Library Progress International
Vol.44 No. 3, July-December 2024
P.25702-25711

Print version ISSN 0970 1052
Online version ISSN 2320 317X

Original Article

Available online at www.bpasjournals.com

Textbook Products with TPACK-Assisted Mandailing Culture Based Realistic Mathematics Learning Model: A Development Study to Learn Critical Thinking Skills

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How to cite this article: Marzuki Ahmad,Gabby Maureen Pricilia,Rahmatika Elindra,Rizki Kurniawan Rangkuti, Dwi Putria Nasution, Ahmad Nizar Rangkuti,Siti Suprihatiningsih (2024) Textbook Products with TPACK-Assisted Mandailing Culture Based Realistic Mathematics Learning Model: A Development Study to Learn Critical Thinking Skills. *Library Progress International,* 44(3), 25702-25711

ABSTRACT

Understanding critical thinking in mathematics learning is crucial since its benefits are relevant to everyday life. Therefore, a learning model is needed that links mathematics with everyday life revolving around culture and technology. The purpose of this study is to produce a textbook product with a realistic mathematics learning model based on Mandailing culture assisted by TPACK which is valid, practical, and effective in teaching students critical thinking skills in mathematics. The utilized development model was the Plomp model which included the preliminary investigation, design, realization/construction, test, evaluation, revision, and implementation stages. From the findings, it was found that the score of the textbook product was in the very valid criteria based on the assessment of 5 validators. Furthermore, it was found that students' responses to the textbook were in the practical category and students' critical thinking skills in mathematics were in the effective category. Additionally, the textbook developed motivated students to learn the concepts and materials contained in the book and helped students think critically in solving mathematical problems. Thus, it is concluded that the textbook with a realistic mathematics learning model based on Mandailing culture assisted by TPACK developed in this study has good quality and is suitable for use in teaching critical thinking skills.

KEYWORDS

Critical Thinking, Mandailing Culture, Realistic Mathematics, Textbooks, TPACK

1. Introduction

Education plays a vital role in the development of critical thinking skills among students. Critical thinking is an important competence that students must have from the beginning of their academic journey to prepare themselves for future challenges [1], [2]. In secondary education, the development of critical thinking skills is essential [2], [3]. Furthermore, integrating critical thinking into educational practices can engage students to cultivate reflective and analytical thinking, ultimately enhancing their academic performance and personal development [4], [5]. Effective pedagogical strategies have been shown to significantly enhance students' critical thinking skills, indicating that the methods used in teaching are as important as the content delivered [6]. Thus, the importance of education in

developing critical thinking skills cannot be overstated, as it lays the foundation for informed decision-making and responsible citizenship in an increasingly complex world [1], [2].

Mathematics education plays an important role in fostering critical thinking skills, which are essential for students' overall cognitive development and problem-solving abilities. Involving students in analytical activities, synthesizing, and evaluating information effectively can improve critical thinking skills [7], [8]. Integration of self-regulated learning strategies in mathematics learning has also been shown to significantly improve students' critical thinking skills [7]. Furthermore, through mathematics education, students are encouraged to reflect on their thinking processes, thereby fostering a mindset that is directed at critical analysis and inquiry [8]. Furthermore, an emphasis on higher-order thinking skills can prepare students to address real-world challenges by applying mathematical concepts in a variety of contexts [9]. In addition, the development of critical thinking through mathematics education will be a basic skill that equips students for lifelong learning [10], [11].

Traditional mathematics teaching methods are characterized by rote learning and lack of contextual relevance. Rote learning, which emphasizes memorizing procedures without understanding, can hinder meaningful learning and critical thinking skills of students [12]. The absence of contextual relevance in mathematics education often results in students viewing the subject as abstract and disconnected from their everyday lives. In regard to this, culturally responsive teaching practices are essential to make mathematics understandable and interesting to students [13]. Research by Hraste, et al. shows that traditional approaches fail to enhance higher-order thinking skills, as they do not encourage students to explore mathematical concepts through problem solving or inquiry-based learning [14]. Consequently, there is an urgent need for educational reform that shifts from rote learning to more dynamic and contextually relevant pedagogies that enhance students' critical thinking and problem-solving skills in mathematics [15].

Learning through rote techniques often leads to shallow understanding and fails to engage students in meaningful mathematical reasoning [16]. This approach not only limits students' ability to apply mathematical concepts in real-world contexts but also hampers their creativity and analytical skills [17]. Conventional mathematics teaching methods often fail to foster critical thinking skills among students, especially since these methods merely rely on memorization and passive learning techniques. Research shows that traditional pedagogical approaches do not engage students effectively, leading to a lack of interest and shallow understanding of mathematical concepts [18]. These data underscore the urgent need for innovative teaching strategies that go beyond traditional methods. By incorporating active learning techniques, such as problem-based learning and cooperative learning, educators can foster a more engaging and effective learning environment to encourage critical thinking and deeper understanding of mathematical concepts [19]. Thus, it is imperative to move beyond conventional approaches to foster the critical thinking skills necessary for students to actualize themselves in an increasingly complex world.

Realistic Mathematics Education (RME) approach is a pedagogical framework that emphasizes the use of real-world contexts to enhance students' understanding and engagement in mathematics learning. Originating in the Netherlands, RME is based on the belief that mathematics should be connected to students' everyday experiences, making learning more meaningful and relevant [20], [21]. Research has shown that RME not only improves students' mathematical representation skills but also fosters critical thinking, problem-solving skills, and self-efficacy in mathematics [22], [23]. On the other hand, other findings showed that students who are taught using the RME approach RME demonstrated significant improvements in mathematical communication skills and logical reasoning compared to those who experienced traditional teaching methods [24]. By placing mathematical concepts in realistic contexts, RME encourages students to actively engage with the material, facilitating deeper understanding and retention of mathematical knowledge [25]. Consequently, the RME approach is a promising alternative to address the need for more effective teaching approaches in mathematics education.

Furthermore, the RME approach is in line with the need for educational models that prioritize cultural relevance, as it acknowledges students' diverse backgrounds and incorporates their cultural contexts into the learning process [23]. RME plays a role in creating engaging and culturally responsive mathematics education that not only enhances students' mathematical understanding but also prepares them for real-world applications of mathematics. Local culture integrated into the learning process, especially Mandailing culture, is essential to creating a more meaningful and engaging educational experience for students. Culturally relevant pedagogy emphasizes the importance of incorporating students' cultural backgrounds into the curriculum, which can enhance their understanding of the material and foster a sense of identity and belonging [26]. This approach is in line with the idea that education should reflect students' diverse cultural contexts, allowing them to draw connections between their heritage and academic content [27]. Furthermore, research shows that when students see their culture represented in the classroom, it can lead to improved academic outcomes and a greater sense

of responsibility in their learning [28]. Therefore, integrating Mandailing culture into the learning process not only enriches the educational experience but also supports the development of individuals who are culturally competent and can navigate and make contributions to a diverse society.

Technological Pedagogical Content Knowledge (TPACK) framework serves as an essential method for integrating technology into the teaching process, providing educators with a comprehensive understanding of how technology, pedagogy, and content knowledge intersect. TPACK emphasizes the interaction between three core components, namely *Technological Knowledge* (TK), *Pedagogical Knowledge* (PK), and *Content Knowledge* (CK), which together enable educators to create enriched learning experiences [29], [30]. By utilizing the TPACK framework, educators can design learning experiences that are not only technologically enriched but also pedagogically sound and contextually relevant for the students, thereby increasing their engagement and improving learning outcomes [31]. Research has shown that the TPACK framework helps teachers recognize the potential of new technologies to transform their teaching practices, enabling them to create more interactive and dynamic learning environments [32]. Furthermore, the application of TPACK encourages educators to reflect on their teaching practices and adapt their approaches to meet the diverse needs of students, ultimately leading to more effective technology integration in education [33]. Thus, the TPACK framework plays a vital role in guiding educators toward a more holistic and integrated approach to teaching in the digital age. This integration allows for the contextualization of mathematical concepts within familiar cultural narratives, making learning more meaningful for students [34]. For example, using local cultural practices and examples can help students relate abstract mathematical ideas to their everyday lives, fostering a deeper understanding and appreciation of the subject matter and their cultural heritage [35]. When teachers effectively combine TPACK with local cultural elements, they not only increase student engagement but also promote critical thinking and problem-solving skills, ultimately leading to better educational outcomes.

Several related studies reveal significant gaps in the development of textbooks that effectively integrate RME, local culture, especially Mandailing culture, and the TPACK framework, specifically in fostering critical thinking skills in mathematics. There has been research that has highlighted the benefits of integrating local culture into mathematics education. However, it was argued that the integration often fails to incorporate the TPACK framework to assess how technology can further enrich these culturally contextualized learning experiences [36], [37], [38]. Furthermore, the TPACK framework provides a valuable lens for understanding the interactions between technology, pedagogy, and content knowledge, yet little research has focused on creating resources that utilize this framework in conjunction with culturally relevant practices that specifically teach critical thinking in mathematics. This lack of integration not only limits the potential for developing culturally responsive instructional materials but also hinders the ability to foster critical thinking skills in students, which are essential to their academic and personal growth. It is hoped that by incorporating cultural elements, such as those from the Mandailing culture, into the TPACK framework, educators can further enhance the relevance and engagement of mathematics instruction in the classroom. Therefore, there is an urgent need for research that addresses this gap by developing textbooks that combine RME, local culture, and TPACK to create a more holistic and effective approach to contextualized mathematics education. Thus, contributions to TPACK when enriched with cultural context will serve as a powerful tool to transform mathematics education into a more inclusive and impactful learning experience.

2. Scope and Methodology

Development was carried out on the product of a textbook with a realistic mathematics learning model based on Mandailing culture assisted by TPACK in teaching students critical thinking skills in mathematics. To achieve this goal, development research was conducted [39] using stages including *Preliminary Investigation, Design, Realization/Construction, Test Stage, Evaluation and Revision, and Implementation. The subjects of the study w*ere students of class VII of SMP Negeri 2 Padangsidimpuan. The subjects of the study comprised 2 classes, namely the experimental class which was class VII-3 with 34 students and the control class which was class VII-1 with 35 students. The object of the study was a textbook product that was deemed valid, practical, and effective.

The research instruments used were validation sheets, student response questionnaire sheets, and students' critical thinking ability tests in mathematics. The validation sheet was given to measure the management of the validity level of the textbook product with a review of the aspects of format, language, content, and illustrations that had been prepared previously. Meanwhile, the practicality sheet aimed to see the practicality of the textbook with a review of the Ease Aspect, Interest Aspect, Usefulness Aspect, Efficiency Aspect, Content Suitability Aspect, and Language Aspect. Furthermore, the students' critical thinking ability test in mathematics included interpreting, analyzing, evaluating, and inferring which aimed to measure the effectiveness of the textbook product involving pretests and posttests.

Data collection was carried out in accordance with the

stages described previously. In the *Preliminary Investigation, Design, and Realization/Construction stages*, a textbook product was produced that was in accordance with the information from the interviews and theoretical studies that had been conducted. After that, the product entered the *Evaluation and Revision* and the *Implementation stages.* These stages involved the pretest-posttest control group design. These also involved the experimental class, namely class VII-3 and the control class, namely class VII-1. Both experimental and control classes were given a pretest and posttest. In the pretest and posttest stage, the practicality and effectiveness of the textbooks developed were tested. Furthermore, the experimental class was treated with learning activities involving textbooks with a realistic mathematics learning model based on Mandailing culture assisted by TPACK. In the control class, regular learning was carried out as is usually done at the school, namely learning with a regular model involving lecture methods, questions and answers, and assignments.

Data analysis was carried out using a descriptive method, namely by converting the obtained scores into a range of 0-100. After that, the next step was to determine the interpretation of the data validation, questionnaire results, and test results with several categories. The categories were $86 \leq PRS \leq 100$ which was at a very high level; $76 \leq PRS < 86$ which was at a high level; $66 \leq PRS < 76$ indicating average level ;$56 \leq PRS < 66$ which was at a low level; and $0 \leq PRS < 56$ which was considered a very low level. Furthermore, for the critical thinking ability test, it was continued with inferential statistical analysis using the independent sample t-test. Before the usage of the t-test, prerequisite tests were conducted, namely the normality and homogeneity of data variance tests. After that, interpretation of the N-gain test results was carried out to obtain the level of product effectiveness. The analysis of the level of effectiveness was determined based on the average value of the Normalized N-Gain by interpreting it on the effectiveness level criteria based on the normalized N-gain with the interpretation of the effectiveness of $Ngain$ < 3 (Low), 3 ≤ $Ngain$ < 7 (Medium), and $Ngain \geq 7$ (High) [40] .

3. Result

Initially, the *Preliminary Investigation* Stage which provided information about the need for textbooks that are in accordance with the teaching materials and relevant learning approaches to be developed for grade 8 junior high school students was undertaken. In addition, integration of culture and technology is needed in the textbooks that are developed. Therefore, the teaching materials used were numbers with sub-materials of sequences in numbers, addition, subtraction, multiplication, division, and exponents in numbers. Furthermore, the developed textbook with a realistic mathematics learning model based on Mandailing culture assisted by TPACK was designed. Mandailing culture that involves habits related to Mandailing culture which includes traditional ceremonies or activities related to culture was used as a situation in the problem in the textbook. Furthermore, the TPACK used was the use of technology to carry out learning activities that include a projector accompanied by the presentation of material in the form of video, audio, and PowerPoint presentations.

After that, in the *Design stage,* the design of the textbook was carried out according to the information obtained in the *Preliminary Investigation stage.* In this stage, the design of the textbook was prepared, including the making of the cover, foreword, table of contents, concept map, materials, practice questions, bibliography, and conclusion. The textbook was prepared with a focus on number material. After the textbook had been prepared properly, it was continued with the *Realization/Construction stage* of the textbook product, whereas in this stage the textbook was printed as needed for use in the next development stage.

The next development stage was the *Test, Evaluation, and Revision stage.* In this stage, the developed textbook product was evaluated through expert validation and field trials. The validation process involved 5 validators who provided assessments on the developed textbook product. The results of the validator assessment are shown in Table 1.

Table 1. Textbook validation results

Assessment indicators	Score	Percentage (%)
Textbook format	160/175	91.43
Textbook language	132/150	88.00
Contents of the textbook	151/175	86.29
Textbook illustration	68/75	90.67
Average value	128/144	89.10

From Table 1, it can be seen that when reviewed from the aspects of format, language, content, and illustration, the textbook met very high criteria. Thus, the textbook was in the valid criteria. Furthermore, there were several suggestions from the validator, namely improving the writing of foreign languages, improving sentences with ambiguous meanings, and improving the use of punctuation. The suggestions submitted became directions for researchers to improve the textbook manuscript.

The next stage was to conduct a field trial. The field trial activity began with a pretest of students' critical thinking skills in mathematics in the experimental and control groups. Furthermore, learning activities were carried out in the experimental and control classes for 4 meetings. The next step was a posttest. This was done to test the practicality and effectiveness of the developed textbook products. The practicality of the textbook was tested by giving

a questionnaire to students who had participated in the learning activities. The results of the student response questionnaire regarding the practicality of the textbook can be seen in Table 2.

Table 2. Textbook practicality questionnaire results

Assessment indicators	Experimental Class		Control Class	
	Score	Percentage (%)	Score	Percentage (%)
Convenience Aspect	577/680	84.85	523/700	74.71
Aspect of Interest	591/680	86.91	524/700	74.86
Aspect of Benefit	591/680	86.91	537/700	76.71
Efficiency Aspect	601/680	88.38	571/700	81.57
Content Suitability Aspect	602/680	88.53	559/700	79.86
Linguistic Aspects	590/680	86.76	568/700	81.14
Average value	592/680	87.06	547/700	78.14

From the table presented previously, it appears that the percentage of practicality of the experimental class textbooks was at an average value of 87.06 in the very high category and the percentage of practicality of the control class textbooks was at a value of 78.14 (high category). From these achievements, the percentage of practicality of the textbook in both the experimental class and control class was in the practical category. Furthermore, it can be understood that the practicality of textbooks in the experimental class was better than the practicality of textbooks in the control class. In other words, the practicality of textbooks with a realistic mathematics learning model based on Mandailing culture assisted by TPACK was better than the practicality of regular textbooks that were usually applied in schools where the study was carried out.

Furthermore, the effectiveness of the textbook is reviewed from the achievement of students' critical thinking skills in mathematics. The achievement of these abilities is seen from the experimental class and the control class. Descriptive analysis of these achievements can be seen in Figure 1.

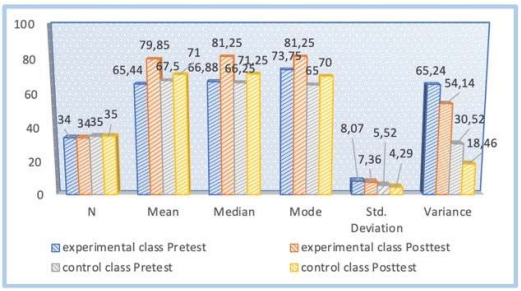

Fig. 1. Achievement of critical thinking ability test results in mathematics

From the achievement, it can be seen that the average post-test score of the experimental class (79.85) was higher than that of the control class (71.00). The difference in achievement occurred based on the difference in achievement of each indicator in the pre-test and post-test of the experimental and control classes. Additionally, the graph of the difference in achievement can be seen in Figure 2.

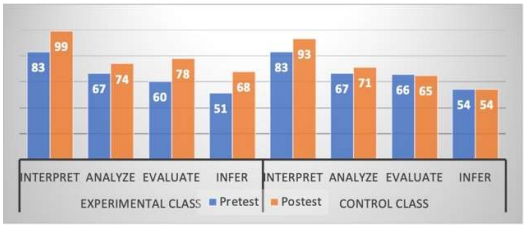

Fig. 2. Pretest posttest achievement of students' critical thinking skills in mathematics

Furthermore, inferential statistical analysis was carried out by first conducting normality and homogeneity tests. The results of the data testing can be seen in Table 3.

Table 3. Results of Normality and Homogeneity Test Analysis

Statistics Test	Experimental Class		Control Class	
	Pretest	Posttest	Pretest	Posttest
One-Sample Kolmogorov-Smirnov Asymp. Sig. (2-tailed)	0.658	0.850	0.845	0.973
Levene Statistics (Significance)	0.405		0.129	

From Table 3, it can be seen that through the One-Sample Kolmogorov-Smirnov test, Asymp. Sig. (2-tailed) pretest posttest experimental class and control class' values were above the alpha level of 0.05 (>0.05). Thus, the data on the pretest and posttest experimental class are normally distributed. Furthermore, through the **Levene Statistic test,** data from the experimental class and control class are each above the alpha level of 0.05 (>0.05). Thus, it can be concluded that the variance of students' critical thinking ability data is homogeneously distributed. With the fact that the variance of students' critical thinking ability data was normal and homogeneous, the data analysis was worthy of being continued with an inferential statistical test with an independent sample t-test. The t-test was conducted on the N-gain index of the sample. The results of the independent samples t-test N-gain of critical thinking ability can be seen in Table 4.

Table 4. Results of independent sample t-test analysis

Independent Samples Test		t-test for Equality of Means		
		t	df	Sig. (2-tailed)
N-gain KBKM	Equal variances assumed	3,187	67	0.002
	Equal variances not assumed	3,186	66,756	0.002

From the achievements given, it can be observed that the acquisition of t = 3.187 with df 67. Then, the t table with a α two-sided test level was 1.66792. The t-count was greater than the t-table. Furthermore, by comparing the acquisition of Sig. (2-tailed) = 0.002 <level α(0.05), there was a significant difference

between the critical thinking skills of students in the experimental class and the control class. In other words, the achievement of critical thinking skills of students in the experimental class was significantly different from the control class. By considering the N-gain value, the achievement of the average n-gain value of the experimental class was 0.41, and the control class was 0.29. Thus, the increase in critical thinking skills of students in the experimental class was better than the control class which means that the achievement of critical thinking skills of students in the class that carried out learning by implementing textbooks with a realistic mathematics learning model based on Mandailing culture was significantly better than the ordinary textbooks used in the school where the research was conducted.

4. Discussion

The development of textbooks with a realistic mathematics learning model based on Mandailing culture assisted by TPACK was proven to generate valid, practical, and effective results as it met valid criteria in various dimensions such as format, content, language, and illustrations. The TPACK framework that combines knowledge of technology, pedagogy, and content was essential to improving the effectiveness of mathematics education. Research has shown that teachers who effectively use the TPACK framework can significantly improve teaching practices and student learning outcomes [29], [34], [41]. Furthermore, the integration of TPACK in teacher training has been associated with positive changes in teacher beliefs and efficacy regarding the use of technology in mathematics teaching [30], [42]. In addition, the emphasis on culturally relevant pedagogy, such as incorporating Mandailing culture into mathematics learning, is in line with contemporary educational practices that advocate contextual learning experiences [43]. This approach not only fosters students' critical thinking skills but also increases their engagement and understanding of mathematical concepts. Validation of textbook components further supports their potential to facilitate meaningful learning experiences that are culturally responsive and pedagogically sound, thereby contributing to the overall goal of developing critical thinking skills in mathematics education [21], [44].

Furthermore, the practicality of textbooks with realistic mathematics learning models based on Mandailing culture assisted by TPACK reviewed from the aspects of Ease, Interest, Usefulness, Efficiency, Content Appropriateness, and Language also met the practical criteria. The Realistic Mathematics Education (RME) approach has been proven to be able to engage students effectively by connecting mathematical concepts with real-life situations, thereby increasing their motivation and understanding [21], [44]. This connection not only makes mathematics more relevant but also fosters deeper involvement with materials that are not only practical but also in line with contemporary educational practices and are very important for developing critical thinking skills. Furthermore, the achievement of student response results in the use of textbooks with realistic mathematics learning models based on Mandailing culture assisted by TPACK was better than regular textbooks used by the school where the research was conducted. This shows that the involvement of cultural aspects and TPACK in textbooks provides good support so that the textbooks get better responses from students. The results of the study also demonstrated that the use of textbooks that present a realistic mathematics learning model based on Mandailing culture supported by the TPACK framework resulted in much better student responses compared to conventional textbooks used in the same educational environment. This improvement can be attributed to the integration of cultural aspects, which are in line with students' backgrounds and experiences, thus encouraging a more engaging learning environment [45]. The incorporation of local cultural elements not only enriches the content but also promotes a sense of relevance and connection among students, which is essential for effective learning. Furthermore, the TPACK framework facilitates the integration of technology and effective pedagogical strategies, ensuring that learning materials are not only culturally relevant but also pedagogically sound. Therefore, students' positive responses to textbooks underscore the importance of culturally aware educational resources in enhancing the learning experience in mathematics education.

The results of the study showed a significant increase in students' critical thinking skills, as evidenced by the results of the pretest and posttest when utilizing textbooks that combine realistic mathematics learning models based on Mandailing culture supported by the TPACK framework. This increase can be attributed to the ability of textbooks to engage students in high-level thinking processes, such as interpreting, analyzing, evaluating, and concluding mathematical concepts in culturally relevant contexts [46]. Responsive teaching through the integration of local culture into subject matter consistently shows greater encouragement of student engagement and motivation towards critical thinking [46]. Research [45] shows that students who are exposed to a realistic mathematics education approach show better problem-solving skills and improved critical thinking compared to those who learn through traditional methods. Furthermore, the TPACK framework facilitates the effective integration of technology and pedagogy, ensuring that learning experiences are not only relevant but also conducive to developing essential skills for the 21st century [47]. Thus, the positive results observed in this study are in line with the existing literature, which reinforces the importance of culturally sensitive and pedagogically sound educational resources in enhancing students'

critical thinking skills in mathematics education.

The increase in students' critical thinking ability achievement using textbooks developed with realistic mathematics learning models based on Mandailing culture assisted by TPACK is better than the achievement of students using textbooks that are usually applied in schools where the research was conducted. This is due to the fact that the developed textbook products were found to be more motivating for students and facilitated them with cultural and technological aspects to think critically. This increase can be attributed to the ability of the developed textbook to motivate students and provide guidance through cultural and technological lenses, thus fostering an environment conducive to critical thinking [31]. The integration of local cultural elements into learning materials not only increases student engagement but is also in line with the principles of culturally responsive pedagogy. Furthermore, it can also improve students' academic outcomes. Previous studies have highlighted that the TPACK framework plays an important role in integrating technology and pedagogy effectively, allowing educators to create more interactive and meaningful learning experiences [48], [49]. Research [50] shows that when teachers use TPACK effectively, they can significantly improve students' critical thinking and problem-solving abilities. Thus, the positive results observed in this study are consistent with the existing literature, which reinforces the idea that culturally relevant and technologically integrated educational resources are essential for developing critical thinking skills in mathematics education.

The research findings illustrate that the textbook developed with the Mandailing culture-based realistic mathematics learning model supported by the TPACK framework not only met the criteria of practical validity but also showed effectiveness in improving learning outcomes. This contribution is significant in the context of current and future education, as it highlights the importance of integrating cultural relevance and technological support in educational resources. The incorporation of local cultural elements encourages greater student engagement and motivation, which are essential for effective learning [51]. Furthermore, the TPACK framework enhances the pedagogical strategies used in this textbook, ensuring that it is not only informative but also interactive and conducive to critical thinking [52]. As education systems increasingly recognize the need for culturally responsive teaching, the implications of this textbook go beyond immediate classroom benefits and pave the way for a more inclusive and effective educational landscape that values diversity and promotes deeper understanding among students [53], [54]. Thus, the development of this textbook is an important point of departure toward modernizing mathematics education and preparing students for a more interconnected and culturally aware world.

5. Conclusion

The development of a textbook with a realistic mathematics learning model based on Mandailing culture, supported by the TPACK approach, was proven to be successful in creating a valid, practical, and effective learning resource. The developed textbook not only met the set academic criteria but also successfully motivated students to be more active in learning mathematical concepts and materials. With a contextual approach, students were encouraged to think critically in solving mathematical problems, which made the learning process more interesting and meaningful. The results of this study indicate that the integration of local culture in mathematics learning was able to increase student engagement, as well as strengthen their critical thinking skills, which are important skills in the 21st-century education. Therefore, this textbook is expected to be a reference for educators in designing learning that is more innovative and responsive to students' background, and make a positive contribution to improving the quality of mathematics education in schools.

6. Acknowledgement

The authors would like to send their gratitude to the Indonesian Ministry of Education and Culture, Research and Technology for Higher Education for providing funding for the research activities.

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