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Stem-Integrated Digital Book to Foster Students' Creativity in Vocational Education

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ABSTRACT

Vocational education must be flexible to address industrial challenges and prepare students for workforce participation. However, there is still a lack of innovative digital learning media that integrates STEM approaches to foster creativity in vocational contexts. This study aimed to design interactive digital book learning media based on STEM approaches, ensure its suitability for vocational high school students, and evaluate its usability at the SMK level. The research employed the ADDIE model, implemented holistically from analysis through evaluation. Validation results indicated a feasibility score of 94.67% for the media component and 95.56% for the material component, both categorized as *Very Valid*. Usability testing with students yielded a feasibility score of 99.01%, classified as *Very Feasible*. Furthermore, comparative analysis of pre- and post-treatment scores revealed an average improvement of 36.16, with a normalized gain of 86.71, interpreted as *High*. These findings demonstrate that the use of STEM-based interactive digital books effectively enhances creative thinking skills among vocational high school students, particularly those in the DPIB program. The implications of this study highlight the potential of STEM-integrated digital media as a sustainable learning innovation that can be adopted across vocational education settings to strengthen students' creativity and readiness for future industry demands.

Keywords: Creative Thinking; Interactive Digital Book; Stake Out Measurement; STEM

INTRODUCTION

Investment growth in Indonesia is being driven by the government's ongoing commitment to infrastructure development, alongside substantial investments in the manufacturing and mining sectors, which serve as the foundation for advancing downstream industrial policies [1]. In line with these developments, the qualifications required of the future workforce are expected to evolve dynamically in response to rapid technological progress [2]. Vocational education, therefore, plays a crucial role in equipping graduates with the competencies, skills, attitudes, and professional behaviors necessary to enter and contribute to the productive industrial sector [3]. This need arises because the business and industrial landscape continuously demands a workforce that not only adapts to rapid changes but also demonstrates strong academic and practical skills to remain competitive [4].

The participation of vocational students is largely influenced by occupational aspirations, market demands, and personal challenges, which underscores the importance of flexibility in vocational training [5]. To stay relevant in the labor market, SMK graduates must acquire the ability to learn and adapt rapidly [2]. This creates a pressing need for specialized programs that foster creativity and innovation as essential preparation for entering the world of work or entrepreneurship [6]. However, not all learning models effectively promote creativity; in fact, online learning has been shown to have little to no impact on the creative development of vocational school students [7].

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The rapid advancement of industrial development has intensified global competitiveness and accelerated the transition toward an industrial-based economy [8]. This transformation has significantly reshaped the landscape of vocational education, as technological innovation continues to drive profound changes across industries [9]. In this context, graduates of vocational schools are required to demonstrate a broad spectrum of skills that can be applied across diverse professions, positions, and stages of career development [2]. Accordingly, vocational education must be strategically designed to align with the dynamic evolution of technological knowledge, production processes, and industrial demands, ensuring that graduates remain adaptable and relevant in a rapidly changing workforce [10].

The novelty of this study lies in its focus on developing interactive digital book teaching materials based on the STEM approach. This innovation is intended not only to provide engaging learning media but also to strengthen students' creative thinking skills, an aspect that remains underexplored in vocational schools in Indonesia. At the same time, STEM-based learning has been widely acknowledged for its effectiveness in facilitating knowledge acquisition, retention, and the development of real-world problem-solving abilities [11]. Building on these insights, this study addresses a critical gap in vocational education by integrating STEM principles into interactive digital resources aimed at enhancing student creativity.

LITERATURE REVIEW

An alternative to developing learning in vocational schools is using interactive digital books. The use of digital books employs technology to convey information quickly through sound, graphics, images, animations, and videos, also offering richer content compared to conventional books [12]. The implementation of interactive digital books is relevant across various levels of education, including vocational schools, due to the need for practicality, speed, and ease of access [13]. It is also reinforced that the review of Technology-Enhancing Learning can improve interaction among learners, enhance perceived satisfaction, and increase speed [14]. Another benefit is that students can use digital books as a STEM learning approach, because they can optimize storage space and minimize costs [15].

In secondary education, the STEM approach requires integration between various disciplines and is relevant to technology-based vocational schools [16]. STEM-based learning strongly supports learning that emphasizes holistic and interactive outcomes and plays a role in solving real problems in learning [17]. Also, STEM learning can effectively address improving science literacy with the integration of technology in learning [18]. It is also corroborated by the opinion that STEM education can be effective in getting graduates who can apply concepts to the real world for problem solving, not just limited to knowledge of science, math, and technology concepts [19]. The STEM indicators on which the interactive digital books are based are as follows: engineering of the design process, science or mathematics integration, advanced manufacturing technology, and collaborative group work [20].

Material for interactive digital books specifically for vocational schools with competency in Design, Modelling and Building Information, with land surveying as a subject. The definition of geometry is the art of determining relative positions above or below the earth's surface, by measuring distances, angles, directions vertically or horizontally [21]. Also, land surveying is a field of science that studies measuring and processing data from land measurement results [22]. The focus of the material is on land surveying regarding taking staking out measurements. The following are several competencies that must be mastered, namely studying implementation drawings related to stake out, carrying out stake out measurements, and checking the results of stake out measurements [23].

The development of interactive digital books based on a STEM approach will be tested on its effectiveness with one variable, namely, creative thinking. Creative thinking is an important skill that can be a provision for global competitiveness for businesses and countries [24]. Creative thinking is the process of synthesizing past knowledge and experiences to generate new ideas, concepts, and solutions [25]. Because students' creativity can be observed from their personalities when exploring the objects around them [26]. The indicators of creative thinking are as follows: flexibility, fluency, elaboration, originality, and imagination [27].

METHODOLOGY

This study employed a research and development (R&D) approach, which involved a research method for developing and testing the resulting products that will later be developed in the field of Education [28]. The R&D using the ADDIE model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate [29]. In the analysis stage, gaps in vocational learning were identified, objectives for product development were determined, and project planning for interactive digital book teaching materials was prepared. The design stage involved developing the STEM-based digital book model, preparing instruments (teaching materials, pre-test, post-test, and student response questionnaires), and verifying performance goals. The development stage focused on producing content, creating supporting media, drafting user guides, conducting expert validations for content and media, and revising based on feedback. Implementation involved classroom trials with students to assess the feasibility and effectiveness of the digital book on a broader scale. Finally, the evaluation stage consisted of summative assessments and expert reviews to measure the quality and impact of the product. The research was conducted with Class X DPIB students at SMKN 2 Jember during the 2025/2026 academic year, with X DPIB 1 as the trial sample.

The validity of the learning devices was assessed using validation sheets containing specific aspects and indicators, which were completed by expert validators to evaluate both content and media quality [31]. Content validity and media validity were tested to ensure the instruments measured the intended aspects accurately [30]. Two expert validators reviewed the interactive digital book, and their assessments formed the validation data. An instrument is considered valid if it measures what it is intended to measure, while reliability ensures consistency across measurements [30]. For test items, validity and reliability analyses were conducted using Microsoft Excel 365. The criteria for acceptance were a significance value (Sig. 2-tailed) < 0.05 for validity and a Cronbach's Alpha > 0.6 for reliability. Validation results for the interactive digital book were analyzed using a 5-point Likert scale to determine the overall feasibility of the product. The results obtained from the media and material validation tests are then interpreted according to Table 1.

Table 1. Criteria for Validity Test of Interactive Digital Books

Value	Interpretation
81 - 100	Perfectly Valid
61 - 80	Valid
41 - 60	Fairly Valid
21 – 40	Less Valid
0 - 20	Not Valid

Learning instruments can be used in research only if they meet the criteria of being valid or highly valid [31]. Even when validity is achieved, revisions are made in accordance with validator feedback to improve the instruments. The revised interactive digital book was then implemented with teachers and students to determine its feasibility. Feasibility analysis involved collecting data from product trials, summing scores across sessions, and calculating percentage values using a Likert scale. These results reflect the overall feasibility of the developed interactive digital book in the learning process. The results obtained from the feasibility test are then interpreted in Table 2.

Table 2. Interactive Digital Books Product Feasibility Test Criteria

Value	Interpretation
81 - 100	Very feasibility
61 - 80	feasibility
41 - 60	Fairly feasibility
21 – 40	Less feasibility
0 - 20	Not feasibility

Next, the effectiveness of the developed product was analyzed using the N-Gain test approach. This method measures the improvement in learning achievement or understanding following the implementation of an instructional intervention, whether in the form of a model, method, or media [32]. In this study, the effectiveness of the interactive digital book was evaluated in relation to students' creative thinking skills.

The results of the N-Gain calculation were then categorized according to the criteria in Table 3 [32].

Table 3. N-Gain Score Criteria

Value	Intepretation
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Medium
$g < 0.30$	Low

The results of the N-Gain analysis are divided into three categories. The product is declared effective if the calculation results of the n-gain formula indicate a high value. The data obtained from the administration of questionnaires/surveys is analyzed by determining the number of students who provide positive and negative responses for each category asked in the survey. Positive responses mean that students support, feel happy, and are interested in the components and learning activities through the application of the model. Negative responses mean the opposite. To determine the achievement of learning objectives based on student responses, if the number of students giving positive responses must be greater than or equal to 80% of the total subjects studied. Finally, data analysis was conducted, including normality tests to determine data distribution, t-tests to compare pretest and post-test results, and N-Gain tests aimed at measuring the effectiveness of the Interactive digital books in enhancing Creative Thinking.

RESULTS

Development of Project-Based Learning-STEM-Based Interactive Digital Book

In the development of these interactive digital books, the researchers used the ADDIE development model applied to the X DPIB 1 class at SMKN 2 Jember. This development model consists of five stages: Analyze, Design, Development, Implementation, and Evaluation. First, in the analysis stage, the researcher conducted observations of the learning activities in class X DPIB 1 SMKN 2 Jember, interviews with colleagues, and analyzed the alignment of the vocational school curriculum with job market demands.

The analysis results showed that there was a mismatch between the students' learning process in class because the learning materials still adhered to government standards and had not yet followed industry demands. The learning process is still focused on the individual level, with no collaboration yet. Therefore, the development of teaching materials that meet job demands is highly needed by vocational schools. Teaching materials can also accommodate learning that emphasizes collaboration, as job demands require collaboration with colleagues.

Second, the design stage involves creating the teaching materials, specifically an interactive digital book. The material was divided into three chapters. In the development strategy formulation stage, the STEM approach model was used. The integration will result in an interactive digital book that is relevant to vocational high school students.

Third, the Develop stage. In this stage, we create the content for the interactive digital book. Starting with creating a concept map for each chapter on the topic of Conducting Stake Out Measurements.

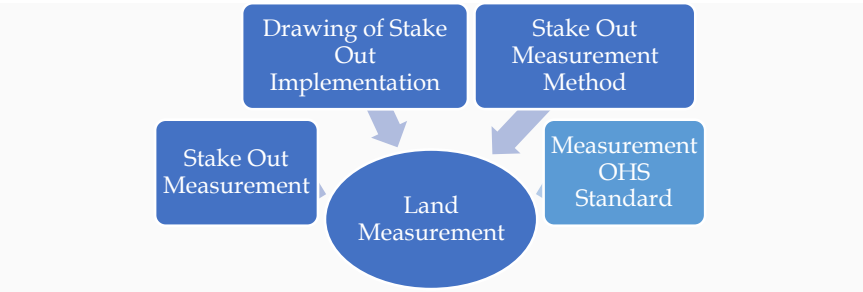

Figure 1. Concept map of the material

The next step is to create comprehensive content for the interactive digital book. Supporting media such as graphics and educational videos are also included in the interactive digital book. Then, it is followed by creating guides for students and teachers. Ended with product testing to be validated by subject matter and media experts. Fourth, the Implementation stage. The stage of preparing the learning environment for limited product trials. The product trials are limited to 10 students in the field.

Finally, the Evaluate stage. This stage assesses the results of the product validation that has been developed. The assessment results from media and material experts are summarized to obtain the outcome. The next step is to write the research results on the product that has been validated by the experts. The feasibility results of the interactive digital book product by two experts for each media and material. Here are the results of the product validation by media experts, which can be seen in Table 4.

Table 4. Media Expert Validation Results

Aspect	Score
Cover Design	23
Content Design	48
Score Acquisition	71
Percentage	94.67%

The validation results from media experts show a score of 94.67%, which means "very valid." The interactive digital book media, based on the suggestions and input from media experts, includes several recommendations related to product development, as shown in Table 5.

Table 5. Media Expert Suggestion Results

Description Feedback
• The cover design gives a glimpse into the content of the book without giving away important information.
• Avoid too much text or design elements that can be distracting

As for the media expert's input, the researcher made product revisions. The first is related to the cover design, which does not provide enough figures related to the material, presented in Figure 4.

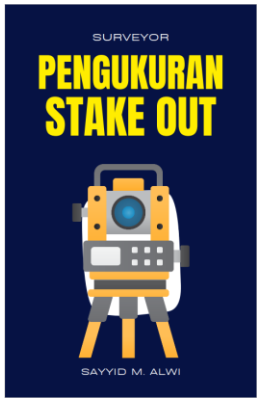

Figure 2. Cover Design Revision

Second, the results of product validation by material experts obtained a score of 95.56% with the interpretation of “Very Feasible”. The conclusion that the interactive digital book product is very valid from the material expert is presented in Table 6.

Table 6. Material Expert Suggestion Results

Aspect	Score
Suitability of learning media with Competency Outcomes	19
Suitability of student activity steps with material on learning media	14
Suitability Summary of material with learning media	14
Score Acquisition	43
Percentage	95.56%

Based on the suggestions and input from the material experts, there are several inputs related to product development, as in Table 9.

Table 7. Results of Material Expert Suggestions

Description Feedback
• The digital book has presented material that is relevant to the learning needs of SMK. So that it really helps bridge the needs of schools and industry. • Expanded with case studies that match real conditions in the field will be more complex.

Regarding the input from the subject matter expert, the researcher revised the product. First, concerning the case study in the digital book, which lacked illustrations related to the material, a revision was presented in Figure 5.

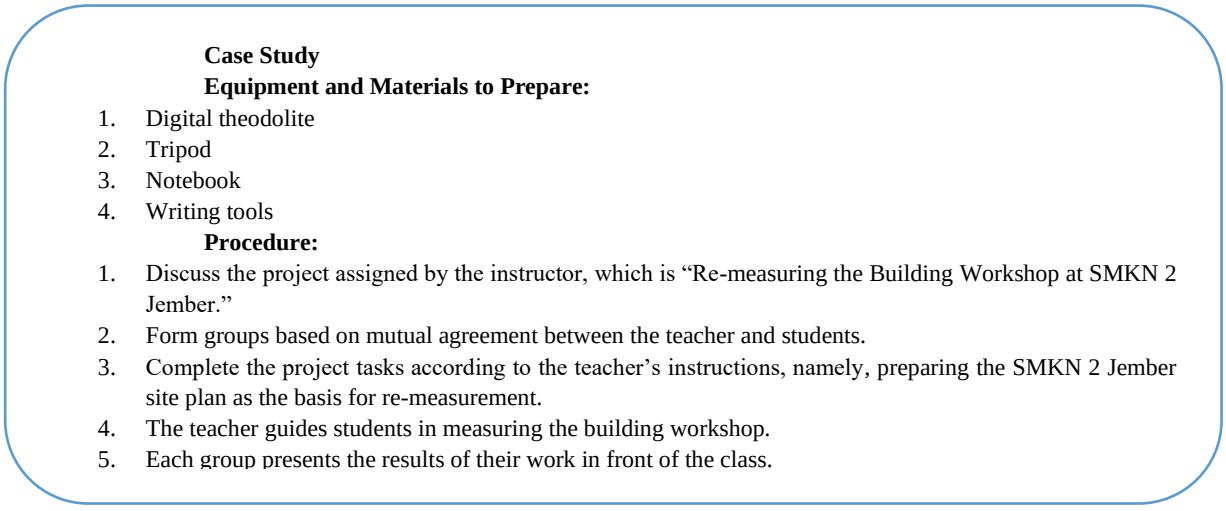

Figure 3. Product Revision with Case Study

The results of the developed product were tested to determine its feasibility. The total feasibility score percentage from the teachers indicates that it is very suitable to be tested on students. Based on the questionnaire results outlined in Table 8.

Table 8. Student Testing

Respondents	Score (%)	Interpretation
Students	99.01	Very Feasibility

Responses from students indicate a feasibility level of 99.01%. Therefore, based on these responses, it can be concluded that the media in the form of an interactive digital book is highly suitable for implementation in the subject of Land Surveying at vocational schools. This is in line with previous research which stated that students in the experimental class using a

mathematics digital book have better mathematical thinking skills than the control class [33]. Other results also support that the use of digital book has more strategies for completing tasks [34].

Level of Effectiveness of an Interactive Digital Book on Creative Thinking and Collaboration Skills

The final part of the ADDIE development model is Evaluation. This stage aims to measure the effectiveness of the developed interactive digital book. Based on the development results, the interactive digital book shows results without revisions. This aligns with the expectation that the final product can enhance the effectiveness of the material on Conducting Stake Out Measurements. The effectiveness of the product is measured by two things. First, pre-test and post-test measurements were conducted in the X DPIB1 class at SMKN 2 Jember. The initial stage is to test the initial abilities with a pre-test on 30 students with 15 multiple-choice questions. After testing the media in the form of an interactive digital book, a post-test was conducted on the students. Thus, pre-test and post-test results will be obtained as per Table 9.

Table 9. Pre-test and Post-test Result

Description	Pre-test	Post-test
Average	45.00	87.69
High Score	67	84
Lowest Rate	37	72
Number of Completed Student	2	28
Learning Completeness	5.56 %	98%

The assessment results in the pre-test and post-test show a significant comparison, as shown in Table 9. The score obtained from the pre-test was 45.00, while the post-test score increased to 87.69. Therefore, when compared, there is a difference of 36.16. At the pre-test stage, no students were able to achieve learning completeness, with a percentage of 5.56%. However, at the post-test stage, a learning completeness percentage of 98% was achieved. This data can be concluded that the developed product is effective in improving learning comprehension, as evidenced by the significant difference between before using the interactive digital book and after applying it to the material on Performing Stake Out Measurements. The results reinforce that the digital book method has proven to help motivate students to achieve post-test scores through external motivation [35]. It is also supported that students experience an improvement in nursing practice performance after completing the program [17].

To ensure that the tested data is normal, a normality test was conducted using the Shapiro-Wilk test. The results of the pretest and post-test normality tests can be seen in Table 10.

Table 10. Normality Test

Parameters	Shapiro Wilk	
		Sig.
MoCA-Ina pretest	30	0.068
MoCA-Ina pretest	30	0.132

Based on table 10, the results of the pretest normality test conducted using the SPSS application show sig = 0.068. While the normality test results for post-test scores show sig = 0.132. If the significance value is> 0.050, the normality test criteria are considered normal.

Furthermore, a paired T test was conducted to determine the difference in the mean scores of the pretest and post-test. The purpose of this T test is to determine the significance level of the difference in the average student scores on the pretest and post-test.

Table 11. Paired T Test

Result	Paired T Test	
	N	Sig. (2-tailed)
MoCA-Ina pre-test post-test	30	< 0.001

Based on Table 11 for the paired T-test, it shows a significant value of 0.000 (less than 0.005), indicating a significant difference between the pre-test and post-test results. These results indicate that the use of interactive digital book can enhance creative thinking.

After the data testing has shown a normal distribution, an N-Gain test can be conducted. The purpose of the N-Gain test is to determine whether the scores obtained from the pretest and posttest can experience an average change [32]. The data shows an average improvement if the N-Gain value criteria are > 0.3 for the moderate criterion and > 0.7 for the high criterion.

Table 12. N-Gain Test

Result	N	Interpretation
Skor N-Gain	30	86.71

DISCUSSION

The N-Gain test results of 86.71, categorized as *very high*, indicate that the implementation of a STEM-based interactive digital book can significantly enhance students' creative thinking and collaboration skills. These findings are supported by previous research demonstrating that interactive digital learning media fosters active student participation, enabling learners to engage meaningfully in the learning process and develop their problem-solving and creative abilities [36]. By integrating STEM principles into digital books, teachers are provided with opportunities to innovate in designing teaching materials that align with modern technological tools, thereby encouraging pedagogical creativity and flexibility [37]. Furthermore, creativity is particularly nurtured in Project-Based Learning (PjBL) frameworks within STEM, allowing students to apply skills in locally relevant contexts, such as those found in vocational high school programs [38]. Creative thinking in this context not only supports the generation of multiple solutions but also facilitates strategic problem-solving, enabling students to approach challenges with greater flexibility and originality [39]. In addition, the deliberate selection of interdisciplinary materials, for example, through collaboration with mathematics, has been shown to enhance communication, problem-solving, creative thinking, and self-confidence, contributing to the holistic development of vocational students' skills [40]. Collectively, these insights suggest that STEM-based interactive digital books serve as an effective medium for fostering critical 21st-century skills [46] in vocational education.

The findings of this study are further supported by existing research demonstrating the effectiveness of STEM-based learning in enhancing student outcomes. For instance, students who engaged with the STEM approach were found to outperform peers taught using traditional scientific learning methods combined with verification practicum techniques [41]. This highlights the advantage of STEM-based instruction in actively engaging students and promoting higher-order thinking skills, as it emphasizes problem-solving, inquiry, and application rather than rote procedures. Similarly, studies on e-books developed through STEM Integrated Creative Problem Solving (BOTIPOSTEM) indicate that such digital resources are highly relevant and effective for fostering critical and creative thinking skills among students [42]. These results underscore the potential of technology-mediated STEM learning tools to provide interactive, student-centred learning experiences that extend beyond conventional classroom methods. Additionally, STEM-based instructional materials, such as Physics Student Worksheets, have been positively evaluated by teacher practitioners and have demonstrated tangible improvements in students' critical thinking abilities, as reflected in their work outputs [43]. Collectively, these studies confirm that STEM-oriented teaching materials whether delivered via interactive digital books, worksheets, or integrated problem-solving modules play a pivotal role

in cultivating essential 21st-century skills, particularly creativity, critical thinking, and problem-solving, in diverse educational contexts. The convergence of these findings with the results of the current study strengthens the argument for implementing STEM-based interactive learning media in vocational education, where the development of both technical and cognitive skills is critical.

Moreover, findings of our research on the development of an interactive digital book employing a STEM approach to enhance creative thinking and collaboration skills among vocational students align with and are supported by Aini's works [44]. Both studies emphasize the integration of STEM methodologies with digital tools to foster critical cognitive skills. Specifically, the aforementioned study utilized a STEM-based Project-Based Learning (PjBL) digital book incorporating ethnomathematics to improve students' mathematical critical thinking abilities. This approach aligns with our findings, which demonstrate that the use of an interactive digital book based on the STEM approach significantly enhances creative thinking and collaboration skills among vocational students. The study provides a supportive framework for our research, highlighting the efficacy of STEM-based digital learning tools in developing critical thinking and collaboration skills among students.

Furthermore, our study shows that STEM-based interactive digital books enhance creative thinking and collaboration in vocational education, highlighting the versatility of STEM-PjBL digital tools across different subjects and learning contexts [45]. Pramasdyahsari's findings [47] demonstrate how context-based STEAM activities can enhance students' creativity in problem-solving and design. Similarly, our findings show that STEM-based interactive digital books in vocational education can improve creative thinking and collaboration skills, highlighting that integrating real-world contexts with STEM approaches effectively supports higher-order cognitive skills across different learning settings.

The novelty of this study lies in its focus on the vocational education context, which has been less frequently examined in the literature compared to general or secondary education. Our findings provide practically relevant evidence that students in vocational tracks not only benefit from STEM-based interactive digital books but also become faster and more precise in grasping vocational material. This highlights the critical role of such media in supporting specialized skill-based education. Several important implications emerge from these results. First, vocational curricula should integrate STEM-based interactive digital books more systematically, as they have been shown to accelerate understanding and foster creativity in vocational subjects. Second, the scalability and accessibility of digital books enable wider deployment, particularly in remote or under-resourced vocational schools, thus reducing educational disparities. Third, the effectiveness of these innovations underscores the need for targeted teacher training, ensuring that educators are equipped not only with STEM content knowledge but also with the skills to design, implement, and evaluate interactive digital learning materials that enhance creativity and collaboration. Finally, while the present study provides strong quantitative evidence of improved creative thinking, further research is required to investigate long-term retention, the specific impact of different interactive features (such as simulations or embedded feedback), and comparative outcomes between digital, blended, and face-to-face STEM instruction in vocational education settings.

CONCLUSION

This study demonstrates that the learning outcomes of X DPIB students in the land measurement subject, specifically on stake out measurement material at SMKN 2 Jember, can be significantly improved through the use of an Interactive Digital Book based on the STEM approach. Validation results indicated a media feasibility of 94.67% and material feasibility of 95.56%, both categorized as *Very Valid*, while student-tested product feasibility reached 99.01%, indicating the digital book is *Very Feasible*. Pretest-posttest analysis showed an average improvement of 36.16 and an N-Gain of 86.71, classified as *high*, confirming that STEM-based interactive digital books effectively enhance students' creative thinking and practical skills in vocational learning. Despite these positive results, this study has several limitations. The research was conducted with a single vocational school and limited to X DPIB classes, which may affect the generalizability of the findings. Additionally, the study focused

only on short-term learning outcomes, leaving long-term retention and application unexamined. The findings have important implications for vocational education. STEM-based interactive digital books can serve as effective learning media to enhance creativity, problem-solving, and collaboration skills, while also providing accessible, flexible learning resources that can be applied across diverse vocational contexts. For future research, it is recommended to expand the study across multiple vocational schools and subject areas, examine long-term retention and skill transfer, and explore the impact of different interactive features, such as simulations or embedded assessments, on student learning outcomes.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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