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Implementing Jambi Culture-Based Interactive E-Book with Toontastic 3D Animation Using RME to Improve Learning Interest

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Abstract

This study aims to examine the effectiveness of implementing a Jambi culture-based interactive e-book integrated with FILATOD, a Toontastic 3D animation-based learning medium, using the Realistic Mathematics Education (RME) approach to improve students' learning interest in mathematics. This study employed a quasi-experimental design with a pretest–posttest control group involving 64 students of SMPN 7 Muaro Jambi. Data were collected using a learning interest questionnaire and classroom observation sheets. The results showed that the experimental group experienced a significant increase in learning interest, with the mean score improving from 66.31 in the pretest to 84.47 in the posttest, while the control group increased from 65.84 to 72.06. Independent-samples t-test analysis indicated a significant difference between the two groups ($p < 0.05$), with a very large effect size ($d = 1.28$). These findings demonstrate that integrating Jambi cultural contexts, Toontastic 3D animation, and RME specifically improves students' learning interest by connecting mathematical concepts to familiar local experiences, presenting contextual problems through engaging animated narratives, and guiding students to construct mathematical understanding from realistic situations. The combination of these three elements strengthens students' attention, curiosity, enjoyment, participation, and persistence during mathematics learning. Therefore, culturally contextualized digital learning media supported by animation and RME can serve as an innovative instructional strategy to enhance students' affective engagement and improve the quality of mathematics learning.

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INTRODUCTION

Education in the digital era requires innovative learning media that can create engaging, meaningful, and student-centered learning experiences (Bond et al., 2020; Hwang & Lai, 2021; Marlina & Widodo, 2020). In mathematics education, learning is often perceived as abstract and difficult, which can reduce students' interest and participation (Smale-Jacobse et al., 2021; Sugandi & Bernard, 2018; Wijaya, 2018). Learning interest is an important affective factor because it influences students' attention, persistence, and willingness to engage in mathematical tasks (Harackiewicz & Priniski, 2020; Ryan & Deci, 2020; Yuliani & Saragih, 2020). When students show low interest in learning, they tend to participate

passively and rely on memorization rather than conceptual understanding (Saglam & Goktenturk, 2024; Siregar & Surya, 2019). Therefore, strengthening learning interest becomes a strategic goal in improving the quality of mathematics instruction, particularly in classroom contexts where students' engagement is still limited (Nugroho & Prasetyo, 2021; Zulkardi & Putri, 2020).

One approach that can enhance learning interest is the integration of interactive digital learning media (Hwang & Chien, 2022; Listanto et al., 2023; Septian & Ramadhanty, 2020). Interactive e-books provide multimodal learning resources that combine text, images, hyperlinks, and interactive features to support flexible and engaging learning processes (Kucirkova & Littleton, 2021; Sari & Susanti, 2022). Compared to conventional printed materials, interactive e-books can stimulate students' curiosity and sustain attention through dynamic content presentation and interactive learning elements (Chen & Huang, 2025; Darmaji et al., 2019). In addition, integrating digital animation into learning media can increase engagement by helping students visualize mathematical concepts and contexts more clearly (Bétrancourt, 2020; Chen & Wu, 2022; Yoon & Wang, 2020). Animation-based learning media also allow abstract concepts to be represented visually, making mathematical ideas easier for students to understand (Kleftodimos, 2024; Supriadi & Damayanti, 2019; Widodo et al., 2019). In this context, Toontastic 3D as an animation creation application enables the development of short animated films that present narrative-based explanations and contextual problem situations in an attractive format (Chen & Chen, 2020; Lin & Chen, 2022). Such animation-supported learning media have the potential to improve students' motivation and learning interest because they reduce monotony and create a more enjoyable learning experience (Nugroho & Prasetyo, 2021; Yuliani & Saragih, 2020).

In addition to technology, contextual relevance is essential for creating meaningful learning experiences that connect academic content with students' daily lives (Ann Tomlinson & Moon, 2022; Nasir et al., 2021). Culture-based learning media, particularly those grounded in local contexts, can strengthen relevance by connecting mathematical concepts to students' lived experiences and cultural environments (Mauladaniyati et al., 2025; Nasir et al., 2021; Ní Shé et al., 2023). Integrating Jambi cultural elements into learning materials allows students to perceive mathematics as part of everyday life rather than an isolated set of formulas (Fitriani et al., 2020; Zulkardi & Putri, 2020). Culture-based learning can also support identity formation and strengthen students' emotional connection to learning activities (Dookurong Dilor, 2025; Nasir et al., 2021; Sugandi & Bernard, 2018). Therefore, combining interactive digital media with local culture may provide an effective pathway to enhance students' learning interest and engagement.

Realistic Mathematics Education (RME) offers a strong pedagogical foundation for contextual learning in mathematics by emphasizing meaningful learning through real-life situations (Gravemeijer et al., 2021; Van den Heuvel-Panhuizen & Drijvers, 2020). RME emphasizes learning through meaningful contexts, guided reinvention, and progressive mathematization, enabling students to construct mathematical understanding from realistic situations (Fitriani et al., 2020; Putri et al., 2019; Suh & Calabrese, 2025). In RME-based learning environments, students are encouraged to explore contextual problems, discuss solution strategies collaboratively, and gradually develop mathematical models (Wijaya, 2018; Zulkardi & Putri, 2020). This learning process supports not only cognitive development but also affective engagement, because students are more likely to be interested when learning activities are meaningful and connected to their environment (Ryan & Deci, 2020; Yuliani & Saragih, 2020). Therefore, integrating RME with interactive media and cultural contexts may strengthen students' interest in learning mathematics.

Although interactive e-books, animation-based media, culture-based learning, and RME have been widely studied in mathematics education, previous studies have mostly examined these components separately. Research on interactive e-books tends to focus on multimedia access and motivation, but rarely embeds local cultural contexts as mathematical problem situations (Huang et al., 2021; Kleftodimos, 2024). Studies on animation-based learning often emphasize visualization and engagement, yet many still use generic narratives that are not rooted in students' sociocultural environment (Kleftodimos, 2024; Sari et al., 2024). Meanwhile, RME and ethnomathematics studies highlight the importance of realistic and culturally meaningful contexts, but they are often implemented through printed worksheets or teacher-led activities without interactive digital media and animated narrative support (Harackiewicz & Priniski, 2020; Ryan & Deci, 2020; Yuliani & Saragih, 2020). This indicates a clear research gap: there is limited empirical evidence on how digital interactivity, Toontastic 3D animation, Jambi cultural contexts, and RME pedagogy can be integrated into one coherent instructional model to improve students' learning interest. This integrated model is necessary because each component addresses a different dimension of learning interest: the interactive e-book supports autonomy and structured access; animation attracts attention and clarifies contexts; Jambi culture strengthens relevance and emotional connection, while RME guides students to construct mathematical meaning from realistic situations.

Based on classroom observations conducted at SMPN 7 Muaro Jambi, students' interest in mathematics learning is still relatively low, as indicated by limited participation, reluctance to ask questions, and reduced enthusiasm during problem-solving activities. This condition suggests that conventional learning resources and instructional approaches may not sufficiently stimulate students' engagement. Therefore, innovative learning media are needed to create enjoyable, contextual, and meaningful learning experiences. The implementation of a Jambi culture-based interactive e-book integrated with FILATOD (Toontastic 3D animation) using RME is expected to provide multimodal engagement, contextual relevance, and realistic problem-solving experiences that increase students' learning interest.

The novelty of this study lies in integrating three key components: (1) an interactive e-book as a structured digital learning resource, (2) FILATOD (Toontastic 3D animation) as narrative-based visual scaffolding, and (3) Jambi cultural contexts embedded within an RME learning framework to strengthen relevance and affective engagement. Unlike previous studies that examine digital media or RME independently, this study investigates their combined effect in enhancing students' learning interest through culturally contextualized realistic mathematics learning (Pratama & Wulandari, 2021; Supriadi & Damayanti, 2019; Wijaya, 2018; Yuliani & Saragih, 2020).

Therefore, this study aims to examine the implementation and effectiveness of a Jambi culture-based interactive e-book integrated with Toontastic 3D animation using RME to improve students' learning interest. The hypotheses formulated are H_0: there is no significant effect of implementing the interactive e-book with Toontastic 3D animation using RME on students' learning interest; and H_a: there is a significant effect of implementing the interactive e-book with Toontastic 3D animation using RME on students' learning interest.

METHODS

This study employed a quantitative approach using a quasi-experimental design with a pretest–posttest control group model (Creswell & Creswell, 2017). The design was used to examine the effectiveness of implementing a Jambi culture-based interactive e-book integrated with FILATOD (Toontastic 3D animation) using Realistic Mathematics Education (RME) in improving students' learning interest in mathematics (Fraenkel &

Wallen, 1990). The experimental group received instruction using the interactive e-book and Toontastic 3D animation within an RME learning sequence, while the control group was taught using conventional learning resources commonly used in the classroom without the interactive e-book and animation integration.

The research was conducted at SMPN 7 Muaro Jambi during the 2024/2025 academic year. The population consisted of all seventh-grade students enrolled in the selected school. Two intact classes were selected as the sample using simple random sampling to ensure equal opportunity for class selection. The experimental class consisted of 32 students, and the control class consisted of 32 students (N = 64). The two classes had comparable academic characteristics based on teachers' information and prior learning records.

The main instrument used in this study was a learning interest questionnaire administered before and after the intervention. The questionnaire consisted of 25 Likert-type items with a 5-point scale (1 = strongly disagree to 5 = strongly agree) measuring students' interest dimensions, including attention, enjoyment, willingness to participate, curiosity, and persistence in learning mathematics. The instrument was adapted from established motivation/interest measurement principles and was reviewed through expert judgment by three validators (one mathematics education expert and two instructional media experts) to ensure content validity and clarity. Reliability testing was conducted using Cronbach's alpha, with $\alpha \geq 0.70$ indicating acceptable internal consistency. In addition, an observation sheet of learning engagement was used to support the interpretation of questionnaire results by documenting students' participation, questioning behavior, and responsiveness during learning activities.

The instructional materials used in the experimental group consisted of a Jambi culture-based interactive e-book and FILATOD animation developed using Toontastic 3D. The interactive e-book was designed in a digital format containing learning objectives, contextual problems, Jambi cultural narratives, visual representations, guided questions, discussion tasks, reflection activities, and interactive navigation features such as hyperlinks and embedded multimedia elements. The Toontastic 3D animations were developed as short animated films lasting approximately one to three minutes. These animations presented Jambi cultural situations related to the mathematical topics being learned and were used to introduce contextual problems, support students' visualization of problem situations, and stimulate discussion. Students accessed the interactive e-book and animation through smartphones or school-supported digital devices during classroom learning.

To clarify the implementation of the intervention, the experimental learning process was organized according to the phases of realistic mathematics education. In the first phase, understanding contextual problems, students opened the interactive e-book and watched a short Toontastic 3D animation that introduced a realistic problem based on Jambi cultural contexts. The animation functioned as an initial stimulus to attract students' attention and help them imagine the problem situation. After watching the animation, students read the contextual problem in the e-book, identified known and unknown information, and answered guiding questions provided in the e-book. In this phase, the teacher facilitated students' understanding of the problem without directly giving formulas or solution procedures.

In the second phase, developing informal strategies and mathematical models, students worked individually or in small groups using worksheets and interactive prompts embedded in the e-book. They explored possible strategies, created simple representations, and connected the cultural context from the animation to mathematical ideas. The e-book provided visual aids, guiding questions, and spaces for students to record their strategies, while the animation helped students recall the realistic situation being discussed. The

teacher encouraged students to use their own reasoning and initial models before moving toward more formal mathematical procedures.

In the third phase, discussion and comparison of strategies, students presented their solutions and compared different strategies with their classmates. The interactive e-book was used as a discussion guide containing prompts for explaining reasoning, comparing answers, and evaluating the suitability of strategies. Selected scenes or screenshots from the Toontastic 3D animation were revisited when students needed to clarify the context of the problem. During this phase, the teacher guided students to identify similarities and differences among strategies, ask questions, and refine their mathematical reasoning through classroom discussion.

In the fourth phase, formalization and reflection, the teacher guided students to transform their informal strategies into more formal mathematical concepts. The interactive e-book provided summaries, concept reinforcement, practice questions, and reflection prompts. Students completed reflection activities related to what they learned, how they solved the contextual problem, and how the mathematical concept was connected to Jambi cultural situations. The Toontastic 3D animation was used as a concluding reference to reconnect the formal concept with the original realistic context. Through this process, students were expected to experience mathematics as meaningful, visually understandable, and culturally relevant.

The intervention was conducted over four meetings. Each meeting followed the same RME-based learning structure but used different contextual problems and animated narratives related to Jambi culture. The sequence of implementation is presented in Table 1.

Table 1 Implementation of interactive e-book and toontastic 3d animation in rme phases across four meetings

Meeting	RME Phase	Implementation of Interactive E-Book	Implementation of Toontastic 3D Animation
1	Understanding contextual problems	Students accessed the opening section of the e-book, read the learning objectives, and answered guiding questions related to the contextual problem.	Students watched a short animation introducing a Jambi cultural situation as the starting point of the mathematics problem.
1	Developing strategies and models	Students used e-book prompts to identify information, create simple representations, and propose initial solution strategies.	Animation scenes helped students recall the problem context and visualize the relationship among objects in the situation.
1	Discussion and comparison	Students used discussion questions in the e-book to explain and compare their strategies.	Selected animation scenes were revisited to clarify the context during discussion.
1	Formalization and reflection	Students completed concept summaries, practice items, and reflection prompts in the e-book.	The animation was linked back to the formal mathematical concept as a concluding contextual reference.
2	Understanding contextual problems	Students opened the second e-book activity and analyzed a new contextual problem based on Jambi culture.	Students watched a new animated story presenting a realistic mathematical situation.
2	Developing strategies and models	Students used visual aids and guided questions in the e-book to construct informal models.	Animation supported students' understanding of the sequence and meaning of the problem.

Meeting	RME Phase	Implementation of Interactive E-Book	Implementation of Toontastic 3D Animation
2	Discussion and comparison	Students discussed different solution methods using prompts provided in the e-book.	Animation screenshots were used to support clarification during group discussion.
2	Formalization and reflection	Students completed reinforcement questions and reflected on the relationship between the mathematical idea and the cultural context.	The animation was used to reconnect the mathematical concept to the original Jambi cultural narrative.
3	Understanding contextual problems	Students explored the third e-book activity and identified important information from the contextual task.	Students watched an animation presenting another Jambi cultural context related to the lesson topic.
3	Developing strategies and models	Students developed models, representations, and solution strategies through guided activities in the e-book.	Animation helped students visualize the realistic situation and maintain attention during exploration.
3	Discussion and comparison	Students presented their solutions and responded to peer strategies using discussion prompts.	Relevant animation scenes were replayed to support contextual interpretation.
3	Formalization and reflection	Students summarized the mathematical concept and completed reflective questions in the e-book.	Animation served as a contextual anchor to strengthen the meaning of the formal concept.
4	Understanding contextual problems	Students accessed the final e-book activity and analyzed the contextual problem independently with teacher guidance.	Students watched the final Toontastic 3D animation connected to Jambi cultural situations.
4	Developing strategies and models	Students used e-book activities to develop more systematic strategies and mathematical representations.	Animation supported students' interpretation of the problem and encouraged curiosity.
4	Discussion and comparison	Students compared solution strategies and justified their reasoning through class discussion.	Animation scenes were used selectively to clarify misunderstandings and reinforce the context.
4	Formalization and reflection	Students completed final practice, concept reinforcement, and reflection activities in the e-book.	The animation was used to conclude the learning sequence by connecting the formal mathematical concept with the cultural context.

The control group learned the same mathematical topics over four meetings using conventional learning resources commonly used in the classroom. The teacher explained the material, provided examples, guided students to complete exercises, and discussed answers without using the Jambi culture-based interactive e-book or Toontastic 3D animation. This procedure was conducted to compare the effectiveness of the integrated intervention with regular classroom instruction.

Data analysis was conducted using SPSS Statistics version 26. Descriptive statistics were calculated to obtain mean, standard deviation, and score ranges. Prior to hypothesis testing, normality was examined using the Shapiro–Wilk test and homogeneity of variance

using Levene's test ($p > 0.05$). The hypothesis was tested using an independent sample t-test to compare posttest learning interest scores between the experimental and control groups at a significance level of 0.05. To determine practical significance, Cohen's d was computed to measure the magnitude of the intervention effect.

The research procedure consisted of four stages. First, the preparation stage included developing the interactive e-book and FILATOD animation, validating instruments, and preparing RME-based lesson plans. Second, a pretest learning interest questionnaire was administered to both groups. Third, the treatment stage was implemented over four meetings: the experimental group learned using the interactive e-book and FILATOD within RME learning activities, while the control group learned using conventional materials. Finally, a posttest learning interest questionnaire was administered, followed by data analysis and interpretation of findings.

RESULTS AND DISCUSSION

Descriptive statistics were used to describe students' learning interest scores before and after the intervention. The pretest results indicate that both groups had relatively similar initial learning interest levels. The comparison of pretest and posttest learning interest scores for the experimental and control groups is presented in Table 1.

Table 1 Descriptive statistics of students' learning interest scores

Group	Test	N	Minimum	Maximum	Mean	SD
Experimental	Pretest	32	56	78	66.31	5.92
Experimental	Posttest	32	72	95	84.47	6.18
Control	Pretest	32	55	77	65.84	6.01
Control	Posttest	32	60	86	72.06	6.44

As shown in Table 1, the experimental group's mean score increased from 66.31 to 84.47, indicating a substantial improvement in learning interest after the use of the Jambi culture-based interactive e-book integrated with FILATOD (Toontastic 3D animation) using RME. In contrast, the control group showed a smaller increase from 65.84 to 72.06 after conventional instruction. Overall, the experimental group demonstrated a larger mean gain ($\Delta = 18.16$) compared to the control group ($\Delta = 6.22$), suggesting stronger learning interest development through the intervention.

This increase indicates that the intervention did not only produce a general improvement in students' learning interest but also created more visible affective engagement during mathematics learning. The higher posttest mean in the experimental group suggests that students became more attentive, more willing to participate, more enthusiastic in following learning activities, and more persistent in completing contextual mathematical tasks. This pattern is important because learning interest is multidimensional; it includes not only students' positive feelings toward learning but also their attention, curiosity, participation, and perseverance during the learning process.

Prior to hypothesis testing, the data met the assumptions of normality and homogeneity ($p > 0.05$). An independent sample t-test was conducted to determine whether there was a significant difference in posttest learning interest scores between the two groups. The results are presented in Table 2.

Table 2 Independent sample t-test results (posttest learning interest)

Variable	t	Sig. (2-tailed)
Learning Interest	7.218	0.000

Table 2 shows that the significance value was 0.000 (< 0.05), indicating a statistically significant difference between the experimental and control groups' posttest learning interest scores. Therefore, the null hypothesis (H_0) is rejected and the alternative hypothesis

(H_a) is accepted. This finding confirms that implementing the interactive e-book integrated with FILATOD using RME significantly improves students' learning interest.

To determine the magnitude of the intervention effect, Cohen's d was calculated. The effect size obtained was d = 1.28, which is categorized as very large (d > 0.80). This indicates that the intervention not only produced statistically significant differences but also had a strong practical educational impact in increasing students' learning interest.

The very large effect size suggests that the difference between the experimental and control groups was educationally meaningful. In practical terms, students who learned through the Jambi culture-based interactive e-book, Toontastic 3D animation, and RME experienced a stronger affective response than students who learned through conventional instruction. This means that the intervention was not merely attractive as a digital medium but functioned as a learning design that supported students' attention, enjoyment, curiosity, participation, and persistence in mathematics learning.

In addition to questionnaire data, observation data was collected during the learning sessions to support the findings by documenting students' engagement in classroom activities. The summary of observation results is presented in Table 3.

Table 3 Summary of observations of student learning interests

Indicator	**Experimental (%)**	**Control (%)**	**Interpretation**
Active participation during discussions	88.0	70.0	Higher in experimental group
Questioning behavior (asking/responding)	84.0	66.0	Higher in experimental group
Task persistence (completing tasks on time)	90.0	74.0	Higher in experimental group
Enthusiasm/attention during learning activities	92.0	72.0	Higher in experimental group
Average	88.5	70.5	Experimental group more engaged

Table 3 shows that students in the experimental group demonstrated consistently higher engagement across all observed indicators compared to the control group. The highest difference was observed in enthusiasm/attention during learning activities, suggesting that the interactive e-book and FILATOD animation supported students' attention and enjoyment during RME-based learning sessions. These observation findings strengthen the questionnaire results by indicating that increased learning interest was also reflected in students' actual classroom behavior.

The second strongest aspect was task persistence, with the experimental group reaching 90.0% compared to 74.0% in the control group. This suggests that students were more willing to complete mathematics tasks when the problems were presented through familiar Jambi cultural contexts and guided by the RME learning sequence. The contextual and realistic nature of the tasks may have helped students perceive the problems as meaningful and worth solving, thereby strengthening their perseverance.

Active participation during discussions also improved substantially, with the experimental group reaching 88.0% compared to 70.0% in the control group. This finding indicates that the intervention encouraged students to become more involved in classroom interaction. The discussion prompts in the interactive e-book and the contextual situations presented through animation provided concrete materials for students to talk about, compare, and explain. As a result, students were not only listening to teacher explanations but also actively engaging in mathematical discussion.

The lowest, although still high, observed indicator in the experimental group was questioning behavior, which reached 84.0%. This shows that students' curiosity and

willingness to ask or respond to questions improved, although this aspect was slightly lower than attention, persistence, and participation. This may indicate that while the animation and cultural contexts successfully stimulated curiosity, students still needed teacher support and classroom habituation to express questions more confidently. Nevertheless, the 18.0% difference from the control group shows that the intervention contributed positively to students' questioning behavior and curiosity during learning.

Overall, the observation data indicate that the aspect of learning interest that improved most strongly was attention/enthusiasm, followed by task persistence, active participation, and questioning behavior. These findings strengthen the questionnaire results by showing that the increase in learning interest was reflected not only in students' self-reported scores but also in observable classroom behaviors. Therefore, the intervention can be considered effective in improving both affective perception and actual engagement during mathematics learning.

Overall, the results confirm that the implementation of a Jambi culture-based interactive e-book integrated with Toontastic 3D animation within an RME learning framework is effective in improving students' learning interest in mathematics at SMPN 7 Muaro Jambi.

The results of this study indicate that implementing a Jambi culture-based interactive e-book integrated with FILATOD (Toontastic 3D animation) using Realistic Mathematics Education (RME) significantly improves students' learning interest. The experimental group showed a substantial increase in learning interest scores compared to the control group, and the effect size was very large, indicating strong practical significance. This finding suggests that the intervention did not merely improve students' interest superficially but created a learning environment capable of shifting students' affective orientation toward mathematics. Learning interest is a critical affective variable because it influences attention, persistence, and willingness to engage in learning tasks, and it often precedes deeper cognitive engagement. Thus, the observed improvement implies that the intervention successfully addressed a core challenge in mathematics education, helping students find mathematics meaningful, approachable, and worth engaging with.

The observation data provide a more specific explanation of how students' learning interests improved. The highest observed indicator was enthusiasm/attention, which reached 92.0% in the experimental group. This suggests that the combination of animation, interactive digital content, and culturally familiar contexts was particularly effective in capturing students' attention during mathematics learning. Attention is an important initial component of learning interest because students are unlikely to participate, ask questions, or persist in tasks when they are not first attracted to the learning situation. In this study, Toontastic 3D animation appeared to function as an attention trigger by presenting contextual mathematical problems in a visual and narrative form. At the same time, the interactive e-book helped sustain attention by providing organized learning activities, visual representations, and guiding questions.

The second prominent improvement was found in task persistence, which reached 90.0% in the experimental group. This indicates that students were more willing to complete learning tasks when mathematical problems were connected to realistic and culturally meaningful situations. Persistence is closely related to students' perception that a task is meaningful and manageable. Through the RME approach, students were guided to solve problems gradually, beginning with contextual situations, developing informal strategies, discussing solutions, and formalizing mathematical ideas. This structure may have reduced students' tendency to give up quickly because they were not immediately required to use abstract formulas. Instead, they could begin from situations that were easier to imagine and interpret.

Active participation during discussion also showed a high percentage, reaching 88.0% in the experimental group. This finding indicates that the intervention encouraged students

to engage more actively in classroom learning. The interactive e-book provided prompts and activities that required students to identify information, propose strategies, and compare solutions, while the animation provided a shared visual context that could be discussed by the whole class. The Jambi cultural context also helped students relate mathematical problems to familiar experiences, making them more confident to participate. In this sense, participation increased because students had concrete references and meaningful contexts to support their ideas.

Questioning behavior, which reflects students' curiosity and responsiveness, reached 84.0% in the experimental group. Although this was the lowest among the observed indicators, it remained substantially higher than the control group. This finding suggests that the intervention stimulated students' curiosity, but asking questions still required greater confidence and classroom habituation. Students may have been more attentive and enthusiastic at first, while their willingness to ask questions developed gradually as they became more familiar with discussion-based and contextual learning. Therefore, the slightly lower questioning behavior does not indicate weakness of the intervention; rather, it shows that curiosity and verbal responsiveness may require longer intervention time to develop more strongly.

Why RME Strengthens Learning Interest Through Meaningful Contexts

One central mechanism explaining the improvement in learning interest lies in the pedagogical foundation of RME. Realistic Mathematics Education emphasizes learning through meaningful contexts, guided reinvention, and progressive mathematization, where students construct mathematical ideas from realistic situations rather than receiving formulas as finished products (Van den Heuvel-Panhuizen & Drijvers, 2020). In RME, contextual problems act as entry points that make mathematics psychologically accessible and socially meaningful (Gravemeijer et al., 2021; Wijaya, 2018; Zulkardi & Putri, 2020). When students perceive learning tasks as connected to their lived experiences, they are more likely to experience relevance and curiosity, two core affective drivers of learning interest (Harackiewicz & Priniski, 2020; Ryan & Deci, 2020). This is consistent with the motivational principle that learners engage more deeply when they can recognize the usefulness and meaning of learning in relation to real situations.

In the present study, RME likely increased learning interest by shifting classroom activity patterns: instead of passively receiving mathematical procedures, students engaged in exploring realistic situations, discussing strategies, and gradually formalizing mathematical ideas (Van den Heuvel-Panhuizen & Drijvers, 2020; Gravemeijer et al., 2021; Putri et al., 2019). Such participation tends to foster a sense of ownership over learning because students feel that their reasoning and exploration matter in building understanding (Wijaya et al., 2020; Zulkardi & Putri, 2020; Fitriani et al., 2020). This aligns with constructivist learning logic embedded in RME, where knowledge is built through activity and interpretation rather than transmitted. Importantly, interest does not merely emerge from entertainment; it develops when students experience productive struggle and meaning-making in contexts that feel interpretable and relevant (Hidi & Renninger, 2006; Ryan & Deci, 2020; Harackiewicz & Priniski, 2020). Therefore, RME functions as an affective catalyst because it invites students into mathematics as a human activity connected to reality, rather than as isolated symbolic manipulation.

This explanation is supported by the observation results, particularly the high scores for task persistence and active participation. Students in the experimental group were more persistent in completing tasks and more active in discussions because the RME sequence allowed them to start from realistic problems before moving toward formal mathematical concepts. The gradual movement from context to model and then to formalization made

mathematics feel more accessible, which likely strengthened students' willingness to remain engaged in the learning process.

The Role of Interactive E-Books: Autonomy, Navigation, and Sustained Attention

Beyond pedagogy, the interactive e-book format likely strengthened learning interest by improving access, autonomy, and the structure of learning experiences (Listanto et al., 2023). Digital interactive materials can increase engagement when they allow students to navigate content flexibly, revisit explanations, and interact with representations at their own pace (Kucirkova & Littleton, 2021; Septian & Ramadhanty, 2020; Sari & Susanti, 2022). From a motivational standpoint, autonomy-supportive learning environments contribute to stronger engagement and interest because students feel greater control over their learning process (Ryan & Deci, 2000; Bond et al., 2020; Marlina & Widodo, 2020). The interactive e-book in this study appears to have provided structured navigation and multimodal resources, including text, images, hyperlinks, and embedded media, which can reduce frustration caused by unclear learning steps and support students' self-paced exploration (Hwang & Chien, 2022; Huang et al., 2021; Darmaji et al., 2019). When students can access explanations and resources independently, their attention is more likely to persist because they are not entirely dependent on teacher talk or one-time explanations.

This is also consistent with interest development theory. Hidi and Renninger (2006) explain that interest can progress from situational interest to maintained situational interest when meaningful engagement and perceived value are sustained. Interactive e-books likely helped maintain interest beyond the initial novelty by providing structured content that supports understanding (Hwang & Lai, 2021; Huang et al., 2021; Kucirkova & Littleton, 2021). When students understand more, they tend to feel more competent, and competence is associated with deeper engagement and positive affect toward learning (Ryan & Deci, 2000; Harackiewicz & Priniski, 2020; Nugroho & Prasetyo, 2021). This suggests that the interactive e-book did not only attract attention but also supported sustained involvement, reflected in higher persistence and enthusiasm indicators in classroom observations (Bond et al., 2020; Marlina & Widodo, 2020; Yuliani & Saragih, 2020).

The observation data support this interpretation. Students in the experimental group showed high enthusiasm/attention and task persistence because the e-book provided clear learning steps, guided questions, visual support, and reflection activities. These features helped students remain focused on the learning process and complete tasks more consistently. Thus, the interactive e-book contributed not only to digital access but also to the maintenance of learning interest through structured and autonomous engagement.

Why Animation (FILATOD/Toontastic 3D) Supports Interest and Conceptual Visualization

The use of animation is another critical mechanism that can explain increased learning interest and engagement. Animation provides dynamic visualization that helps learners understand processes, relationships, and contextual scenarios more concretely than static images. In instructional design research, animation tends to be beneficial, especially when it supports comprehension of dynamic or sequential information and aligns with learning goals (Höffler & Leutner, 2007; Johnson & Mayer, 2009; Kleftodimos, 2024). The Cognitive Theory of Multimedia Learning argues that learners process information through dual channels, visual and verbal, and learning improves when multimedia supports selecting relevant information and integrating it with prior knowledge (Johnson & Mayer, 2009; Chen & Chen, 2020; Lin & Chen, 2022). In this study, FILATOD animation likely functioned as a visual narrative scaffold that made contextual problems easier to imagine and emotionally engaging.

The motivational benefit of animation should not be interpreted simply as entertainment. Animation can trigger situational interest through novelty and aesthetic appeal, but it can also sustain interest when it supports understanding and clarifies the meaning of problems (Harackiewicz & Priniski, 2020; Ryan & Deci, 2020). When students see a context in animated form, especially a culturally familiar narrative, they can more easily interpret the situation and focus cognitive energy on reasoning rather than guessing what the problem means (Kleftodimos, 2024; Chen & Wu, 2022; Yoon & Wang, 2020). This aligns with classroom observations showing higher enthusiasm and attention among students exposed to animation-supported learning media.

In this study, animation contributed most clearly to the attention and enjoyment aspects of learning interest. The highest observation score, enthusiasm/attention at 92.0%, indicates that animated narratives helped create an attractive learning atmosphere. However, the role of animation was not limited to attracting students' attention at the beginning of learning. Because the animation was connected to Jambi cultural contexts and RME problems, it also helped students understand the situation being discussed. Therefore, FILATOD functioned as both an affective stimulus and a cognitive scaffold.

Cultural Context (Jambi Culture) as a Driver of Relevance, Identity, and Engagement

A distinctive contribution of this intervention is the integration of Jambi cultural contexts into the learning media and RME tasks. Culture-based contexts can function as relevance anchors: they connect mathematical problems to familiar practices, artifacts, stories, or social experiences. In culturally responsive pedagogy, connecting learning to students' cultural backgrounds supports engagement and meaning-making. When students see their own cultural environment reflected in learning materials, learning becomes socially and emotionally legitimate; it feels like "this learning is about us," not about abstract content unrelated to identity.

The use of Jambi culture likely strengthened interest through two linked pathways. First, it increased contextual familiarity, reducing the psychological distance between mathematics and everyday life. Second, it increased emotional resonance: cultural narratives can activate curiosity, pride, and personal connection. These affective responses are important because interest is not only a cognitive state but also an emotional orientation toward learning activities. In mathematics education, ethnomathematical perspectives argue that mathematics is embedded in cultural practices, and incorporating culture helps learners reinterpret mathematics as meaningful social knowledge rather than only formal symbol systems. When cultural contexts are embedded within RME, they function not as decorations but as authentic, realistic situations that initiate mathematization. This alignment makes the intervention theoretically coherent: culture provides context, RME provides pedagogy, and the interactive e-book plus animation provides multimodal scaffolding.

The observation results show that cultural context was particularly related to participation and curiosity. Students became more willing to discuss and respond because the problems were based on situations closer to their cultural environment. This familiarity may have reduced students' hesitation to engage with mathematical tasks, since they could begin reasoning from contexts they recognized. In this way, Jambi culture strengthened the relevance dimension of learning interest and helped transform mathematics from an abstract school subject into a meaningful activity connected to students' lived experiences.

Explaining the Very Large Effect Size: Synergy of Pedagogy, Media, and Context

The very large effect size indicates that the intervention produced strong practical impact, not merely statistical significance. This magnitude is best explained as a synergy between multiple elements rather than a single factor. The RME approach structured learning around

meaningful problems and discussion; the interactive e-book provided autonomy and organized access to learning resources; the animation strengthened visualization and attention; and cultural contexts increased relevance and emotional connection. Each element supports interest through different mechanisms, and together they create a stronger combined influence. This is consistent with motivational design theory, which suggests that effective learning environments integrate attention, relevance, confidence, and satisfaction to sustain motivation. In this study, animation likely contributed to attention; culture and RME contributed to relevance; the interactive structure and guided reinvention supported confidence; and successful engagement with the problem produced satisfaction.

The pattern of observation results supports this synergistic explanation. Attention/enthusiasm showed the greatest improvement, indicating that animation and interactive media effectively attracted students' engagement. Persistence and participation were also high, indicating that RME and the structured e-book supported sustained involvement. Questioning behavior improved but remained slightly lower than the other indicators, suggesting that curiosity was stimulated but still required longer habituation through discussion-based learning. Therefore, the intervention improved learning interest in a layered way: first by attracting attention, then by sustaining engagement through meaningful tasks, and finally by encouraging students to participate and express curiosity.

Moreover, the observational data strengthen the interpretation that interest gains were not merely self-reported but also reflected in classroom behavior, participation, questioning, persistence, and enthusiasm. This behavioral confirmation is important because affective improvements can sometimes be inflated in self-report measures. The consistency between improvements in the questionnaire and observational engagement suggests that the intervention influenced both subjective interest and observable learning behavior.

Contribution to Existing Knowledge and Implications

This study contributes to existing knowledge by demonstrating that learning interest in mathematics can be significantly strengthened through an integrated design that combines culturally grounded contexts, RME pedagogy, and multimedia scaffolding. While prior research often investigates digital media, animation, or contextual learning separately, this study suggests that affective outcomes may be maximized when these components are integrated coherently. The results support the argument that interest development is not incidental but can be intentionally designed through learning environments that trigger situational interest and then sustain it through meaning, competence, and relevance.

Specifically, this study shows that different aspects of learning interest are supported by different components of the intervention. Toontastic 3D animation mainly supports attention and enjoyment; the interactive e-book supports sustained attention, autonomy, and persistence; Jambi cultural contexts support relevance, curiosity, and participation, while RME supports meaningful mathematical construction and task persistence. This integrated contribution distinguishes the present study from previous studies that examined digital media, animation, culture-based learning, or RME separately.

In practice, the findings suggest that schools, especially those with low engagement in mathematics, can benefit from adopting culturally contextualized interactive media aligned with pedagogical frameworks such as RME. Teachers are encouraged to move beyond "media as decoration" toward "media as scaffold," ensuring that animation and interactivity serve clear learning goals and support students' understanding. Additionally, cultural integration should be approached as a meaningful context for mathematization, not only as aesthetic elements. When done well, this approach supports both affective engagement and deeper mathematical sense-making.

CONCLUSION

This study concludes that implementing a Jambi culture-based interactive e-book integrated with FILATOD (Toontastic 3D animation) using Realistic Mathematics Education (RME) is effective in improving students' learning interest in mathematics at SMPN 7 Muaro Jambi. The experimental group showed a greater increase in learning interest than the control group, supported by a very large effect size. Theoretically, this study contributes by demonstrating that learning interest can be strengthened through the synergy of digital interactivity, animated visualization, local cultural relevance, and realistic mathematics pedagogy. Practically, the findings indicate that teachers can enhance students' attention, enthusiasm, participation, curiosity, and persistence by using culturally contextualized digital media that are not merely decorative but function as scaffolds for meaningful mathematical learning.

This study is limited to one school, a relatively small sample, and a short intervention period, which may restrict generalizability. Future research is recommended to involve broader samples, longer implementation periods, and qualitative data such as interviews or student reflections to examine how students' learning interest develops during culturally contextualized digital mathematics learning. Overall, the integration of Jambi cultural contexts, Toontastic 3D animation, interactive e-books, and RME offers a promising instructional strategy for strengthening students' affective engagement and improving the quality of mathematics learning.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

The study was conceptualized by M and ANI, who formulated the research focus, theoretical framework, and integration of Jambi cultural contexts, Toontastic 3D animation, interactive e-book design, and Realistic Mathematics Education. M and S contributed to the research design, methodological planning, and development of the intervention procedure. ANI developed the initial manuscript draft, prepared the research instruments, and contributed to the development of the interactive e-book and FILATOD animation materials. S contributed to data organization, instrument administration, and the coordination of classroom implementation. ANI and N conducted data analysis and interpretation of the statistical findings. M and N provided scholarly supervision, critical review, and theoretical refinement of the manuscript, particularly in relation to mathematics education, RME, and affective learning outcomes. All authors contributed to manuscript revision, approved the final version of the article, and agreed to be accountable for all aspects of the work.

AI DISCLOSURE STATEMENT

The authors used AI-based language editing and reference-search assistance tools to support grammar refinement and improve the clarity of the manuscript. The use of these tools was limited to language improvement and did not influence the research design, data analysis, or interpretation of the results. The authors take full responsibility for the content and the final version of the manuscript.

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