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Jurnal Ilmiah Ilmu Terapan Universitas Jambi
Vol. 9 No. 4. December 2025, pp. 1444-1458 DOI. 10.22437/jiituj.v9i4.49113
Research Article

BRIDGING CULTURE AND TECHNOLOGY: A PROJECT-BASED LEARNING BASED 3D ANIMATION FILM FOR MOTIVATING STUDENTS IN MATHEMATICS

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Article Info
Received: May 02, 2025
Revised: Jul 08, 2025
Accepted: Oct 05, 2025
OnlineVersion: Oct 28, 2025

Abstract
Low motivation among students in learning mathematics, which is often viewed as abstract and disconnected from everyday life, remains a persistent challenge in Indonesian education. This study aims to develop and test the effectiveness of a 3D animated film based on ethnomathematics integrated with the Project-Based Learning (PjBL) model to enhance students' learning motivation and cultural appreciation. The research employed a Research and Development (R&D) approach following Borg and Gall's model through several stages: product design, expert validation, preliminary trials, field implementation, and operational evaluation. The participants consisted of junior high school students divided into control and experimental groups. Data were collected through expert validation sheets, student response questionnaires, and learning motivation scales. The validation results indicated that the 3D animated film achieved a score of 82%, categorized as "good" and suitable for classroom implementation. Statistical analysis revealed a significant increase in learning motivation in the experimental group compared to the control group, as evidenced by higher pretest–posttest gain scores. The novelty of this study lies in the integration of 3D animation and ethnomathematics within the PjBL framework an innovative combination that contextualizes mathematical concepts through local cultural wisdom while promoting active, project-based engagement. This research contributes to the growing field of culturally responsive digital learning media by demonstrating that ethnomathematics-based animation not only enhances motivation but also bridges traditional cultural values with modern technological learning approaches, offering a scalable model for 21st-century mathematics education.

Keywords: 3D Animated Film, Ethnomathematics, Learning Motivation, Project-Based Learning

INTRODUCTION

Contemporary education demands the cultivation of competencies that extend beyond the mere mastery of academic knowledge, encompassing critical thinking, creativity, collaboration, and problem-solving abilities. As emphasized by Hasan and Hidayati (2023), 21st-century education prioritizes the

development of "competencies to face an increasingly complex, dynamic, and technology-driven world." However, the realization of such transformative learning goals often encounters barriers in the form of conventional, teacher-centered pedagogical practices that rely heavily on rote memorization and procedural repetition (Tanti et al., 2021; Kurniawan et al., 2022; Giro & Haji, 2024; Ajadi & Ayanlowo, 2025). This traditional paradigm limits students' opportunities to apply knowledge meaningfully, especially in mathematics, where abstract concepts are frequently detached from students' lived experiences consequently diminishing their motivation and engagement (Supriyadi, 2021; Alkilany et al., 2025; Demon & Santos, 2025).

Mathematics is often perceived as an abstract and emotionally distant subject, disconnected from the cultural and social realities of learners. To address this disconnection, Project-Based Learning (PjBL) has been widely recognized as an instructional approach that enables students to contextualize mathematical concepts through hands-on, real-world projects (Tanti et al., 2021; Eriza & Hadi, 2023; Asmaningrum et al., 2025; Fetmirwati et al., 2025). Complementarily, ethnomathematics defined by Diantina et al. (2023), Fauzi and Lu'luilmaknun (2019), and Valda et al. (2022a) as "a way of viewing mathematics as a cultural product that reflects the social values of a community" offers an alternative framework for linking mathematical learning with local wisdom and cultural practices. Despite these promising frameworks, educators often struggle to effectively integrate PjBL and ethnomathematics in classroom practice. The teaching of mathematics still frequently lacks tangible and culturally relevant visualization, leading to an incomplete implementation of culturally contextualized pedagogy. As highlighted by Diantina et al. (2023), ethnomathematics provides a vital opportunity to bridge this pedagogical divide by rooting mathematical learning within the cultural heritage of the community. This pedagogical tension raises a critical question about the effectiveness of conventional teaching approaches that continue to dominate mathematics classrooms compared to innovative, contextually grounded, and technology-supported alternatives. Supporting this argument, Valda et al. (2022) assert that "technology-based learning, such as animated media, can provide immersive visual experiences that significantly enhance student motivation and interest."

The integration of technology into education has shown substantial potential in mitigating students' learning disengagement. According to Abidi et al (2017), Supriyadi (2021) and Putri and Nadlif (2023), the use of technology-based media particularly 3D animated films can help students visualize abstract mathematical concepts more clearly and concretely. Such immersive visual experiences not only enhance comprehension but also strengthen motivation and engagement. Hidayatullah and Csíkos (2024) and Rachmawati et al. (2020) further emphasize that well-designed visual learning media reduce cognitive load, enrich mental representations, and improve conceptual understanding. Similarly, Putu et al. (2020) found that 3D animation effectively translates abstract mathematical ideas into accessible and meaningful visual forms, thus improving students' grasp of difficult concepts.

Despite these promising findings, integrating technology and culture in mathematics education remains a complex challenge. While technology effectively enhances visualization, many educational media fail to incorporate local cultural dimensions, resulting in learning tools that are technologically advanced but culturally irrelevant. Pradita et al. (2021) note that while 3D animation facilitates conceptual understanding, it often overlooks cultural values that could strengthen contextual learning. Likewise, Safitri et al. (2020) argue for a more holistic approach that recognizes mathematics as inherently connected to culture, yet many digital learning tools continue to ignore these dimensions. Valda et al. (2022) similarly point out that aligning technical and cultural elements in learning media remains a major obstacle, reducing the relevance and authenticity of the learning experience. These issues highlight the necessity for collaboration among technology developers, educators, and cultural experts to design learning media that are both pedagogically sound and culturally responsive.

Within the framework of Self-Determination Theory (SDT), Elvira and Nirwana (2022) explain that students' intrinsic motivation increases when learning experiences are perceived as relevant, meaningful, and personally engaging. Therefore, developing 3D animated films based on ethnomathematics through the PjBL model can foster intrinsic motivation by combining cultural contextualization, interactive visualization, and project-based learning principles. As stated by Teplá et al. (2022), "the optimal learning experience occurs when students feel challenged but are able to connect what they learn with their personal experiences and contexts." While previous studies have separately demonstrated the effectiveness of ethnomathematics in contextualizing learning and 3D animation in visualizing abstract concepts, there remains a critical research gap regarding the integrated development and empirical validation of technology-based ethnomathematical media within a PjBL framework. Most

prior research has focused only on product design or theoretical aspects, lacking experimental evidence on how such integration directly impacts students' motivation, engagement, and understanding of mathematical concepts within culturally meaningful contexts.

To address this gap, the present study develops and evaluates a 3D animated film based on ethnomathematics through the Project-Based Learning (PjBL) model aimed at enhancing students' learning motivation in mathematics. This study not only contributes to the development of culturally grounded and technologically advanced learning media but also provides empirical evidence on their pedagogical effectiveness. Furthermore, this research responds to teachers' ongoing challenges in integrating culture and technology in mathematics education (Prasetya et al., 2024). As a practical contribution, the study offers guidance for educators in designing meaningful learning experiences that reflect both cultural identity and technological innovation, aligning with contemporary educational principles that stress contextual relevance and learner engagement (Suherman, 2025).

RESEARCH METHOD

This study employed the Research and Development (R&D) model proposed by Borg and Gall (1983), which consists of ten systematic stages: (1) research and information gathering, (2) planning, (3) development of the product draft, (4) preliminary field testing, (5) revision based on trial results, (6) main field testing, (7) revision of the product after field testing, (8) operational field testing, (9) final product refinement, and (10) dissemination and implementation. The development process was carried out progressively until the final product a 3D Animated Film based on Ethnomathematics was refined and validated for classroom implementation. This model was chosen because it provides a comprehensive framework for developing, testing, and validating educational products through iterative cycles of design, evaluation, and revision to ensure both effectiveness and practicality in real learning contexts (Borg & Gall, 1983).

The research participants were involved across three trial stages: preliminary, field, and operational field trials. The preliminary trial involved four students from Grade VIII G, while the main field trial included nine different Grade VIII G students who did not participate in the initial stage. The operational field trial involved 29 students from Grade VIII H, divided into two groups Class A with 19 students and Class B with 10 students selected using a cluster random sampling technique. In this sampling method, Class A served as the experimental group, receiving the 3D animated film intervention, whereas Class B functioned as the control group, receiving conventional instruction. This sampling strategy ensured unbiased group assignment and increased the internal validity of the study's findings.

The instruments used in this research included expert validation sheets, student response questionnaires, and a learning motivation questionnaire. The expert validation sheets were completed by content and media experts to assess the validity, feasibility, and quality of the developed product, ensuring alignment with pedagogical and technological standards. The open-ended student questionnaires were designed to capture students' experiences and perceptions of the learning process after using the 3D Animated Film based on Ethnomathematics. These were administered to all trial participants to collect feedback for product improvement. The learning motivation questionnaire, adapted from Lavado et al. (2024), employed a pre-test and post-test design and was distributed to operational field trial participants to measure changes in students' learning motivation before and after the implementation of the learning media.

Data analysis was conducted using a combination of qualitative and quantitative techniques. Qualitative descriptive analysis was applied to describe the development stages and assess the feasibility and effectiveness of the 3D Animated Film based on Ethnomathematics during the preliminary and field testing phases. Quantitative data analysis was carried out in the operational field trial stage to measure the impact of the developed media on student motivation. The independent sample t-test was employed using SPSS version 21 at a significance level of 0.05 to test the research hypotheses. Comparative analyses were performed to evaluate differences between pre-test and post-test scores within the experimental and control groups, as well as between post-test scores of both groups (Mou, 2024). This mixed-method analytical approach allowed the researcher to comprehensively assess the product's validity, practicality, and effectiveness as a learning tool for enhancing student motivation in mathematics learning.

RESULTS AND DISCUSSION

The creation of a 3D animated film based on ethnomathematics, utilizing the Project-Based Learning (PjBL) model to enhance student motivation, was carried out through a carefully structured nine-stage development process. This journey included the following steps: (1) conducting thorough research and gathering relevant information; (2) strategic planning; (3) drafting the initial product; (4) conducting preliminary trials; (5) revising based on trial results; (6) conducting field testing; (7) refining the product in response to field trial feedback; (8) conducting operational field testing; and (9) finalizing the product through comprehensive refinement. Each stage was informed by insights gained from extensive research, as detailed in the following explanation.

Information Gathering Stage

At this stage, initial information indicated that students' learning motivation was still low. This was evident from the average pre-test score in students' creative writing, which was 63.32. The common problems faced by students regarding their learning motivation included: (1) persistence in completing tasks; (2) resilience in facing difficulties; and (3) quickly becoming bored with routine tasks (Tugtekin et al., 2022).

Based on the identified problems, the development of the 3D Animated Film Based on Ethnomathematics using the PjBL Model was carried out, along with the preparation of learning tools consisting of a syllabus, teaching modules, learning motivation assessment instruments, and learning media based on animated films. This development was necessary to support students' learning motivation. Good motivation can support academic needs and enable students to engage in enjoyable learning experiences.

Design Stage

The development of the 3D Animated Film Based on Ethnomathematics using the PjBL Model had to consider various aspects to ensure its applicability in the field. Several steps were taken during this design stage. The first step was to create a needs map for developing the 3D Animated Film Based on Ethnomathematics using the PjBL Model, referring to the expected outcome an improvement in students' creative writing skills. The second step was the formulation of course objectives, achievement indicators, and key topics in the syllabus. The third step was planning the learning scenario using the PjBL model (Hmelo-Silver, 2004; Charlize et al., 2025; Hafiz et al., 2025; Tanti et al., 2025). The fourth step was designing the students' learning motivation instrument. The syllabus and teaching modules were typed on A4 paper with 1.5 line spacing, while the learning motivation assessment was integrated into the 3D Animated Film Based on Ethnomathematics using the PjBL Model (Thomas, 2000; Diaz et al., 2025; Hagad & Riah, 2025; Jackson & Alfaki, 2025).

The fifth step was producing the 3D Animated Film Based on Ethnomathematics. The film was created using *Create Studio* software, chosen because it is more engaging for producing 3D animations, integrates the latest technology, and can be applied in the learning process. The initial interface of *Create Studio* is shown in Figure 2.

Figure 2. Snapshot of the Animation Film using Create Studio

CreateStudio distinguishes itself through the seamless integration of specialized features within its interface. The library of animated 3D characters, the lipsync animation function to synchronize character mouth movements with audio, and the special effects panel to enhance visual appeal are all easily accessible from the main interface. CreateStudio provides a sophisticated and functional user

interface, carefully designed to facilitate the creation of engaging 3D animated films. Upon launching the application, users encounter a sleek and systematically organized homepage (Muhammad, et. al, 2022; Islami et al., 2025; Klinaku et al., 2025; Tanti et al., 2025). The top section of the interface features the main menu, granting quick access to essential functions, including starting a new project, exploring the template gallery, and adjusting application settings. Just below this menu, a compilation of recent projects is displayed, allowing users to seamlessly continue their work with minimal effort. The prominent "Create New" button invites users to embark on their creative endeavors (Le & Aye, 2025; Mor, 2025; Surnarni & Mauladaniyati, 2025).

Product Draft Development Stage

The product draft development stage is a critical phase focusing on refining the final offering, based on validation by experts in the field. This validation process plays a pivotal role in gathering valuable insights that drive improvements and ensure compliance with established standards. The evaluations conducted by these experts, as outlined in Table 2, indicate that the developed components which include the syllabus, teaching module, learning motivation instrument, and 3D animated film learning media received a commendable score of 82. Among the constructive feedback highlighted by the experts was the suggestion to incorporate additional assessment criteria into the creative writing evaluation instrument, providing evaluators with clearer and more definitive benchmarks for their assessments.

Table 1. Expert Assessment of Each Aspect

Aspect	Total Score
Relevance of material to the syllabus	16
Alignment of material coverage and learning scenarios in the teaching module	26
Accuracy of assessed aspects in the learning motivation instrument	16
Clarity of material and language in the 3D animated film learning media	24
Total Score (sum of all aspects)	82

Initial Trial and Product Revision

After undergoing a comprehensive validation process, during which subject-matter experts confirmed its feasibility, the program was trialed with a selected group of students. This initial trial involved four students from Class VIII G, who participated in a learning experience centered on 3D Animated Films based on Ethnomathematics. Following the session, they were invited to provide feedback through an open-ended questionnaire regarding their learning experience. Insights gathered from this trial revealed several key suggestions: (1) the learning procedures should be simplified to make them more accessible; and (2) the animation components should be enhanced to be more engaging and dynamic in the educational media.

Field Trial and Product Refinement

The field trial was conducted after revisions were made based on feedback from the initial trial. This time, the participants consisted of nine first-year students, different from those involved in the first trial. During the field trial, these students engaged with the 3D Animated Film based on Ethnomathematics, reflecting the learning experience of the original subject. Upon completion, they were asked to share their insights through an open-ended questionnaire focused on their learning experiences. Feedback from this stage highlighted the need for further refinement of the film's text, specifically recommending the use of larger, more legible fonts to enhance readability.

Operational Field Trial and Final Product Refinement

Following revisions based on feedback from the previous trials, the operational field trial was carried out. Participants in this trial consisted of 29 eighth-grade students from Class VIII H, randomly divided into two groups: one serving as the control group and the other as the experimental group (Suhroh et al., 2020). Prior to the trial, all participants completed a pre-test questionnaire designed to assess their learning motivation. This pre-test aimed to measure students' motivation levels before exposure to the treatment involving the Ethnomathematics-Based 3D Animated Film (Kearney & Schuck, 2014).

Analysis of the pre-test results revealed an average learning motivation score of 62.8 across all students, with the experimental group achieving a slightly higher average of 63.89. The analysis showed no significant differences between the mean scores of the control and experimental groups, indicating that their creative writing abilities were essentially comparable. This finding was further supported by the results of hypothesis testing using the pre-test data from both groups (Horton & David, 2018). The proposed hypotheses were as follows: the Null Hypothesis (Ho) stated that there was no significant difference between the mean scores of the two groups, while the Alternative Hypothesis (Ha) suggested otherwise. After carefully assessing the prerequisites for hypothesis testing, it was confirmed that both datasets demonstrated normal distribution and homogeneity (Zakaria & Malik, 2019; Linh et al., 2025). Therefore, a hypothesis test was conducted to compare the two groups. The results yielded a definitive significance level (2-tailed) of 0.741, which exceeded the 0.05 threshold. This indicates that the null hypothesis (Ho) was accepted, and the alternative hypothesis (Ha) was rejected. Consequently, it can be confidently concluded that there were no statistically significant differences between the mean scores of the two groups (Bian et al., 2022).

After administering the pre-test, the experimental group engaged in the transformative treatment focused on the Ethnomathematics-Based 3D Animated Film. The process culminated in both groups completing the post-test questionnaire (Dikkers & Wilms, 2020). Analysis of the post-test results revealed a significant increase in student learning motivation after the treatment, with the control group achieving an average of 69.7, while the experimental group achieved an impressive 76.2. This significant improvement is further illustrated in the bar chart presented in Figure 3.

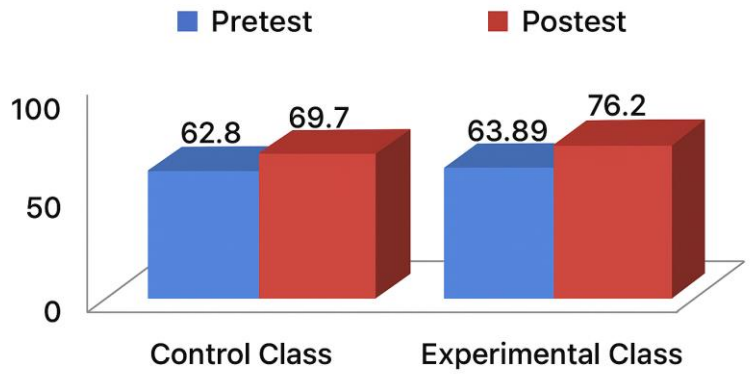

Figure 3. Average Questionnaire Scores of Pretest and Posttest in Control and Experimental Classes

The results indicate a significant improvement in creative writing skills in both the control and experimental groups after the treatment. Specifically, the control group demonstrated an increase of 6.9, while the experimental group showed a more substantial improvement of 12.31. Furthermore, clear differences were observed in the mean scores across several datasets, including: (1) the pretest and posttest scores of the control group; (2) the pretest and posttest scores of the experimental group; and (3) the posttest scores of the control and experimental groups. This compelling evidence underscores the effectiveness of the treatment provided (Putra et al., 2024).

The differences in the mean scores among these three groups will be determined following the completion of hypothesis testing. Prior to this, it is essential to conduct prerequisite tests, including assessments of normality and homogeneity (Pratama & Yelken, 2024). The normality test was carried out using SPSS version 16, covering all datasets: specifically, the pretest data for both the control and experimental groups, as well as the posttest data for these groups. The hypotheses for the normality test are as follows: the null hypothesis (Ho) states that the data are normally distributed, while the alternative hypothesis (Ha) states that the data deviate from a normal distribution. The findings of the normality test are presented in Table 2.

Tabel 2. Normality Test of Pretest and Posttest in Control and Experimental Classes

Group	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest Control	.180	20	.088	.932	20	.170
Pretest Experiment	.168	18	.194	.924	18	.152
Posttest Control	.222	20	.011	.940	20	.240
Posttest Experiment	.157	18	.200*	.913	18	.098

Based on the findings presented in Table 3, it can be concluded that all datasets exhibit a normal distribution. Following the normality assessment, a homogeneity test was subsequently conducted. The hypotheses formulated for this homogeneity test were as follows: (H0): the data variances are homogeneous, and (Ha): the data variances are not homogeneous. The homogeneity test was applied to several data groups, specifically: (1) the pretest and posttest results of the control group; (2) the pretest and posttest results of the experimental group; and (3) the posttest results of the control and experimental groups. The results of the homogeneity test for the control group's pretest and posttest data are detailed in Table 3.

Table 3. Homogeneity Test of Pretest and Posttest of Control Class

Levene Statistic	df1	df2	Sig.
.099	1	38	.755

Based on the data presented in Table 4, the obtained significance value was 0.755, which exceeds the established significance level of 0.05. This indicates that the null hypothesis (Ho) is accepted, while the alternative hypothesis (Ha) is rejected. Thus, it can be concluded that the variances of the pretest and posttest data for the control group are homogeneous. The subsequent homogeneity test was conducted on the pretest and posttest data of the experimental group. The results of this homogeneity test are also detailed in Table 4.

Tabel 4. Homogeneity Test of Pretest and Posttest in the Experimental Class

Levene Statistic	df1	df2	Sig.
.023	1	34	.881

The analysis presented in Table 5 indicates the acceptance of the null hypothesis (Ho) and the rejection of the alternative hypothesis (Ha). Consequently, it can be concluded that the data variances are homogeneous. The final homogeneity test was conducted on the posttest data of the control and experimental groups, with the results of this homogeneity assessment detailed in Table 5.

Tabel 5. Homogeneity Test of Posttest in Control and Experimental Classes

Levene Statistic	df1	df2	Sig.
.031	1	36	.861

Based on the findings presented in Table 6, the null hypothesis (H_0) was accepted while the alternative hypothesis (H_1) was rejected. This leads to the conclusion that the data variances are homogeneous. After confirming that the data were normally distributed and homogeneous, hypothesis testing was conducted on three different groups: (1) the pretest and posttest of the control group; (2) the pretest and posttest of the experimental group; and (3) the posttest results of the control and experimental groups. The hypothesis testing was carried out using SPSS version 16. The hypotheses for this analysis were formulated as follows: H_0 states that there is no significant difference in the means between the groups, while H_1 states that there is a significant difference in the means. The results of hypothesis testing for the pretest and posttest data of the control group are detailed in Table 6.

Tabel 6. Hypothesis Testing of Pretest and Posttest in the Control Class

	Levene's Test		t-test for Equality of Means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean Dif	Std. Error Dif	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.099	.755	-2.185	38	.035	-6.900	3.158	-13.293	-507
Equal variances not assumed			-2.185	37.417	.035	-6.900	3.158	-13.296	-.504

The results obtained from the hypothesis test conducted on the pretest and posttest data of the control group showed a significance level (2-tailed) of 0.035, which is below the alpha level of 0.05 established for this study. Consequently, the null hypothesis (Ho) was rejected, and the alternative hypothesis (Ha) was accepted. This indicates that there is a statistically significant difference in the mean scores between the pretest and posttest of the control group.

Subsequently, a similar hypothesis test was conducted on the pretest and posttest data of the experimental group. The findings from this hypothesis test are presented in Table 7.

Tabel 7. Results of Hypothesis Testing Experimental Class

	Levene's Test		t-test for Equality of Means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean Dif	Std. Error Dif	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.023	.881	-3.901	34	.000	-12.33	3.162	-18.759	-5.908
Equal variances not assumed			-3.901	34.000	.000	-12.33	3.162	-18.759	-5.908

The findings from the hypothesis test indicate the rejection of the null hypothesis (Ho) in favor of the alternative hypothesis (Ha). Consequently, it can be concluded that there is a significant difference in the mean scores between the pretest and posttest data of the experimental group.

Subsequently, the next hypothesis test was conducted by comparing the posttest data of the control class and the experimental class. The results of this hypothesis test are presented in Table 8.

Tabel 8. Results of Hypothesis Testing for Posttest in Control and Experimental Classes

	Levene's Test		t-test for Equality of Means						
	F	Sig.	T	df	Sig. (2-tailed)	Mean Dif	Std. Error Dif	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.031	.861	-2.132	36	.040	-6.522	3.060	-12.728	-.316
Equal variances not assumed			-2.130	35.443	.040	-6.522	3.060	-12.728	-.307

It can be concluded that there is a significant difference in the mean posttest scores between the control and experimental groups. Furthermore, following the operational field trial, the final product underwent a series of refinements. These improvements were applied to the comprehensive product

development, which included: (1) the syllabus, (2) the teaching module, (3) the assessment instrument for the student learning motivation questionnaire, and (4) the learning media, specifically the 3D animated film based on ethnomathematics. Most of the refinements were focused on the learning media, particularly the 3D animated film, involving the simplification of instructions, the selection of appropriate color gradations, and the revision and verification of the animation film.

Feasibility of 3D Animated Film Learning

The feasibility of learning through 3D animated films was demonstrated by the evaluations conducted by subject-matter experts, who assigned a total score of 82 across various criteria. This score, which reflects a commendable level of quality, aligns with the standard values established in Table 9, which categorizes scores within the range of six.

Table 9. Standard Scores

Standard Score	Interpretation
9	Excellent
8	Good
7	More than Sufficient
6	Sufficient
5	Poor
4	Very Poor

A score of 82 corresponds to the standard level of 8, which indicates commendable performance. This demonstrates that all the developed products including the syllabus, the teaching module, the learning motivation questionnaire, and the 3D animated film media have successfully met the feasibility criteria with a satisfactory quality level. However, it is important to note that although these products have met the feasibility standards, there remain several areas that require improvement before they can be considered fully ready for extensive implementation (D'Ambrosio, 2006; Nisa et al., 2025).

In addition, the evaluation of web-based learning was further informed by feedback from students who participated in the various trial phases, including the limited trial, field trial, and operational field trial (experimental group). A total of 29 students were surveyed regarding their experiences with the Ethnomathematics-Based 3D Animated Film. Their feedback was collected through a five-point Likert scale questionnaire, which included the following response options: (1) very good, (2) good, (3) fair, (4) less adequate, and (5) poor. The assessment of students' responses regarding feasibility is illustrated in Figure 4.

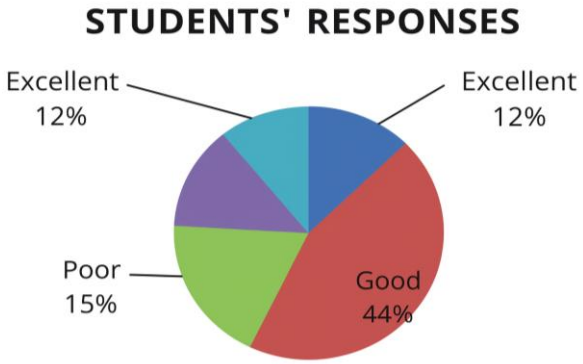

Figure 4. Students' Responses to the 3D Animated Film

The use of Ethnomathematics-Based 3D Animated Films has been positively received by the majority of students. Specifically, five students rated the film as "very good," fifteen classified it as "good," five considered it "fair," three evaluated it as "poor," and one student rated it as "very poor." The overall positive evaluations from most students indicate that the Ethnomathematics-Based 3D Animated Film is suitable for integration into the educational process, particularly in enhancing students' motivation to learn (Gerdes, 1999). Conversely, the negative assessments from a small minority of students appear to stem from dissatisfaction with character selection or animation, which may have reduced their engagement and motivation to learn. The feasibility of web-based learning was assessed by students based

on two main criteria: (1) ease of use and (2) the ability to enhance students' learning motivation (Kabuye, 2024). The 3D Animated Film Learning Approach informed by Ethnomathematics offers distinct advantages. As articulated by Marisa (2014), the quality of student learning is enhanced, which correlates with increased enthusiasm and motivation to engage in the learning process (Teo & Smith, 2019). Such enthusiasm and motivation are essential components in improving the overall quality of student learning, particularly in relation to boosting students' motivation levels (Huang & Liaw, 2018; Saindah, 2025; Rahajo & Kumyat, 2025).

The results of this study reveal that the integration of ethnomathematics and Project-Based Learning (PjBL) through 3D animated films has a significant positive impact on students' motivation in learning mathematics. This finding addresses the long-standing challenge that mathematics is often perceived as abstract, difficult, and disconnected from real life, which leads to low student engagement. The developed 3D animated film, rooted in local cultural values, successfully bridges this gap by contextualizing mathematical concepts within familiar cultural narratives and everyday experiences. This aligns with the view of Gerdes (1999) and D'Ambrosio (2006) that ethnomathematics can serve as a cultural lens through which mathematics becomes more meaningful and accessible to learners. By employing the PjBL model, students were encouraged to take active roles in constructing knowledge, solving problems, and producing creative outputs, which enhanced their sense of ownership and autonomy in learning. The use of 3D animation as a visual medium further strengthened these effects by transforming abstract ideas into dynamic, concrete representations that are easier for students to understand and relate to. This visual engagement aligns with findings from Huang & Liaw (2018) and Teo & Smith (2019), who noted that interactive multimedia significantly enhances intrinsic motivation by fostering curiosity and enjoyment in learning.

The integration of Ethnomathematics-Based 3D Animated Film learning, alongside the application of ethnomathematics and Project-Based Learning (PjBL), has proven to be effective in improving both student learning outcomes and learning motivation. This assertion is reinforced by research conducted by Sunwinarti and Suwito (2016), which revealed that the average learning outcomes achieved through the implementation of Ethnomathematics-Based 3D Animated Film learning surpassed those obtained through traditional teaching methods (Chen & Huang, 2020). The observed increase in average scores from pretest to posttest for both the control and experimental groups along with the superior average performance of the experimental group demonstrates that Ethnomathematics-Based 3D Animated Film learning makes a significant contribution to enhancing students' motivation within the learning process (Sastradika., et al. 2021).

The effectiveness of this approach is evident in the experimental findings, which show that students exposed to the ethnomathematics-based 3D animation achieved higher post-test motivation scores compared to those taught with conventional methods. This improvement reflects the synergy between cultural contextualization, visual interactivity, and experiential learning. The 3D animated film not only captivated students' attention but also instilled pride and interest by incorporating elements of their own culture into mathematical learning. From the theoretical perspective of Self-Determination Theory (SDT), this learning experience fulfills students' psychological needs for competence, autonomy, and relatedness (Elvira & Nirwana, 2022). When students perceive learning as relevant to their cultural identity and daily life, their intrinsic motivation increases, resulting in deeper engagement and persistence. The findings thus demonstrate that learning environments which integrate cultural content with digital interactivity can transform students' attitudes toward mathematics, making it both enjoyable and personally meaningful. Moreover, this study contributes to the evolving discourse on technology-enhanced learning by providing empirical evidence that the integration of digital media and ethnomathematics can effectively overcome the motivational barriers typically encountered in mathematics education.

The implications of these findings extend to several dimensions of educational theory and practice. Theoretically, this study reinforces the importance of culturally responsive pedagogy and supports the integration of motivational theories within technology-enhanced learning frameworks. It confirms that embedding cultural values in digital media aligns with SDT's principle that meaningfulness and relevance drive intrinsic motivation. Pedagogically, the study offers a model for teachers to implement mathematics instruction that is creative, contextual, and student-centered. By using the PjBL model, teachers can facilitate active inquiry and collaboration while leveraging 3D animation to visually explain complex concepts. This approach empowers students to become not only consumers of knowledge but also creators of learning artifacts that reflect their cultural heritage. Technologically, this

research provides a practical example of how educators can use accessible software, such as Create Studio, to design engaging learning materials without requiring extensive technical expertise. It demonstrates that innovation in educational technology can be achieved even with limited resources, as long as cultural relevance and pedagogical intent guide the design process.

From a policy perspective, this study supports the principles of Indonesia's Merdeka Curriculum, which emphasizes contextual, creative, and technology-integrated learning that nurtures cultural literacy and student independence. The developed media exemplifies how local wisdom can be embedded into digital learning innovations to foster holistic student development. It also encourages educational policymakers to support programs that promote digital literacy among teachers, particularly in creating localized learning content that resonates with students' identities. Nevertheless, this research acknowledges several limitations that can inform future investigations. The study involved a relatively small sample from one junior high school, limiting the generalizability of its results. Moreover, it focused solely on motivational outcomes, without assessing the effects on conceptual understanding or academic achievement. The short duration of implementation also prevented evaluation of long-term motivational changes or retention effects.

Given these limitations, further research is recommended to expand the implementation of ethnomathematics-based 3D animation across diverse educational levels, regions, and cultural settings to ensure broader applicability. Future studies should incorporate additional variables such as learning achievement, creativity, and problem-solving skills to provide a more comprehensive assessment of effectiveness. Longitudinal studies would also be valuable in examining how sustained exposure to such culturally embedded digital learning media influences long-term motivation and learning habits. Collaboration between educators, cultural experts, and multimedia designers is essential to ensure that future learning media remain both pedagogically sound and culturally authentic. In addition, professional development programs should be established to train teachers in designing and applying digital ethnomathematics-based learning tools effectively in their classrooms.

CONCLUSION

This study successfully developed and validated a 3D animated film based on ethnomathematics integrated with the Project-Based Learning (PjBL) model as an innovative and engaging learning medium for mathematics education. The expert validation process confirmed that all developed components including the syllabus, teaching module, learning motivation instrument, and 3D animated film achieved a high level of feasibility, with a total score of 82, indicating strong validity and alignment with curriculum and pedagogical standards. Through a structured sequence of preliminary, field, and operational trials, the findings demonstrated that the 3D animated film was effective in significantly enhancing students' learning motivation, as evidenced by notable improvements in posttest results within the experimental group compared to the control group. This improvement suggests that integrating ethnomathematics with 3D animation can create a more contextual, culturally relevant, and immersive learning experience that fosters deeper engagement and curiosity among students. Moreover, the developed media offers practical benefits it is easily accessible, user-friendly, and cost-effective, enabling teachers to adopt it without requiring extensive technical resources. The 3D ethnomathematics film not only makes learning more interactive but also connects mathematical concepts to students' local cultural heritage, reinforcing identity and appreciation for indigenous knowledge while enhancing conceptual understanding. The implications of this study extend to both theory and practice. Theoretically, it supports the integration of ethnomathematics and digital-based PjBL approaches as a framework for promoting contextualized STEM learning that bridges cultural values and modern technology. Practically, it provides educators with a concrete model for developing culturally responsive digital learning tools that align with 21st-century education goals particularly in fostering motivation, creativity, and digital literacy. Therefore, the implementation of 3D ethnomathematics-based animated films can serve as a strategic innovation for improving the quality and relevance of mathematics education, helping to produce learners who are not only skilled in mathematical reasoning but also culturally grounded and technologically adept.

ACKNOWLEDGMENTS

Thank you to all colleagues who have helped, so that this research can be carried out and completed.

AUTHOR CONTRIBUTIONS

Author 1 creates articles and creates instruments and is responsible for research, author 2 analyzes research data that has been collected, author 3-4 assist in research data analysis, instrument validation, and input research data.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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