being developed (Kalkbrenner, 2021). In line with Chhetri & Khanal's (2024) research, a developed product can be deemed valid or suitable for testing if it achieves an average score of 85-100%. After all validators confirmed that Prototype 2 is highly valid, the developed digital instructional materials can be tested on students during learning activities.

Upon further review based on indicators, the results of the recapitulation, assessed in terms of content feasibility, obtained an average of 87.33%. The feasibility of design and presentation, language, and suitability with the CBL model also achieved averages of 87.5%, 85.33%, and 86.66%, respectively. From this assessment, the design and presentation aspect also achieved the highest average compared to the others. The validators also commended the visual presentation for its use of good colors that are easy on the eyes and the clarity of the presentation structure. Although it received a highly valid rating, the validator provided several suggestions for improvement, including enlarging the image size for greater clarity, correcting spelling errors, improving the sentence structure of the questions, and adding an introduction to the topic of probability at the beginning of the story.

At this stage, after the digital instructional materials have been validated by the validators, they are deemed highly valid for use. The researchers then conducted a one-to-one trial involving two students. The assessment used consists of a column containing comments or suggestions related to the developed product. This stage aims to identify any remaining errors or mistakes in the digital teaching material product. This aligns with the research by Beets et al. (2021), which states that the results of individual testing indicated that the product met the criteria and was deemed suitable for further testing at a small scale. The comments and suggestions from the two students are presented in Table 3.

Table 3. One-to-one test results

Students Name	Comments or suggestions
ASF	The digital teaching materials used are excellent, practical, and easy to carry around. The media display is simple yet effective in attracting students' attention. The explanations of the material are easy to understand, helping students gain a deeper understanding of the subject. The inclusion of relevant sample questions and exercises makes it easier for students to understand the material presented by the teacher.
SAA	The digital book display is excellent, eye-catching, and colorful, making students interested in reading and learning. The material is presented clearly, and the exercises provided are highly relevant to the material being taught.

The next stage involves a small-group trial with 10 people using a student response questionnaire to assess the practicality of digital teaching material products that involve user interaction. The data obtained from the student response questionnaires was then analyzed to evaluate the learning process, including presentation, material delivery, benefits, and the CBL learning model. The analysis results provide an overview of the practicality of using the digital teaching material product after it was used in the learning process.

Based on the results of the student response questionnaire, the average scores were 93.66% for the appearance aspect, 89.07% for the presentation of material, 87% for usefulness, and 89.66% for the CBL model. The overall average for Small Group 1 and Small Group 2 was 89.67%, thereby classifying the digital instructional materials as highly practical. This pilot testing process was based on direct user experience to assess practicality prior to implementation in a broader pilot phase (Santos Diaz et al., 2024). The appearance aspect received the highest score, namely 93.66%. This indicates that students greatly appreciate the attractive visual design and ease of navigation in the teaching materials. The flipbook format created through the Flip PDF Professional application provides a modern and engaging learning experience. Students mentioned that the page-turning animation effect, full-screen display, and interactive icons make learning feel like reading a digital magazine, rather than just reading a regular textbook. The presentation of the material received a score of 89.07%. Students found the presentation of the material to be very helpful in understanding the concept of probability. The material was arranged in a logical order that helped them think more clearly. The inclusion of illustrations, videos, and explanations of concepts using clear and communicative language also reinforced the impression that this teaching material was "student-friendly."

In terms of usefulness, the score was 89.66%. Although this was relatively lower than the other aspects, the usefulness score was still in the very practical category. Students felt that this teaching material made it easier for them to understand probability in a real-life context. Many students appreciated the questions based on everyday situations because they helped them to visualize the concept of probability in concrete terms. Finally, the suitability of the CBL model obtained 89.66%, providing an active and meaningful learning experience. Students felt that they were not only reading and doing exercises, but were involved in solving real challenges, searching for information, developing strategies, and reflecting on the learning process. This approach encouraged a sense of ownership of the learning process and made them more enthusiastic about participating. Therefore, it can be concluded that digital materials based on challenge-based learning are highly practical for use in learning activities.

Implementation

After the validator declared the teaching materials to be highly valid, they were tested individually and on a small scale. The researcher then conducted the next stage, which was a field test or large-scale test carried out in a class of 30 students. This stage was conducted during two classroom learning activities.

The trial began with a pretest to assess the students' initial abilities before using the teaching materials. Next, the students participated in the learning process using the digital teaching materials that had been developed. After all learning activities were completed,

the students took a posttest to measure their final abilities. The results of the pretest and posttest are presented in Figures 6 and 7.

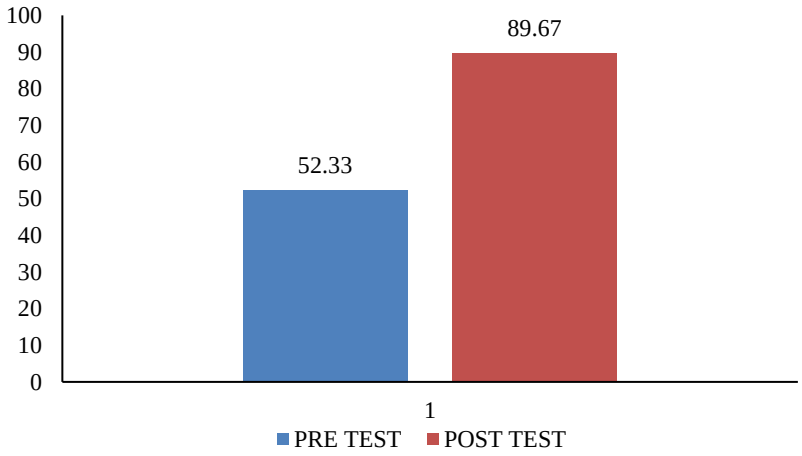

Figure 6. Pre-test and post-test results

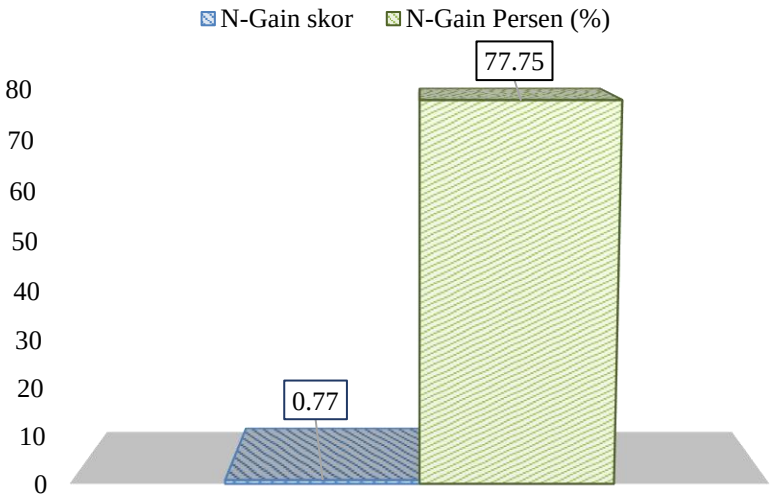

Figure 7. N-Gain test

Based on the test results, the average pretest score was 52.33, while the average posttest score was 89.67. The improvement in learning outcomes was calculated using N-Gain and achieved a score of 77.75, falling within the high category. This indicates that the teaching materials used were effective in providing optimal improvement in learning outcomes for students.

Before conducting the difference test, a normality test was first conducted. The results showed that the pretest and posttest data obtained significance values of 0.097 and 0.075, both of which were greater than 0.05, indicating that the data were normally distributed. With the normality assumption fulfilled, a paired sample t-test was conducted to determine the significance of the difference in learning outcomes.

The results of the paired sample t-test showed a sig. (2-tailed) value of 0.000, which is less than 0.05, indicates a significant difference between the pretest and posttest scores.

These findings suggest that the use of Challenge-Based Learning digital teaching materials has a potentially positive impact on improving student learning outcomes.

Based on the analysis presented above, it can be seen that digital teaching materials incorporating probability content, developed using the challenge-based learning model, have the potential to positively impact the learning process, helping students understand probability concepts. According to Ramaila & Mpinga (2022), the use of digital teaching materials in the learning process can foster learning motivation and have a positive impact on learning outcomes. Additionally, based on the results obtained, students stated that the developed digital teaching materials have a positive impact on learning outcomes, making them suitable for use in teaching and learning activities.

This is also in line with the opinion of Agustine & Apriani (2021), who stated that development products based on challenge-based learning in probability material can increase student engagement and understanding. Similarly, in this study, CBL was proven to activate students' roles in problem-solving and foster their curiosity. However, there was a significant difference in the form of media used. The product developed in this study used digital media in the form of an interactive flipbook, while Agustine & Apriani used printed worksheets.

Evaluation

In research and development, evaluation is the final stage of the process. This stage aims to determine whether the digital material product is valid, practical, and has potential effects after undergoing the development and implementation stages. Evaluation results can be obtained through validation provided by three validators, aimed at determining the validity of the digital teaching materials that have been developed. Once the developed product is validated by the validators, it is deemed suitable for individual testing with students. Subsequently, a small-group test is conducted using a student response questionnaire to assess the practicality of the developed digital teaching materials.

The analysis of student learning test results aims to determine the potential effects of digital teaching materials based on challenge-based learning used in learning activities, as measured by pre-tests and post-tests. The implementation stage focuses on measuring the potential effects of teaching materials on improving student learning outcomes. The assessment is conducted through the analysis of pretest and posttest results using normality tests, N-Gain tests, and paired sample t-test.

Research Limitations

Although the study's results indicate that digital teaching materials based on Challenge-Based Learning (CBL) are highly valid and practical for use in the learning process, several limitations need to be considered. One of the main challenges in implementing these teaching materials is limited access to the internet. Access to digital teaching materials, especially those based on interactive flipbooks, is highly dependent on a stable internet connection. However, during the implementation of the learning process, it was found that some students experienced network limitations in their learning environment, thereby hindering the smoothness of the learning process. This condition presents a technical obstacle that cannot be ignored, particularly in schools with varying digital infrastructure. This is in line with the findings of Gan & Sun (2022), who stated that internet network stability is a major obstacle in digital learning, because the success

of online learning activities is highly dependent on connectivity support and signal quality at the learning location.

In addition to these technical limitations, there are also potential weaknesses inherent in the Challenge-Based Learning (CBL) approach itself. Although CBL encourages active engagement, real-world problem solving, and collaboration, this approach may not always be suitable for all types of students. For example, students with a preference for more structured learning or those with limited initial skills in critical thinking may feel overwhelmed by open-ended and complex challenges. This requires intensive guidance from teachers, and if this is not provided, it may lead to confusion or a decline in motivation to learn.

From a media perspective, the use of a highly structured flipbook format, despite being visually appealing and interactive, may pose risks in limiting students' flexibility and creativity in tackling challenges. The predetermined narrative structure and sequence of materials may reduce the space for free exploration. Therefore, further evaluation is needed regarding the balance between the direction of the materials and students' freedom of thought. In addition, the implementation of CBL in practice also requires teachers to be prepared to manage challenge-based learning processes, from designing challenge scenarios and guiding students' search for solutions to evaluating the learning process and outcomes holistically. This suggests that the use of CBL requires educators to be trained and prepared, which may pose an obstacle in schools with limited resources.

Considering these limitations, the use of CBL-based digital teaching materials needs to be adapted to local conditions and student characteristics, and supported by teacher training and adequate infrastructure so that learning implementation can run optimally and sustainably.

▪ CONCLUSION

Based on the research results, it can be concluded that digital teaching materials on probability, utilizing the challenge-based learning model, are valid, practical, and have potential effects. The overall average validity survey score was 86.66%, meeting the criteria for “highly valid.” The overall assessment of the student response survey sheets yielded a score of 89.67%, meeting the criteria for “highly practical.” Meanwhile, the potential effect obtained through learning outcomes, as evaluated by pretests and posttests, showed high effectiveness. However, a significant difference was found between the pretest and posttest scores using the t-test. It can be concluded that digital teaching materials are capable of improving student learning outcomes, particularly in probability-related topics.

The results of the study also show that the use of a contextual and challenging CBL approach, combined with interactive digital media, can create a more meaningful, independent, and reflective learning experience for students. The main argument that can be drawn from this research is that digital teaching materials are not only instruments for conveying information, but can also be effective pedagogical tools for delivering learning that encourages active engagement, real-world problem solving, and critical thinking, especially when developed within a CBL framework. Structured design and flexible exploration spaces are key to the success of this product in promoting cognitive and affective engagement among students. High learning outcomes and strong participation

levels indicate that integrating innovative learning approaches with digital technology can produce mathematics learning that is more adaptive to the needs of the 21st century.

However, this study has several limitations that should be noted. Therefore, some concrete suggestions for future research include using an experimental design involving a control group to establish a causal relationship between the use of CBL-based digital instructional materials and their effects, and comparing these effects with those of conventional learning models. Conduct trials in a more diverse school context, including schools with limited access to technology, to determine the effectiveness of these instructional materials under various conditions. Involve teachers more intensively in the development and training process for using digital instructional materials, so that the transition from instructor to facilitator in the CBL model can occur effectively. Add adaptive features or interactive branches to digital instructional materials so that more capable students can explore alternative solutions and not feel constrained by overly linear structures. By considering these suggestions, the development of digital instructional materials in the future can become more inclusive, flexible, and have a broader impact in supporting mathematics learning that is relevant to the challenges of the times.

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