



Development of Ethnomathematics-Based Modules Assisted by the Canva Application to Improve Understanding of Scientific Literacy and Mathematical of Pirie-Kieren Theory

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Abstract: This research is motivated by the limited ethnomathematics learning tools that specifically explore local culture and the lack of analysis of students' scientific literacy and mathematical understanding based on Pirie-Kieren's theory. This study aims to develop an ethnomathematics module based on Tulungagung's traditional batik that is valid, practical, and effective in improving students' scientific literacy and mathematical understanding. Using the Research and Development (R&D) method with the 4D model (Define, Design, Develop, and Disseminate), this study involved 60 ninth-grade students as trial subjects. The research instruments included a validation questionnaire, observation sheets, and an understanding test. The results of the material expert validation showed a percentage of 88.31%, and the teacher practitioner validation was 88.65%, both of which are in the valid category. The small group trial resulted in a score of 81.53% (very good). In the field test, the experimental class used a module assisted by the Canva application, while the control class used conventional teaching materials. The analysis results showed that students in the experimental class were able to achieve eight layers of thinking according to Pirie-Kieren's theory, while the control class only achieved five layers. Thus, the Tulungagung batik ethnomathematics module is proven to meet the quality criteria and has a significant effect on improving students' scientific literacy and mathematical understanding comprehensively.

Keywords: Canva application; Mathematics module; Mathematical understanding of Pirie-Kieren theory; Scientific literacy

Introduction

The learning challenges students face in the learning process are not solely driven by personal factors but are also influenced by the limitations of the teaching materials used. Research reveals that teachers tend to rely solely on school textbooks without utilizing other supporting learning resources (Knight, 2015; Dewantara et al., 2024). However, effective learning requires strategic planning regarding objectives and material delivery to ensure students understand concepts meaningfully (Iqbal et al., 2021; Utami et al., 2025). One crucial topic requiring in-depth conceptual

understanding is geometric transformations (Anjarsari et al., 2023; Orhani, 2023). This topic helps students grasp fundamental concepts such as functions and symmetry through various representations and encourages higher-order thinking skills through the use of technology (Hollebrands, 2003; Götz & Gasteiger, 2022). Geometry plays a central role in connecting abstract mathematics with concrete situations in everyday life (Danlami et al., 2025). Despite the importance of geometry, students' understanding of this topic in Indonesia remains relatively low. This is due to a weak mastery of basic concepts in visualization, drawing, and interpretation of shapes (Trisna et al.,

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2022). There is a gap between the material taught in the classroom and the real-life context of students, so mathematics is often perceived as a foreign and difficult subject. On the other hand, despite the abundance of local technology and culture, the integration of both into structured teaching materials—such as modules—remains very limited.

The geometric transformations in this manuscript are not only seen as purely mathematical objects, but also closely intersect with aspects of science through the process of making Tulungagung Batik: Thermodynamics and Changes of Matter: The Mbatik stage involves melting wax (malam), which relates to the concept of melting point and changes in state of matter; Chemistry of Dyeing: The Dyeing and Nemboki stages involve oxidation reactions and chemical binding of color; Physics of Heat Transfer: The Pelorodan stage uses hot water to remove the malam, an application of the principles of heat and temperature transfer. Thus, studying batik through geometric transformations also strengthens students' scientific literacy in understanding physical and chemical phenomena in the surrounding environment (Anwar & Ramadhani, 2025; Ruswinarsih et al., 2025).

As a solution to the low conceptual understanding and lack of cultural literacy, an ethnomathematics approach acts as a bridge. This approach integrates the material into a cultural context familiar to students, such as batik patterns (Pradana et al., 2022; Dhema et al., 2025). The novelty of this research lies in the development of a Mathematics Module based on Tulungagung Batik Ethnomathematics to improve scientific literacy and the Pirie-Kieren Mathematical Understanding Model. While previous research has

focused on general cognitive learning outcomes, this study specifically maps eight layers of student understanding—from Primitive Knowing to Inventing—through an exploration of Satrio Manah Batik patterns, which have a strong history dating back to the Majapahit era (Sakti et al., 2024; Afifah et al., 2020). This module is designed as a form of sustainable social innovation (Mario Florentino et al., 2022; Kabuye Batiibwe, 2024).

Based on this background, this study aims to develop and test the feasibility of a mathematics module based on Tulungagung Batik Ethnomathematics to improve students' scientific literacy and mathematical understanding based on the Pirie-Kieren stages. In addition, this research aims to raise students' sense of concern and pride in local wisdom while providing alternative learning that supports the socio-cultural era by linking abstract mathematical concepts with real practices in making batik.

Method

The research method applied in this study was Research and Development (R&D), with the aim of developing a geometric transformation module designed to improve students' mathematical understanding and visual thinking. The 4D model, developed by Thiagarajan, Semmel, and Semmel in 1974, was originally designed for developing learning tools, specifically in science education. The name 4D comes from the four main stages in its development: Define, Design, Develop, and Disseminate.



Figure 1. Research flow diagram

This learning development model consists of four main stages: definition, design, development, and dissemination. The definition stage focuses on determining learning needs through an analysis of competency gaps, tasks, key concepts, student characteristics, and the selection of Tulungagung batik relevant to mathematics learning. The design stage then aims to develop learning strategies by designing the flow of materials, methods, media, evaluation instruments, and initial prototypes of learning tools such as lesson plans and ethnomathematics modules. In the development stage, the designed tools are validated by experts, revised based on feedback, tested on a limited basis, and further refined based on the trial results. The final stage, dissemination, involves implementing the learning tools more widely, publishing the development results, and distributing them to teachers and schools.

Result and Discussion

Define

Through this stage, the researcher analyzed student needs and discovered that learning using ethnomathematics-based modules had never been implemented before. Further analysis led to the researcher conducting Focus Group Discussions (FGDs) with several stakeholders, including batik artisans, batik gallery owners, batik entrepreneurs, students, and lecturers. The FGDs yielded several findings regarding batik issues in Tulungagung. The following presents the findings from the FGDs. In 1978, the Baronggung batik business was established in Mojosari Village, Kauman. This batik features distinctive motifs such as Sekar Jagad, Burung Merak, Ombak Banyu, Parisauli, and Bunga Nirwana, each with its own distinct philosophical meaning. The Tulungagung batik industry has grown as a home business since 1970, utilizing traditional hand-drawn batik techniques. In the 1980s, stamping techniques were introduced to increase efficiency. Then, in the 1990s, printed batik entered the era, with vibrant colors and faster mass production. The BTA intersection is named after a shop called Batik Tulungagung (BTA) that used to be located on the corner of the intersection. This shop served as a center for batik crafts, a gathering place for artisans, and a hub for the local economy. Although the BTA shop eventually closed, the intersection's name remains widely known and serves as a landmark for the community. Its location is strategic: this intersection serves as a vital route for traffic from Surabaya to the Gayatri Terminal, and is close to facilities such as Bank Jatim, the police station, schools, and pharmacies.

In the mid- to late 1980s and into the Reformation era, the batik sector, like many other micro-enterprises, was hit by declining economic resilience and rising

production costs (labor, raw materials, etc.). Majan Village, once a center for hand-drawn batik, now has only a few artisans, estimated at fewer than 20. Two main factors hindering the survival of traditional batik businesses are: the lack of young batik makers and low wages, making it unattractive to pass on the craft to the next generation. At its peak (the late 1970s to 1980s), Batik Tulungagung (BTA) had a strong network: a cooperative, a multi-purpose building, even a batik kindergarten and a textile company all carried the BTA name. However, from the early 1990s to the early 2000s, the BTA cooperative gradually ceased to function (Geels et al., 2026); . Its building fell into disrepair and was later converted into Bank Jatim. This signal symbolized the decline of Tulungagung batik's glory.



Figure 2. BTA Tulungagung Intersection then and now

The two images above show the name of a famous intersection in Tulungagung. It's usually called the BTA intersection. Today's children will recognize BTA as a restaurant (Bebek Teman Ayam), as shown on the left. However, the name BTA comes from Batik Tulungagung. Batik Tulungagung (BTA) reached its peak in the 1970s. At that time, Tulungagung was able to establish cooperatives and schools using its batik products. However, due to the lack of research on Tulungagung batik during that era, not much can be learned about the conditions in Tulungagung at that time. Stories about the popularity of Tulungagung batik at that time are told through stories passed down from generation to generation by batik artisans.



Figure 3. Tulungagung weaving factory

The image above was obtained by the researcher from the internet. Based on the presentation by the presenter during the FGD, Tulungagung once had a large weaving factory. Therefore, the fabric used for batik was produced locally within the city. Preliminary information obtained suggests that the factory's inoperability is due to a lack of young people interested in weaving. Based on several findings during the ethnomatic analysis, the researcher realized the importance of bringing culture closer to young people, especially students. The younger generation, still in school, are the future of the nation. Without a sense of care and a desire to preserve their culture, it will disappear over time.

Design

At this stage, the researcher designed the ethnomatic component of the module. After conducting FGDs with several batik artisans and identifying several issues related to Tulungagung culture, especially batik, the researcher revised the initial plan for the ethnomatic module. Initially, the ethnomatic module only featured basic batik patterns, as shown in the left image, but this was changed to include full-length batik. This step was taken as an effort to produce successors who love batik and want to make batik.

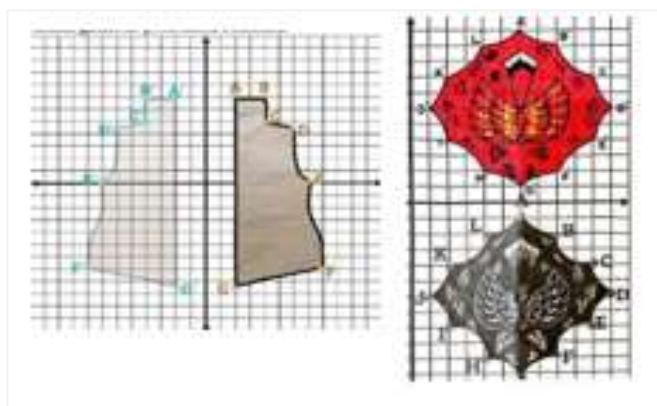


Figure 4. Revised ethnomatics module design

Development

This module utilizes batik motifs and cultural elements as a medium to illustrate mathematical concepts, such as translation, reflection, rotation, and dilation. Each page is visually designed in an ethnic style, using traditional colors, distinctive patterns, and colored navigation icons (such as the translation, reflection, rotation, and result buttons) to facilitate student follow-through. The material is presented through a local cultural approach, enabling students to more easily grasp the concepts through their everyday experiences (Awe et al., 2024; Martin & Towers, 2016). The design was created using Canva, with a colorful display, informative icons, and batik images that

support visual understanding. It follows the Pirie-Kieren theory, where students' understanding builds from prior knowledge to the abstraction stage (Yao & Manouchehri, 2020; Sengul & Argat, 2015). This module is designed for flexible use in both face-to-face and independent learning, as each chapter is complemented by explanations, examples, exercises, and space for reflection (Barua & Lockee, 2024; Sulaiman et al., 2023).



Figure 5. Module view

Once the printed module is complete, the next step is to develop the module using the Canva app. Below is a screenshot of the Canva app.



Figure 6. Module display with the canva app

After the module was completed, the researchers conducted a module validation test. The validity results showed an average score of 88 for the content appropriateness aspect, 91 for the language appropriateness aspect, 90 for the presentation appropriateness aspect, and 89 for the graphic appropriateness aspect. The media expert validation results yielded an average score of 89 for the visual aspect. Relevance to context scored 90. Illustration selection scored 88, graphic appropriateness scored 90, and display scored 91. The material expert and media expert scored 89.6, concluding that the ethnomathematics module was valid and suitable for use. A small group trial was then conducted to determine whether the module was truly ready for use. The following are the results of the small group trial.

Based on the results of the small group trial, the ethnomathematics module received a generally positive response from students. All assessed aspects scored above 85, indicating that the module was quite effective and easy for students to understand. Aspects 2 and 3 received the same score of 89, indicating that both aspects were considered good by students. This aspect likely relates to the relevance of the material to everyday life, the ease of use of the module, or the quality of the practice questions. Aspect 4 received the highest score of 90, indicating that this aspect is a key strength of the module. This aspect likely relates to the clarity of the learning objectives, the relevance of the material to local culture, or the quality of the feedback provided. Based on the results of the small group trial, this ethnomathematics module has the potential to improve students' understanding of mathematics (Masruroh & Amir, 2024; Wongwanich et al., 2026). The following is an example of student work in the trial class.

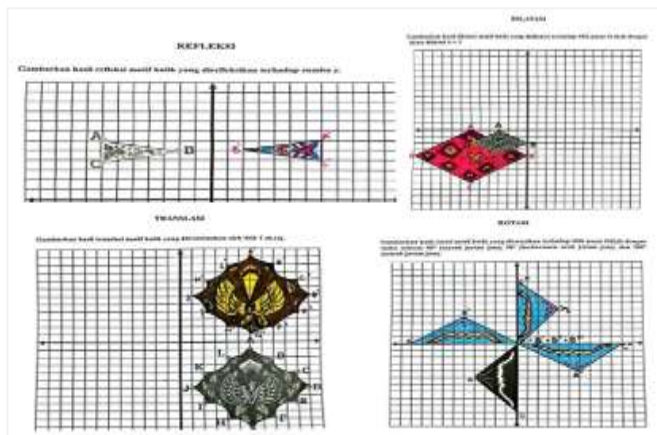


Figure 7. Student work results in the trial class

Disseminate

After the module was proven valid through validation with a validator and a small-class trial, it was declared suitable for use. The module was field-tested. During the field-testing phase of the ethnomatics module development research on Tulungagung batik, learning was conducted in two different classes at MtsN 2 Tulungagung: class A and class B. Class A used the module combined with the Canva application as a learning medium, while class B used conventional methods without additional media. The learning process in class A became more interactive and visual through the use of the module and the Canva application, which positively impacted students' understanding of the geometric transformation concept taught through Tulungagung batik motifs. Meanwhile, in class B, learning was conducted traditionally with lectures and practice problems without the aid of technology. After the learning was completed, students' mathematical

abilities in both classes were measured using the Pirie-Kieren mathematical ability framework.

The results showed that students in class A successfully achieved a proficiency level of up to level 8, indicating they were able to understand concepts in depth and apply them in various contexts. Meanwhile, students in class B only reached level 5, indicating their mathematical understanding was still limited to the basic level and they were less able to develop concepts further. This, difference confirms that the use of modules combined with the Canva application has a positive impact on improving students' understanding of mathematics material, particularly in the context of geometric transformations related to local culture (Santoso & Istiqomah, 2023; Hau et al., 2026). The use of visual and interactive media can help increase students' absorption and understanding, enabling them to reach a higher level of proficiency compared to conventional learning methods. Overall, this field trial confirms that innovation in learning methods that combine technology and local culture can improve the quality of mathematics learning and help students develop their mathematical abilities more optimally (Yabashiru et al., 2025; Talkhan et al., 2025).

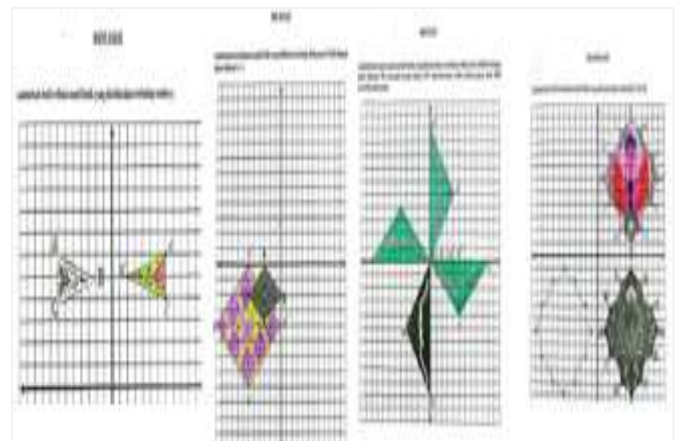


Figure 8. Results of class A students' work

Analysis of Pirie-Kieren Mathematical Understanding While Working on Problems

Visualization

When working on this problem, students first imagine the position of the batik motif before and after it is reflected to the other side of the y-axis. They can see the original image and its reflection, imagining the same shape but in reverse.

Reasoning

Students begin to think about why the points in the image shift position, and how they can be "similar" but on opposite sides of the y-axis. They begin to look for patterns and rules governing this shift.

Informal Deduction

At this stage, students try to draw simple conclusions, for example, that if a point to the right of the y-axis moves to the left by the same distance, then there must be a certain rule behind it.

Formal Deduction

Students begin to use the correct reflection formula, such as changing the x-sign in the point's coordinates from positive to negative to reflect the object about the y-axis. They can now confirm that the reflected point follows the correct mathematical rules.

Integration

Here, students combine their knowledge of reflection with other transformation concepts, such as rotation and translation. They understand that reflection is one way to change the position of an image without changing its shape or size.

Generalization

Students can now expand their understanding, for example, not only reflecting about the y-axis, but also about the x-axis or other lines. They understand that the same principles apply in many situations.

Evaluation

Students begin to review their work, comparing whether the reflected image is symmetrical and follows the rules. They assess for themselves whether their answer is correct or needs improvement.

Rationalization

At this stage, students understand the reasoning behind the reflection rules, for example, why the x-coordinate changes sign and what effect it has on the image's position. They can now explain the reflection process logically and in depth. The results of the field test using six indicators showed an excellent average score. Based on the module's display indicators, it received a score of 80. The material aspect received a score of 83. The practice questions aspect received an average score of 87. The language used received a score of 88. The module's involvement in supporting student understanding received a score of 80. Responses regarding module interest received a score of 87. The effectiveness test resulted in a score of 84.16, indicating the module is in the very good category. The practicality of the Tulungagung batik ethnomatics module was assessed through a questionnaire distributed to teachers and students, the direct users of the module. The questionnaire was designed to reflect the module's ease of use, efficiency, and suitability for supporting classroom learning (Wang et al., 2025; Kim et al., 2024).

Teachers' responses revealed that the module had a clear display, systematic content, and easy-to-understand instructions (Nisa et al., 2022; Wongwanich et al., 2026). Teachers also stated that the module supported contextual learning by linking geometric transformation material to local culture, namely Tulungagung batik. Meanwhile, student responses showed that the module was easy to follow, visually appealing due to its use of Canva designs, and helped them understand material previously considered difficult (Aliviah et al., 2026; Simpson et al., 2025). Some students even mentioned that the use of local batik motifs made the learning experience feel more relevant to everyday life (Gellisch et al., 2023; González-Ceballos et al., 2021). Overall, the questionnaire results indicated that the module was practical, from both the teacher and student perspectives. This confirms that the module is suitable for use in teaching and learning activities and has the potential to increase student participation and understanding of geometric transformation material (Rohendi et al., 2025; Munawaroh & Fitriana, 2025).

Conclusion

Based on the development process and trial results of the developed teaching materials, the following conclusions were reached: The ethnomathematics teaching materials based on Tulungagung batik were developed using a research and development method with a 4D model, which includes the Define, Design, Develop, and Disseminate stages. The teaching materials were declared valid, very good, and effective in improving students' scientific literacy and mathematical comprehension skills based on the Pirie-Kieren theory; The Pirie-Kieren mathematical comprehension skills of students learning using the ethnomatics module showed differences compared to students in the control class. At levels 1–4 of thinking, the experimental class demonstrated good and contextual achievement, meaning students were able to understand the material by relating it to real-life situations. Meanwhile, in the control class, achievement was generally achieved, but understanding still tended to be abstract and detached from context. At levels 5–6 of thinking, students in the experimental class were able to use formal terms and build connections between concepts, indicating a deeper understanding. In contrast, the control class still showed limitations, with learning tending to be rote. At levels 7–8 of thinking, the experimental class demonstrated higher abilities, namely composing and creating, demonstrating higher-order thinking skills. However, the control class had not yet reached this stage. This research was limited to one specific cultural motif and material. Future researchers

could explore ethnomathematics elements in other cultural objects (such as temple architecture or other handicrafts) to broaden the scope of mathematical material.

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Author Contributions

Conceptualization; methodology; validation; F. I. S.; formal analysis; investigation; resources; S. Z. F.; data curation.; M. H.; writing—original draft preparation; writing—review and editing; R. V.; visualization: F. I. S. All authors have read and approved the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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