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Bridging Culture and Mathematics: An Interactive Digital Module with Batik Pattern for Teaching the Concept of Area

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Abstract

Based on the results of observations and literature studies, it is evident that many students struggle to understand the concept of area. Most of them only memorize formulas. Additionally, many students have limited knowledge of the local culture. This study aims to develop interactive digital media based on local culture, specifically in the form of batik patterns, utilizing local materials. The research method used is Research and Development (R&D), employing the ADDIE method, which consists of Analysis, Design, Development, Implementation, and Evaluation. The study's results stated that, according to the validator or media expert, the percentage was 92.86%, categorized as very feasible. The expert provided a percentage of 85.71%, which falls into the very feasible range. The results of the dissemination indicated that the students' responses also showed the media to be very appropriate, with a percentage of 89.64%. The teachers' responses, meanwhile, showed a percentage of 93.75%, which fell within the very feasible category—results of the Wilcoxon Test analysis using the signed rank method. The test shows a $p - value\ of\ 7.45 \times 10^{-9} < 0.05$. It can be concluded that there is a significant increase in pre-test and post-test scores. The median score increased from 65.5 (IQR = 9.25) in the pre-test to 77.0 (IQR = 9.75) in the post-test, indicating an overall improvement in student performance. Furthermore, the calculated effect size (r = 0.85) suggests a large practical impact, confirming that the use of the interactive digital module with batik motifs substantially enhanced students' conceptual understanding of area.

Keywords: Interactive digital modules; local culture; area concepts; batik pattern; mathematics learning

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INTRODUCTION

Globalization and technological advancements have a profound impact on the evolution of civilization, society, and culture. Easy access to foreign cultures through the internet and social media makes foreign cultures more dominant, especially in students' daily lives (Shortland et al., 2024). Often, local cultures are perceived as outdated or irrelevant to modern life. Local cultures such as batik have vibrant aesthetic, historical, and philosophical values and can be a source of inspiration and national pride. The low understanding of local cultures, such as batik, among school students is a worrying problem. Many students are more familiar with foreign popular culture than with Indonesia's cultural heritage (Ozer & Kamran, 2025). This cause can be seen from their lack of knowledge about the history, philosophy, and process

of making batik, as well as the values contained in the heritage of their ancestors (Ramadhan et al., 2021). Understanding local culture is crucial for forming a national identity and developing a sense of love for the homeland (Cairns & Garrard, 2024). One factor contributing to this lack of understanding is the learning approach, which is less engaging and less contextual (Issar, 2021). Many local cultural materials are presented theoretically and do not involve direct experience, which can lead students to feel bored and uninterested. Visits to museums and batik workshops are rarely done routinely. This situation makes it difficult for students to imagine and appreciate the meaning of the culture in depth.

Malang city is one of the big cities located in East Java Province, Indonesia. This city is known as the "Apple City" because it is famous for producing quality apples. Malang also has a cool climate due to its high-altitude location, surrounded by mountains such as Mount Semeru and Mount Bromo (Pemerintah Kota Malang, 2021). In addition to its natural beauty, Malang is also known as a city of education due to the numerous universities. In addition to being known as a city of education, Malang is also known as a city of culture. In Malang City, batik is a cultural heritage that is an important part of local identity. Although batik is better known to come from areas such as Yogyakarta and Solo, Malang also has a distinctive batik pattern known as "Batik Malangan" (Hermanto Candra et al., 2023). This batik is characterized by bright colors and patterns inspired by the natural wealth, local culture, and history of Malang. Patterns such as Mount Semeru, Malangan masks, and peacocks are often featured in Batik Malangan, reflecting the area's beauty and profound philosophy (Basith Rafiqi et al., 2024).

Malangan Batik is not only produced traditionally, but it has also been developed in various modern forms of fashion. The local government and local batik communities actively hold training and exhibitions to introduce Malangan Batik to the broader community, especially the younger generation (Hermanto Candra et al., 2023). This activity is one way to preserve culture while supporting the creative economy in Malang City. Malang City continues to strive to preserve its cultural heritage as part of the nation's cultural wealth (Muluk et al., 2025). Therefore, joint efforts are needed from schools, the government, and the community to increase students' awareness and understanding of local culture. The integration of culture into the curriculum, student involvement in traditional arts activities, and the use of technology to creatively introduce culture can be a solution (Darojah, 2021). With the right approach, students can grow into a generation that is not only academically intelligent but also has a love and concern for the nation's culture. Introducing culture to students does not have to be delivered in art, fine arts, or history subjects. However, it can be integrated with other subjects (Abbas et al., 2022; Fahmi et al., 2022). It will indirectly enable students to gain insight into culture through other subjects. It can also provide an alternative to lessons that are considered difficult to make fun by integrating them.

The results of the study indicated that learning mathematics is often perceived as a boring subject because it primarily involves dealing with numbers and arithmetic. For many students, mathematics is often perceived as a challenging and unappealing subject. This perception is rooted in the view that mathematics consists only of numbers and complex arithmetic formulas (Azmidar & Husan, 2022). When students are faced with a series of calculation problems that seem rigid and abstract, they tend to feel stressed and unmotivated to delve deeper into the material (Sujinah et al., 2023). As a result, mathematics lessons become a feared specter rather than a fun challenge to conquer (Fokuo et al., 2022). Boredom in learning mathematics also often arises because of the monotonous teaching methods. Many teachers still employ conventional methods, such as lectures and practice questions, without providing real-world context relevant to students' lives (Chua et al., 2022; Sunzuma & Luneta, 2023). Mathematics is closely tied to everyday life, from managing finances and understanding time to interpreting data. Without an engaging and practical approach, students will struggle to see the relevance of this lesson.

Additionally, the pressure to achieve high grades in mathematics increases students' anxiety and decreases their confidence (Chishti & Rana, 2021; Jameson et al., 2022; Luu-Thi et al., 2021; Núñez-Peña & Bono, 2019; Smith et al., 2025; Verdeflor et al., 2025). When they fail to understand the concept or make mistakes in calculations, frustration arises. Over time, this creates the perception that mathematics is a subject that can only be mastered by "smart kids". In fact, with the proper methods and a supportive learning environment, all students have the potential to excel in understanding mathematics.

Many students struggle to understand the material on area because these concepts require a solid understanding of plane figures and two-dimensional thinking (Alim et al., 2020; Jain et al., 2022; Shofyan et al., 2021; Yunianto et al., 2024). When students only see two-dimensional images in books or on the board, they often struggle to visualize the real shape of the figure. This results in just memorizing the formula without understanding its meaning. Difficulties also arise when students have to distinguish between all surface areas (Aziiza & Juandi, 2021; Işiksal et al., 2010; Shofyan et al., 2021). It is not uncommon for them to mix up the formulas, such as using the area formula to calculate surface of quadrilateral. The lack of contextual exercises and minimal use of real props also exacerbate the situation. Without concrete visualization, students tend to view this material as a collection of confusing numbers and letters, rather than as a representation of real objects around them.

To overcome these difficulties, teachers can use more interactive and visual learning media, such as paper, cardboard, or digital aids (C. Y. Lee et al., 2023). In addition, linking materials to real objects in everyday life, such as food boxes or aquariums, can help students understand the concept of area more practically. In this way, students will find it easier to understand the differences in concepts and apply them appropriately in various situations (Alkan & Ada, 2024). To change this view, a more creative and enjoyable learning approach is needed (Applebaum, 2025; Hastuti, 2020; Le Thuy, 2025; Pound & Lee, 2021; Supandi et al., 2021; Wahyudi et al., 2020). The use of educational games, interactive technology, and the application of mathematical concepts in real projects can help students feel closer and more interested in this subject. Thus, mathematics is no longer seen as a burden, but as a logical tool for thinking and *problem-solving* that is useful in everyday life.

Several studies have explored the development of learning media based on digital platforms and ethnomathematics, highlighting their potential to enhance student engagement and contextual understanding (Fadilah et al., 2021; Korenova et al., 2024; Mumpuni, 2022; Nugroho et al., 2024; Pradana et al., 2020; Rudyanto et al., 2018; Sunzuma & Umbara, 2025; Susanti et al., 2025). Digital learning media have been widely used to support mathematics instruction, while ethnomathematical approaches have introduced cultural relevance into classroom activities. However, a clear gap remains in the integration of these two elements to specifically teach the concept of area using both non-standard and standard units through culturally meaningful contexts, such as batik patterns. To date, no existing media has been found that explicitly guides students in understanding area by combining non-standard units (e.g., batik motifs) with standard measurements in a unified learning experience. Moreover, there is a lack of digital media that encourages students to design their own batik patterns creatively, allowing for active and personalized exploration of mathematical ideas. This study seeks to address that gap by developing an interactive digital module that integrates batik-based visual elements and student-designed motifs as tools for learning area measurement meaningfully.

This study aims to develop and evaluate an interactive digital learning module that integrates batik patterns to support students' understanding of area. The research specifically focuses on facilitating the measurement of area using both non-standard units (e.g., batik motifs) and standard units (e.g., cm^2), in alignment with the Grade IV mathematics competencies stated in Phase B, which include composing and decomposing flat shapes and measuring area using various units. The indicators targeted in this study involve students'

ability to represent area using visual models, apply measurement strategies, and interpret area meaningfully through cultural contexts. The scope of the study is limited to a single regular Grade IV class in one school, without the inclusion of a control group. Data were collected through pre-test and post-test within a short-term implementation, thus limiting the generalizability and long-term impact assessment of the intervention. Nonetheless, this research offers a culturally rooted and technology-supported approach to strengthen early mathematical thinking in a meaningful and creative way.

METHOD

The type of research used is research and development (R&D), employing the ADDIE method, which consists of Analysis, Design, Development, Implementation, and Evaluation. The analysis or definition stage is an activity that must be carried out by analyzing needs, curriculum, and students. The Design (Planning) stage aims to design solutions to problems identified during the analysis stage. The activities carried out are designing media, assessment instruments, and materials. These elements are then realized into integrated designs. The development stage is the stage of realizing the design that was created during the design stage, so that it becomes a prototype. At this stage, validation is also carried out on the prototype that has been made. The results of the evaluation and validation from experts are used to correct deficiencies in the prototype. So that the media developed is feasible and effective for use. The implementation stage is the activity of implementing media that has been developed and validated. In this study, the distribution was conducted in a single class. The research sample consisted of 28 fourth-grade students from the regular class (non-inclusive) at SD Muhammadiyah 3 Assalaam Malang. The sample was selected using purposive sampling, as the topic of area of plane figures is included in the mathematics curriculum for Grade IV students.

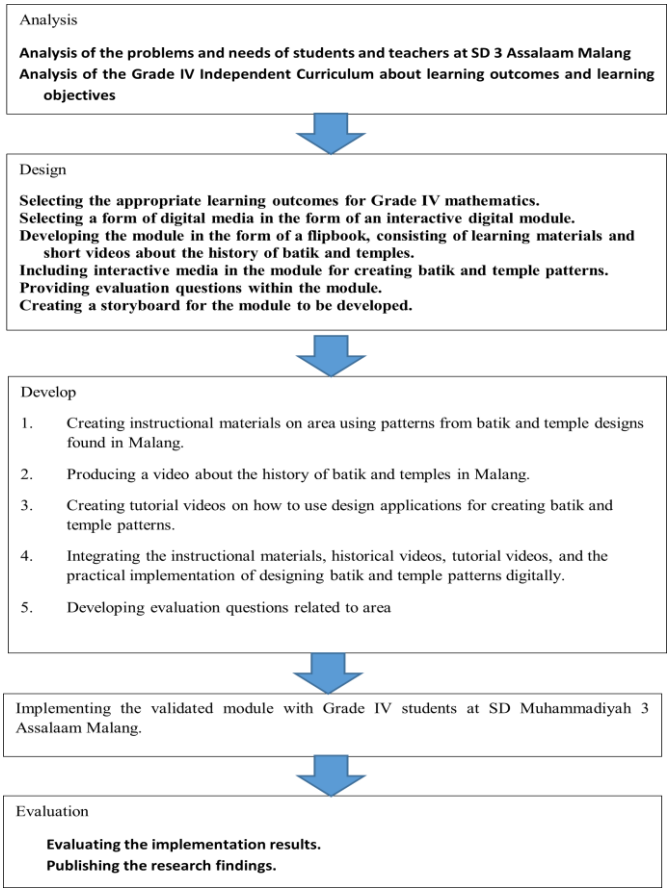

Figure 1. ADDIE

Analysis

At the analysis stage, the activities carried out include analyzing the problems that occur and assessing the needs of students and teachers in mathematics learning at SD Muhammadiyah 3 Assalaam Malang. Interviews were conducted with the principal and teachers to obtain this information. Furthermore, an independent curriculum analysis was conducted to identify learning achievements, learning objectives, and teaching materials. In this study, the research subjects included students, media experts, and material experts.

Design

At the *Define* stage, identify and select the most relevant learning outcomes in grade IV mathematics that support the optimal development of student competencies. Based on the analysis results, the learning media form was chosen as an interactive digital module to enhance student involvement in the learning process. The module was developed in the form of *a flipbook*, which not only contains teaching materials but is also equipped with a short video that introduces the history of batik and temples, serving as a form of integration of local cultural values in learning. In addition, this module provides interactive media that allows students to create batik and temple patterns digitally, thereby strengthening their visual skills and fine motor skills. At the end of each session, evaluation questions are provided as a tool to measure students' understanding of the material covered. To ensure that the flow of material presentation is systematic and engaging, a storyboard is also compiled as an initial design for the development of the digital module that will be used.

Development

At the *Develop* stage, learning materials on area were developed with a contextual approach through the integration of batik patterns and temple patterns typical of the Malang region. This approach is designed to connect mathematical concepts with local wisdom, making learning more meaningful for students. In addition to the primary material, educational videos are also produced that review the history of batik and temples in Malang, serving as a means to strengthen cultural values. To support practical activities, a tutorial on using a design application is created that facilitates students in creating batik and temple patterns digitally. All elements, including teaching materials, historical videos, tutorial videos, and digital design exercises, are harmoniously integrated into a single digital module. The module is also equipped with evaluation questions to measure students' understanding of the concepts of area.

After all components are assembled, a digital module prototype is produced, which is then validated by material experts and media experts to ensure the quality of the content and appearance. Furthermore, limited trials are conducted on small groups of students to observe the effectiveness and appeal of the module. Based on the results of the validation and limited trials, revisions and improvements to the module are made in response to the input received. Table 1 is the validation category.

Table 1. Validation Categories

Percentage %	Category
81-100	Very Feasible
61-80	feasible
41-60	Less feasible
21-40	Not feasible
0-20	Very Unfeasible

Implementation

At the *implementation* stage, a validated and revised interactive digital module was distributed to fourth-grade students at SD Muhammadiyah 3 Assalaam, Malang, as end-users. The implementation of this module was carried out directly in learning activities to measure the effectiveness and achievement of learning objectives. During the implementation process,

observations and evaluations were conducted on student activities and their learning outcomes to determine the extent to which the module improved the understanding of the concept of area in a contextual context.

Evaluation

In addition, the results of this evaluation served as the basis for compiling the final report and disseminating research findings through scientific publications, thereby contributing to the development of digital learning media based on local wisdom in elementary school environments. To test the high and low scores of students' pre-test and post-test results, a normality test was conducted using the Shapiro-Wilk test to assess the normality of the data. To test whether there is a significant increase in the score, a paired-sample t-test will be conducted using the data if it is normally distributed, and a Wilcoxon test will be used if the data is not normally distributed.

RESULTS AND DISCUSSION

Result

Analysis

The initial analysis was conducted to identify the problems and needs faced by students and teachers at SD Muhammadiyah 3 Assalaam Malang. Based on the results of observations and interviews, it was found that a gap still exists between learning needs and the media or devices available, particularly in terms of active student involvement in the learning process. Teachers also expressed the need for innovative learning media that align with the characteristics of elementary school students. Additionally, an analysis was conducted on the Independent Curriculum for grade IV, focusing particularly on learning outcomes and learning objectives. This analysis aims to ensure that the products developed later align with the competencies that students must achieve, encompassing both knowledge, skills, and attitudes. Thus, product development is directed to answer real needs in the field while supporting effective curriculum implementation. The analysis results indicate that the development of this module is primarily focused on Phase B, the measurement element, with learning outcomes that include being able to compose (composition) and decompose (decomposition) various flat shapes in multiple ways. The learning objectives are that students can measure the area of flat shapes with non-standard units and standard units. The cultural aspects developed in the module are batik and temples in the city of Malang.

Design

At the design stage, this produces an interactive digital module design with a local Malang culture theme, arranged in PDF format. Assisted with Canva and then formatted in flipbook form. Flipbooks are developed using the Hyzine website. This module contains learning materials on area, visualized through batik patterns and temple patterns, which represent local wisdom and cultural heritage. In addition to the primary material, the module features a short video on the history of batik and temples, as well as a video tutorial on using design applications to create batik and temple patterns digitally. Interactive features are also embedded in the form of activities that allow students to create pattern designs directly through an integrated application. This module also provides evaluation questions that are arranged according to students' cognitive levels, allowing for the measurement of their understanding and skills after participating in the learning process. All components are packaged in an integrated and attractive manner to create a contextual, interactive, and meaningful learning experience for elementary school students.

Develop

Interactive digital modules are developed with the help of Canva, YouTube, Sketch.io, Rekenweb, and Heyzine websites. The board created at the design stage was then applied to

Canva. A video about the history of batik and temples was created, along with instructions for using the media to create batik and temple patterns, and uploaded to YouTube. For batik patterns using the Sketch.io website. The next stage, which was developed in the media on Canva, was saved in PDF format. The PDF is then converted on the website heyzine. The final result of the conversion is an interactive digital media flipbook.

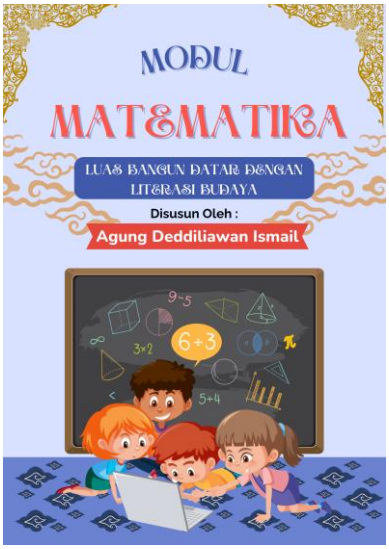

Figure 2. Cover

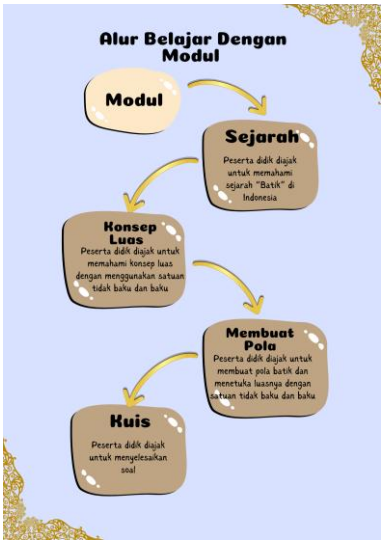

Figure 3. History of Batik

Figure 4. History of Batik

Figure 5. Batik Pattern

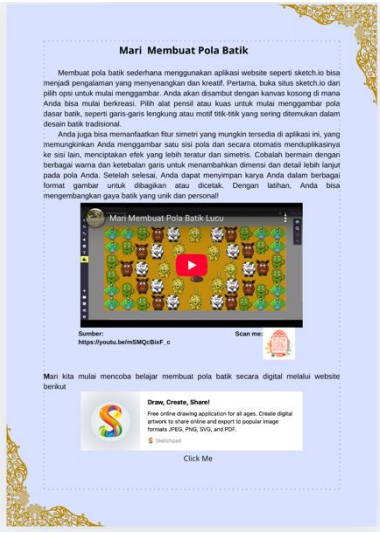

Figure 6. Introduction of interactive media

Figure 7. Example of a cute batik pattern

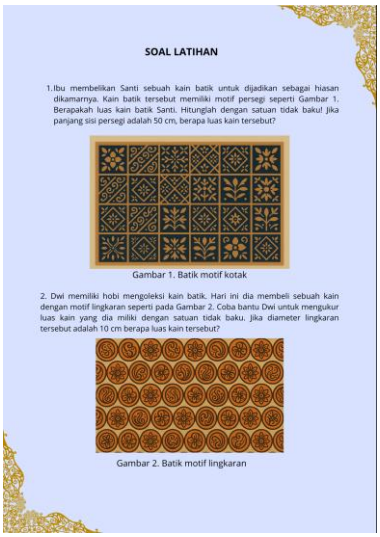

Figure 8. Task for Student

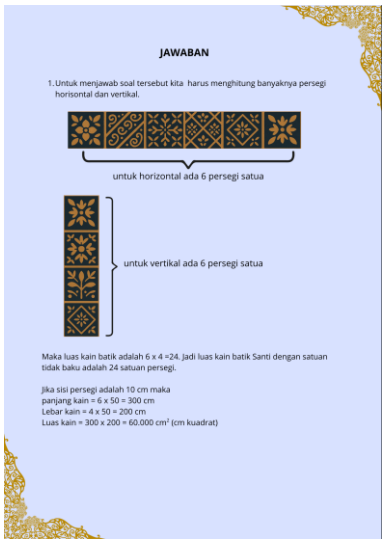

Figure 9. Answer

After interactive digital media has been produced, it is validated in terms of its content and materials. Table 3 is the result of the validation analysis.

Table 2. Media and Material Validation Results

Expert	Score	Average score	Percentage	Std . dev	Category
Media	26	3.71	92.86%	0.488	Very Feasible
Content /material	24	3.43	85.71%	0.535	Very Feasible

Based on Table 2 and Table 1, the percentage of validator 1 is 92.86%. This score falls within the very feasible category. For the second validator, the percentage score is 85.71%. This score falls into the very same category. Feasible. Based on the two validator scores, interactive digital media can be used because it falls within the very feasible category.

Table 3. Limited test or Small test Scale

Respondent	Score	Max Score	Average score	Percentage	Category
Students	142	168	3.38	84.52%	Very Feasible
Teacher	30	32	3.75	93.75%	Very Feasible

Table 3 presents the results of limited trials or small-scale tests, which involved six student respondents and one teacher respondent. Based on the results of the descriptive statistical test, the student response achieved a percentage of 84.52%, and according to Table 1, it was categorized as very feasible. Meanwhile, the teacher's response received a percentage of 93.75%, which means it falls into the very feasible category.

The pre-test and post-test instruments used in this study each consisted of 10 items designed to assess students' conceptual understanding of area. These items were equally divided into two types: five questions required students to calculate area using non-standard units—such as batik motifs or uniform paper cutouts, while the remaining five questions involved standard units of measurement, such as square centimeters or square meters. The test

items were constructed to measure both procedural fluency and the ability to apply concepts in contextual situations. Prior to implementation, the test items underwent expert validation. A media expert reviewed the appropriateness of the question design within the digital format, while a subject matter expert evaluated the content validity, ensuring alignment with the elementary mathematics curriculum. Following validation, the instrument was administered to a sample of 30 students who had previously studied the topic of area. The responses were then analyzed to assess the reliability of the instrument, ensuring that the test items consistently measured the intended learning outcomes.

Table 4. Tabel Cronbach's Alpha of Pre-Test and Post-Test

Test Type	N of Item	Cronbach's Alpha
Pre-Test	10	0.26
Post-Test	10	0.384

Based on Table 7, the results of the instrument reliability analysis show that the Cronbach's Alpha value for the pre-test was 0.26, while for the post-test it was 0.384. These values indicate that the level of internal consistency among the test items falls within the acceptable range for the initial stage of instrument development. Although the values do not yet meet the threshold for high reliability ($\alpha \geq 0.70$), they are still acceptable in the context of exploratory research in elementary education, particularly because the instrument is intended to assess contextual conceptual understanding using a combination of items with non-standard and standard measurement units.

Implementation

After it was stated that interactive digital media is very feasible, the next stage is to disseminate on a larger scale. Before implementing the media, the research objects, consisting of 28 grade IV students, were given a pre-test to determine their initial abilities. Furthermore, the media was implemented and given to 28 objects in the learning. At the end of the learning, the objects were given a post-test and a questionnaire sheet for response. Based on Table 5, the percentage of student responses was 89.54%, which, according to Table 1, falls within the very feasible category. The teacher's response is also in the very feasible category.

Table 5. Response results Large Scale

Respondent	Score	Max Score	Average score	Percentage	Category
Students	702	784	3.58	89.54%	Very Feasible
Teacher	30	32	3.75	93.75%	Very Feasible

Evaluation

At the end of the learning, the object was given a post-test. Based on the analysis, paired pre-test and post-test data were obtained on 28 objects. The next stage is to test the normality of the data. Because the sample size is less than 30, the normality test uses the Shapiro-Wilk test. Based on Table 6, P-value <0.05, then the distribution of the difference between the pre-test and post-test is not normal. To test paired data using a non-parametric test, the Wilcoxon Signed Rank Test is used.

Table 6. Results of normality test, Shapiro-Wilk

	N	Z	p -value
S core	28	0.920	0.034

Based on Table 7, because the p-value < 0.05, there is a significant difference between the pre-test and post-test scores of students. This indicates a significant increase in both the

pre-test and post-test scores. In other words, the interactive digital module based on local culture (batik and temple) has a positive impact on students' understanding of the material on area.

Table 7. Wilcoxon Test Results Signed Rank Test

	N	Z	p -value
S core	28	0.00	7.45×10^{-9}

Descriptive statistics also support this finding: the median pre-test score was 65.5 with an interquartile range (IQR) of 9.25**,** while the median post-test score increased to 77.0 with an IQR of 9.75 in Table 8**.** This increase indicates that most students performed better after engaging with the digital module. The results suggest that the culturally enriched interactive media, incorporating batik patterns, effectively enhanced students' conceptual understanding of area by providing a more contextualized, engaging, and meaningful learning experience.

Table 8. Median and IQR Summary

	Measurement	Median	IQR
1.	Pre-Test	65.5	9.25
2.	Post-Test	77.0	9.75

Since the value of $r = 0.85 \geq 0.50$ in Table 9, it can be concluded that it falls into the category of a large effect. The use of an interactive digital module featuring batik motifs in teaching the concept of area not only demonstrated a statistically significant difference but also had a substantial practical impact on improving students' understanding.

Table 9. Effect size (r)

N	Z-Statistics	r
28	-4.5	0.85

Discussion

The study's results showed that the use of interactive digital media based on local culture, especially those focused on Batik patterns, can improve students' understanding of the concept area of flat shapes. Learning that was initially abstract becomes more concrete and contextual when students are introduced to batik patterns that are rich in geometric shapes (Suanto et al., 2023; Yu et al., 2022). Through digital exploration and manipulation of batik patterns, students not only memorize the area formula but also understand how the concept is applied in everyday life, especially in the richness of Indonesian culture (Basith Rafiqi et al., 2024; Kugler & Kárpáti, 2023). The integration of mathematical content and local cultural elements makes learning more meaningful. This module enables students to build an understanding by linking new knowledge about flat shapes with visual and motor experiences as they create and calculate batik patterns. With this approach, students experience a fun, interactive, and relevant learning process. This finding aligns with the results of research conducted by Wiratmoko and Sampurno (2021), which states that batik can make lessons more fun. The evaluation results showed a significant increase in student understanding scores after using the module, compared to the results before the treatment was given. This media also plays a role in cultural education**.** During the learning process, students not only gain mathematical understanding, but also learn to appreciate local cultural values reflected in batik patterns. It is an important point in strengthening the profile of Pancasila students, especially in developing a character that loves the homeland's culture. Thus, this interactive digital module is not only effective in improving students' academic achievement but also has a positive impact on strengthening cultural identity in the elementary school environment.

The results of the data analysis show a significant increase in scores between pre-test and post-test students after participating in learning using interactive digital media based on local culture. This increase is not a coincidence or natural fluctuation, but rather the result of learning interventions that are systematically designed through media that facilitate students' understanding of the material (Alam et al., 2023; Jameson et al., 2022; Pradana et al., 2020). The consistently increasing post-test scores in most students indicate that the media used have made a real contribution to learning achievement. Statistical testing using the Wilcoxon Signed-Rank Test yields a very small p-value ($p < 0.05$), confirming a statistically significant difference between the pre-test and post-test results. This finding reinforces the notion that the use of appropriate media can facilitate a deeper understanding of concepts among students. Interactive digital modules not only present information but also provide space for students to actively explore, interact, and build meaning, a characteristic of constructivist learning. (Baiduri et al., 2020; Samsudin & Nugraha, 2024). This media not only presents materials visually and interactively, but also links mathematical concepts to local cultural contexts such as batik patterns and temple structures. This approach provides a more meaningful learning experience, helping students understand the concepts of area in a concrete way. The improvement in learning outcomes indicates that students' cognitive, affective, and psychomotor involvement can be achieved simultaneously through the use of contextual and engaging media. Learning is no longer a one-way process; instead, it provides space for exploration and creativity in students. Culture-based media also encourages students to build relationships between academic knowledge and their socio-cultural environment, thus supporting deeper and more sustainable understanding. Thus, culture-based interactive digital media is a practical strategic alternative to improve the quality of mathematics learning in elementary schools.

The media used integrates local cultural elements such as batik and temple patterns, which visually and contextually bring mathematics material closer to the real world of students. Through learning experiences involving visual, audio, and digital manipulative activities, students find it easier to construct an understanding of the concepts of area (C. Y. Lee et al., 2023). Additionally, this approach enables students to become emotionally invested because it incorporates cultural values that are relevant to their daily lives (Hartatik et al., 2025). Thus, a significant increase in learning outcomes after treatment is not just a statistical figure; it reflects the effectiveness of the learning strategies employed. Interactive digital modules based on local culture have proven effective in bridging the gap between mathematical abstraction and concrete contexts that are meaningful to students. This module highlights important implications for teachers and media developers to continue designing relevant, engaging, and contextually relevant teaching materials that improve learning outcomes sustainably (Rabillas et al., 2023).

Using interactive media to create batik patterns in mathematics learning has been shown to significantly increase student engagement. This activity not only provides a fun learning experience but also allows students to be actively involved in the learning process. When students are allowed to be creative with batik patterns using digital tools, they show high enthusiasm and active participation, both individually and in group discussions (Applebaum, 2025; Pound & Lee, 2021; Wiratmoko & Sampurno, 2021). This condition demonstrates that a learning approach incorporating creative activities can enhance students' intrinsic motivation. The activity of creating batik patterns digitally also stimulates students' visual and spatial thinking skills, which are essential for understanding geometric concepts such as area and shape. When students are directly involved in composing patterns, selecting geometric shapes, and modifying designs, they are not only applying mathematical skills but also engaging in an integrative learning process (Chiphambo & Feza, 2020; Ponte et al., 2023; M. Singh et al., 2025; Verdeflor et al., 2024). This process creates meaningful learning situations and encourages students to think critically and reflectively about what they create.

Creating batik patterns in mathematics learning activities provides students with a space to think creatively and express their ideas through geometric shapes. In this process, students not only copy patterns but also design their pattern arrangements, consisting of various flat shapes such as squares, triangles, and circles. This process requires students to consider the size, proportion, and regularity of the shape, thereby encouraging them to think actively visually and spatially (Baiduri et al., 2020; Dintarini et al., 2022; Mueller & Platz, 2022; Nadzeri et al., 2024; Yu et al., 2022). The creativity of students that emerges in making batik patterns is then directly related to their understanding of the concept of surface area (Adha & Putri, 2024; Putra et al., 2022). When students arrange various geometric shapes in one pattern, they indirectly apply their understanding of area units and how to calculate the total area of the shapes. Students designing batik patterns with repeating triangles and squares are required to understand the size and area of each shape so that the pattern remains proportional and aesthetic.

Not only an artistic activity, making batik patterns provides a concrete and meaningful context for students to understand abstract mathematical concepts. Students can see that the concept of area is not only used in textbook questions, but is also applied in real life and local culture (Fernandez & Fernandez, 2020; Hwang et al., 2020; Singer & Voica, 2022). When students measure and compare the areas of the patterns they create, they develop their estimation, measurement, and area calculation skills directly through relevant real-world experiences (Risnanosanti et al., 2024). Thus, the activity of creating batik patterns not only trains students' creative and artistic skills but also serves as a contextual learning strategy that effectively deepens their understanding of mathematics. Linking local culture to subject matter has been proven to strengthen the connection between abstract concepts and students' concrete experiences (Adha & Putri, 2024; Kugler & Kárpáti, 2023; M. Singh et al., 2025). Therefore, this approach is highly recommended for widespread application in mathematics learning, especially at the elementary school level.

This study has several limitations that should be considered when interpreting the results. The implementation of the interactive digital module was conducted in only one regular fourth-grade class at a single school. As a result, the scope of the findings is restricted, and the generalizability to other educational settings or student populations may be limited. The classroom context, teacher involvement, and student characteristics may have influenced the outcomes, making it difficult to draw broader conclusions beyond the specific sample studied. Future research is recommended to expand the implementation across multiple schools with varied socio-cultural backgrounds and learning environments. Such broader application would allow for more comprehensive testing of the module’s effectiveness and its adaptability to different classroom contexts.

Interactive features, such as educational videos and pattern-making applications in digital media, have proven effective in encouraging students to be more engaged in the learning process. Unlike conventional learning, which is only one-way, the presence of interactive elements provides a dynamic and engaging learning experience (Azmidar et al., 2017; Bhowmick et al., 2020; Khakpour & Colomo-palacios, 2020; Kumar et al., 2023; H. Y. Lee et al., 2024; K. Singh et al., 2023). Videos in the module, for example, provide visual and narrative context that makes it easier for students to understand the concepts of breadth and patterns. Meanwhile, the pattern-making application provides students with the opportunity to create their designs, sparking their curiosity and creativity. Active student involvement is evident in the high positive response to the media used by students (Lima et al., 2024; Trigos & Pérez-González, 2023). Most students stated that they felt happy and interested in learning using digital modules because of the features that allowed them to see, hear, and interact directly with the material. Activities such as choosing shapes, combining batik pattern elements, and measuring their area provided a comprehensive and enjoyable learning experience (Caridade et al., 2025; Chen et al., 2023; Russo et al., 2023; Talpur et al., 2024;

Williams et al., 2023). The study demonstrates that interactive features can foster learning conditions that encourage full student participation and engagement. Therefore, Interactive features in digital media play a crucial role in creating active and meaningful learning. High responses from students indicate that the media developed has succeeded in creating a learning atmosphere that is fun, relevant, and encourages exploration. This finding reinforces the notion that effective learning media design should incorporate interactive elements that stimulate various aspects of student development, including cognitive, affective, and psychomotor aspects.

CONCLUSION

Based on the research results, the validator or media expert states that the percentage is 92.86%, which is categorized as very appropriate. The expert gave a percentage of 85.71%, which falls within the very feasible category. The results of the dissemination indicated that the students' responses also showed the media to be very appropriate, with a percentage of 89.64%. The teachers' responses, meanwhile, showed a percentage of 93.75%, which fell within the very appropriate category. Results of the Wilcoxon Test Analysis: Signed Rank. The test shows that $the\ p-value\ =\ 7.45\ \times\ 10^{-9}\ <\ 0.05$. It can be concluded that there is a significant increase in pre-test and post-test scores. The median score increased from 65.5 (IQR = 9.25) in the pre-test to 77.0 (IQR = 9.75) in the post-test, indicating an overall improvement in student performance. Furthermore, the calculated effect size (r = 0.85) suggests a large practical impact, confirming that the use of the interactive digital module with batik motifs substantially enhanced students' conceptual understanding of area.

RECOMMENDATION

Future research is recommended to explore the application of interactive digital modules that integrate local culture with other mathematical concepts and across different grade levels. Additionally, long-term studies could assess the sustained impact of such culturally enriched digital tools on students' learning outcomes and cultural awareness.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Agung Deddiliawan Ismail	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Adityo		✓		✓		✓		✓	✓	✓	✓	✓		
Dyah Worowirastri Ekowati	✓		✓	✓			✓	✓		✓	✓		✓	✓
Erna Yayuk		✓			✓		✓		✓	✓		✓		✓
Alfiani Athma Putri	✓		✓	✓		✓		✓			✓		✓	

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

Ethical approval for this study was granted by Lembaga Penelitian dan Pengabdian Masyarakat (LPPM), Universittas Muhammadiyah Malang.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, ADI, upon reasonable request.

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