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Jurnal Ilmiah Ilmu Terapan Universitas Jambi
Vol. 9 No. 2. June 2025, pp. 546-561 DOI. 10.22437/jiituj.v9i2.41592
Research Article

INQUIRY LEARNING INNOVATION: EFFORTS TO DEVELOP INQUIRY-BASED TEACHING MATERIALS TO INCREASE MATHEMATICAL AND LANGUAGE LITERACY FOR MATHEMATICS STUDENTS AT UNIVERSITY

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Article Info
Received: Feb 04, 2025
Revised: Mar 22, 2025
Accepted: Apr 02, 2025
OnlineVersion: Apr 10, 2025

Abstract
This study aims to develop and assess the effectiveness of inquiry-based teaching materials in enhancing both mathematical and language literacy among university-level mathematics students. Using the Research and Development (R&D) approach with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, the research involved second-semester students from the Mathematics program at Universitas Negeri Padang, selected through purposive sampling. Data were collected via questionnaires, observations, interviews, and tests assessing mathematical understanding and language literacy and analyzed through descriptive and inferential statistics along with thematic analysis for qualitative data. The results revealed significant improvements in student engagement, with 80% of participants reporting enhanced understanding and critical thinking. Furthermore, pre and post-test scores showed a notable increase in both mathematical and language literacy, from an average score of 60 in the pre-test to 78 in the post-test, alongside marked improvements in critical thinking, evaluation, and analysis skills. The findings demonstrate that the inquiry-based approach effectively promotes active learning and enhances both mathematical and language literacy. The novelty of this research lies in integrating inquiry-based learning to simultaneously address both cognitive and literacy skills in mathematics education, offering a more holistic approach to student development. This research suggests that incorporating such methods into the curriculum can foster more interactive, student-centered learning experiences, encouraging educators to adopt these approaches for improving critical thinking and literacy, thus enriching students' academic and professional capabilities.

Keywords: Inquiry based learning, Learning English, Mathematical and language literacy, Mathematics student engagement, Teaching materials.

INTRODUCTION

Mathematical and language literacy are mutually supportive skills for mathematics students (Lee & Lawson, 1996; Hendrawati et al., 2019; Zulfahita et al., 2020; Prince et al., 2021; Melinda et al., 2024). Mathematical literacy includes the ability to understand and use mathematical concepts in various contexts, as well as to communicate mathematical ideas clearly and accurately, both in writing and orally (Ekowati et al., 2019; Reftianty & Kurniawan, 2020; Chamisijatin et al., 2022; Hyskaj et al., 2024). Meanwhile, language literacy involves understanding, using, and communicating language effectively in various contexts, including understanding scientific texts and constructing arguments well (Adisti et al., 2022; Bali et al., 2022; Simamora et al., 2024). These two literacies enable mathematics students to understand academic literature, solve mathematical problems correctly, and convey the results of their analysis or research clearly and effectively.

English language learning for mathematics students is included in mathematical and language literacy (Frith et al., 2004; Street, 2005; Dahm & De Angelis, 2018; Hendrawati et al., 2019; Endra, K., & Villaflor, 2024). In this context, mathematics students need literacy skills in both areas to understand mathematical texts in English, which are often used in scientific literature and research. Mathematical literacy includes understanding mathematical symbols, notations, and concepts often translated or presented in English (Baucal, 2006; Zulkardi & Kohar, 2018; Prince et al., 2021). Meanwhile, language literacy refers to students' ability to understand and use English effectively in academic and professional contexts (Wise & Sevcik, 1993; Scott, 2016; McNally et al., 2019; Ruzin, 2019; Kurniati et al., 2021; Lenchuk, 2020;).

However, mathematics students often face obstacles in mastering mathematical and language literacy, especially in learning English (Zulkardi & Ilma, 2006; Oktradiksa & Mujahidun, 2014; David et al., 2024). One of the main challenges is the vocabulary and technical terminology used in mathematics, which are often difficult to understand if students are not familiar with the academic language or do not master the technical vocabulary. In addition, the sentence structure in English mathematics texts tends to be complex, with long sentences containing various concepts that are difficult to understand. It makes reading scientific texts a challenge for students unfamiliar with the dense and jargon-filled scientific writing style. Another obstacle that often arises is the difficulty in writing and constructing arguments in English because students need to explain the steps to solve mathematical problems systematically and clearly (Hendrawati et al., 2019; Chamisijatin et al., 2022; Firmansyah et al., 2024Ilhami et al., 2025). In addition, although mathematical notation is universal, explaining mathematical concepts in English can be confusing if not accompanied by a sufficient understanding of the vocabulary terms used.

In this case, limited vocabulary in English is the main obstacle, especially in the context of mathematics (Kurnianti, 2017; Retnowati et al., 2018; Kurniati et al., 2021; Trisnaningtyas & Khotimah, 2022; Hasibuan et al., 2024), and to overcome these obstacles, students need to practice regularly, deepen their mathematical vocabulary, participate in group discussions, and utilize various learning resources in English so that they can improve their mathematical and language literacy skills effectively.

Furthermore, mathematics education students must understand that English vocabulary has a more important role than a foreign language; it is also a primary tool for engaging with global research, academic journals, and mathematical technologies that shape modern teaching and learning practices. As future mathematics educators, English proficiency allows them to stay at the forefront of pedagogical innovation, participate in international collaborations, and foster a global perspective in their teaching methods. Therefore, English language skills have become essential today, especially for mathematics education students preparing to face competition in the international job market. English is a tool for global communication and a means to access ever-evolving science, technology, and innovation. (Harmer, 2018; Swan, 2018; Kurniati et al., 2020; Alfian, 2022; Wirnayanti et al., 2024). However, in many cases in higher education, the teaching method of English language courses is still dominated by the traditional teacher-centered approach. It is especially problematic in the context of Mathematics Education, where students must not only master the content but also develop the ability to critically analyze, interpret, and communicate mathematical concepts in a global context. Therefore, integrating effective English language learning strategies into the curriculum of Mathematics Education students is essential to enhance their academic success and professional development. This approach tends to limit students' active engagement. This approach is less practical in developing their critical

thinking skills, which are very important in facing the challenges of the globalization era. (Johnson & Hall, 2021). In this context, the inquiry-based learning approach is a promising alternative to enhance students' learning independence and critical thinking skills.

The inquiry approach encourages students to engage in the learning process independently and actively through exploration and information-seeking. With this approach, students are not only passive recipients of information but also act as learning agents responsible for developing their understanding of the material (Langgeng & Adi, 2017; Kurniati, 2019; Parwati et al., 2020). In language learning, an inquiry-based approach enables students to develop their language skills through more profound analysis, reflection, and learning processes to build more prosperous and meaningful understandings (King, 2015; Duke et al., 2021). Hmelo-Silver et al. (2007) explain that inquiry provides opportunities for students to learn through direct experience and investigative processes, which can ultimately improve their critical thinking skills.

Several studies have shown the benefits of inquiry-based approaches in improving student learning outcomes. For example, Zikra et al. (2020) found that this approach increased student motivation and engagement, especially in foreign language learning. Students who engaged in inquiry-based learning were more interested in exploring the material and improving their comprehension skills. However, this study focused more on secondary school students and did not cover the college context.

Research by Dewi&Nurhadi (2018) in Indonesia showed that the inquiry method at the secondary school level improved students' critical thinking skills and learning independence. However, the study did not specifically develop inquiry-based teaching materials. Meanwhile, research by Wulandari & Susanto (2019) shows that inquiry-based teaching materials have improved students' conceptual understanding of non-language courses in higher education. Students who use inquiry-based teaching materials can better understand the material in depth and are more active in learning. However, this study focuses on courses other than English. It has not highlighted ways of implementing inquiry in developing English teaching materials appropriate to higher education's needs.

King (2015) stated that other literature reviews revealed that inquiry-based approaches can help students build analytical and critical skills needed in second language learning. According to King, the inquiry method allows students to interpret learning materials more deeply because they must explore, collect data, and analyze information independently. However, the study did not specifically examine the application of this method in developing English language teaching materials at the tertiary level in Indonesia.

Similar findings are also supported by recent research. Duke et al. (2022) state that inquiry facilitates students' direct involvement in learning, thereby improving their understanding and critical thinking skills. However, this study focuses more on the general impact of inquiry on learning and less on exploring the development of specific teaching materials using this approach.

With these findings, several gaps in previous research form the basis for this research. First, research highlighting the effectiveness of inquiry-based approaches has mainly been conducted on high school students. In contrast, studies that explore the development of inquiry-based teaching materials specifically for college students are still limited (Hmelo-Silver et al., 2007; Schmidt et al., 2020). Second, studies on inquiry methods in Indonesia, especially in the context of higher education, are still limited. Hence, there is insufficient empirical data on how this method can influence students' critical thinking skills in English learning.

Moreover, Several studies have been conducted on inquiry-based learning innovations, namely research by Professor Michal Zion from Bar-Ilan University (Zion, 2017) studying the application of open inquiry-based learning in biology education. His research shows that this approach can improve students' intellectual flexibility and critical thinking skills, with students involved in open inquiry projects showing higher satisfaction than directed inquiry projects. Furthermore, research on problem-based learning (PBL) in medical education (Norman, 2008) also shows a positive impact, especially in improving doctors' competence in social and cognitive skills, such as dealing with uncertainty and communication skills. Stanford Mobile Inquiry-based Learning Environment (SMILE) (Zhu, C. et al., 2018) is a platform designed to improve students' questioning skills and encourage student-centered learning. SMILE has been implemented in more than 25 countries and has shown increased student engagement in the learning process.

Furthermore, the Self Organized Learning Environment (SOLE) supports self-directed learning (Rajagopal K. et al., 2015), where students learn collaboratively to answer big questions using the internet. This approach has improved students' ability to learn independently and collaboratively. Fifth,

research by Professor Cindy Hmelo-Silver shows how problem-based learning and inquiry can improve students' collaborative and problem-solving skills and how technology can support such learning (Silver, C. E. et al., 2007).

The five studies show that innovation in inquiry-based learning can significantly improve students' critical thinking, collaborative, and problem-solving skills and the relevance of using technology to support such learning. The main difference between the research that the researcher has conducted and previous studies lies in the focus and context of its application. This study focuses on developing inquiry-based teaching materials designed to improve mathematics and language literacy for mathematics students in higher education. This differs from previous studies that focused more on applying the inquiry approach in more general educational contexts, such as biology, medicine, and foreign language learning. This study combines two important literacies (mathematics and language) in the context of mathematics education in higher education. It attempts to develop teaching materials that can be used to support these goals.

In addition, this study also highlights the importance of English language proficiency in the context of mathematics learning. Mathematics students must master English to understand scientific literature in that language, which often contains distinctive mathematical symbols and notations. Although previous studies have discussed improving language literacy, none have specifically examined English literacy in the context of mathematics learning faced by college students. Therefore, this study brings a new focus to developing language skills in this very specific context.

The novelty of this study lies in developing inquiry-based teaching materials tailored to the specific needs of mathematics education students in college to improve mathematics and language literacy, especially English literacy related to mastery of technical terms in mathematics. This study attempts to fill the gap in the existing literature by exploring the application of inquiry teaching materials in the context of mathematics learning in college, which is still very limited. This study also measures the impact of developing inquiry teaching materials on students' critical thinking skills and literacy, which have not been widely studied in this context. Thus, this study provides a new contribution that is more specific and relevant to today's higher education needs.

In addition, many studies have tested the benefits of inquiry in general. However, none have precisely measured the effectiveness of inquiry-based teaching materials in improving students' critical thinking skills in the context of English language learning (Wulandari & Susanto, 2019; Johnson & Hall, 2021). This study aims to fill the gap by developing inquiry-based English teaching materials tailored to the needs of college students and evaluating their impact on their critical thinking skills and active involvement in the learning process.

This research not only enriches theoretical studies related to inquiry-based approaches but also provides practical contributions in the form of teaching materials that can be adopted by English lecturers in universities (Kuhlthau et al., 2019; Alfian, 2022). In addition, the inquiry-based teaching materials developed in this study are expected to be a reference for universities to create a more interactive learning environment and support student-centered learning. By integrating an inquiry-based approach into teaching materials, lecturers are expected to be able to create a more interactive learning process that suits the needs of today's mathematics students. Students who learn using inquiry-based teaching materials are expected to not only be able to improve their English language skills but also have the critical thinking skills needed to face academic and professional challenges in the future (Loyens et al., 2012; Johnson & Hall, 2021).

Thus, the expected outcome of this study is the availability of effective inquiry-based English teaching materials to improve mathematics students' critical thinking skills and learning independence in higher education. This study is also expected to provide empirical evidence that supports the application of inquiry-based learning methods in English learning for mathematics students. With the teaching materials developed, students are expected to be more actively involved in education, have a deeper understanding, and be able to apply critical thinking skills in academic and daily life.

RESEARCH METHOD

The development of inquiry-based teaching materials represents an innovative approach in higher education designed to enhance students' critical thinking in mathematics study programs. This study adopts the ADDIE model as a systematic framework to create relevant and effective English study teaching materials. Involving second-semester students in the mathematics study program at Universitas

Negeri Padang as research subjects, the approach focuses on needs analysis, material development, and effectiveness evaluation through qualitative and quantitative methods.

This research is development research (Research and Development or R&D), which aims to develop inquiry-based English teaching materials for use in mathematics study programs at the university. The development model used in this study is the ADDIE model, which includes five main stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). This model was chosen because it has proven effective in developing structured and gradual teaching materials and is relevant to improving students' critical thinking skills (Wang & Hannafin, 2005; Branch, 2009).

The subjects of this study were students of the Mathematic study program at the Universitas Negeri Padang. This study involved fourth-semester students who already had an adequate foundation in English and took courses following the teaching materials to be developed. The sampling technique used was purposive sampling, a sample selection technique based on specific criteria relevant to the research objectives (Cresswell, 2014). The selection of second-semester students was based on the assumption that they already have basic English language skills in the first semester that enable them to participate actively in an inquiry-based approach.

This research employed the ADDIE model, a structured and iterative framework comprising the phases of the Analysis, Design, Development, Implementation, and Evaluation. The study aimed to develop inquiry-based English teaching materials to enhance students' critical thinking skills. Below is the detailed research procedure: Analysis Phase: In this initial phase, a needs analysis was conducted to identify gaps in existing English teaching materials and ascertain the requirements for inquiry-based materials. Data were gathered through surveys and interviews with faculty members and students in the English study program at a state university in Indonesia. Additionally, the curriculum was reviewed to align the new materials with course objectives. Design Phase: Based on the findings of the analysis, the design of the teaching materials was conceptualized. This phase involved defining learning objectives, selecting relevant topics, and integrating inquiry-based learning strategies. Frameworks for activities and critical thinking exercises were established, following models by Paul & Elder (2006). Development Phase: The teaching materials incorporated interactive and inquiry-based components such as problem-solving tasks, case studies, and guided research activities. Drafts of the materials were reviewed by experts in language education and instructional design to ensure their quality and relevance. Implementation Phase: The developed teaching materials were piloted in a class of fourth-semester students, chosen through purposive sampling. During the implementation, students engaged in activities requiring analysis, evaluation, and inference, which are critical components of the inquiry approach. The learning process was observed, and feedback was gathered to refine the materials. Evaluation Phase: The effectiveness of the teaching materials was assessed using a combination of qualitative and quantitative methods. Student engagement and perception were measured through questionnaires and observations, while semi-structured interviews provided more profound insights into their experiences. Critical thinking skills were evaluated through pre-tests and post-tests based on Paul & Elder's framework. A paired t-test was performed to analyze improvements in test scores, and thematic analysis was applied to qualitative data.

The data collection technique in this study combines qualitative and quantitative methods to obtain comprehensive data on the effectiveness of the developed inquiry-based teaching materials. This data collection method includes several main instruments. First, a questionnaire is used to measure students' responses to inquiry-based teaching materials and their level of satisfaction with the learning experience they have experienced. This questionnaire instrument contains statements adapted from a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree," so it can quantitatively assess students' perceptions (Hamzah et al., 2022; Sugiyono, 2017). Using inquiry-based teaching materials, this questionnaire obtained quantitative data regarding students' perceptions and involvement in learning.

Furthermore, observation techniques are applied during the learning process to directly observe the active involvement of students and the application of critical thinking skills in the classroom. Observation data are collected through sheets compiled based on indicators of involvement and critical thinking skills, as formulated by Suroyya et al. (2022). These observations provide in-depth qualitative data, complementing the data from the questionnaire and providing context regarding student interactions in inquiry-based learning. In addition, semi-structured interviews were conducted with several sample students to explore their responses to the learning materials and inquiry-based learning experiences more deeply. These interviews aimed to collect in-depth data on students' perceptions of the

benefits and challenges of the learning materials, which can later be used for further evaluation and development (Cresswell, 2014).

Finally, a critical thinking test was developed based on the model to measure students' critical thinking skills Paul & Elder (2006), covering analysis, evaluation, and inference skills. This test was given before and after using inquiry-based learning materials, allowing researchers to see significant changes or improvements in students' critical thinking skills after learning with inquiry-based learning materials. The data obtained were analyzed using quantitative and qualitative analysis techniques to better understand the effectiveness of inquiry-based teaching materials. For quantitative analysis, data from questionnaires and critical thinking skills tests were analyzed using descriptive and inferential statistics. Descriptive analysis was used to describe students' perceptions of the teaching materials and their level of involvement in the learning process. Meanwhile, inferential analysis was conducted using a paired t-test to compare students' critical thinking skills scores before and after implementing inquiry-based teaching materials. This t-test aims to measure the significance of changes in critical thinking skills scores so that the impact of inquiry-based learning on improving these skills can be known (Arikunto, 2013).

For qualitative analysis, data obtained from observations and interviews were analyzed using thematic analysis techniques. This analysis process involves several stages: data coding, identification of main themes, and data interpretation. It allows researchers to find relevant patterns or themes related to student engagement and their responses to inquiry-based learning materials. This thematic analysis provides a deeper understanding of student experiences, showing how inquiry-based learning materials can support their active engagement and the development of their critical thinking skills (Miles et al., 2014).

RESULTS AND DISCUSSION

This study produced findings that showed a positive impact of using inquiry-based learning materials on students' perceptions, engagement, and critical thinking skills in learning English in higher education. Data obtained from questionnaires, observations, interviews, and critical thinking skills tests provide a comprehensive picture of the effectiveness of the developed learning materials. The following data analysis describes students' perceptions of the learning materials, their level of active engagement during learning, in-depth responses obtained from interviews, and improvements in critical thinking skills based on test results.

Student Perception and Engagement Questionnaire Results

The questionnaire results showed that students responded positively to inquiry-based teaching materials regarding ease of understanding and involvement in learning. The following table shows the distribution of student responses to several statements related to their perceptions of this teaching material.

Table 1. Students' Perception and Engagement

No.	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	This teaching material helps me understand the material more deeply.	30%	50%	10%	8%	2%
2	I feel challenged to think critically with this teaching material.	45%	40%	10%	5%	-
3	The instructions in this teaching material are clear and easy to understand.	35%	45%	15%	5%	-

No.	Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
4	I feel more involved in the learning process.	50%	30%	10%	8%	2%
5	I felt motivated to find out more.	55%	35%	5%	3%	2%

As many as 80% of students agreed or strongly agreed that inquiry-based learning materials helped them understand the material more deeply. In addition, 85% of students felt challenged to think critically while using these learning materials. It shows that the inquiry method effectively increases student engagement in learning. Meanwhile, 80% of students also agreed or strongly agreed that the instructions in these learning materials were evident, indicating that these learning materials have been well designed to support the independent learning process.

Observation Engagement and Critical Thinking Skills

Observation results during the learning process showed students' active involvement and critical thinking skills. As many as 80% of students were actively involved in class discussions and dared to ask essential questions. In addition, they showed the ability to collaborate in group work, with 85% of them playing an active role in completing joint assignments.

Regarding critical thinking skills, the observation results show that around 70% of students can analyze and evaluate arguments in the teaching materials. Students can also identify relevant evidence and draw logical inferences from the learning materials. As many as 60% of students could draw conclusions based on available information, indicating critical thinking development through inquiry-based teaching materials.

In-depth Student Interviews

The results of the in-depth interviews strengthened the findings from the questionnaire and observations. Several students stated that the inquiry-based teaching materials helped them be more independent and involved in learning. One student said, “I feel more involved and able to dig deeper into the material being studied than the previous method.” This response shows that the inquiry approach has succeeded in encouraging students to be actively involved.

However, some students also expressed challenges, especially at the beginning of the learning process. Some students found it somewhat tricky because this approach required them to find answers independently without much guidance from the lecturer. One student said, "At first, I had a bit of difficulty because I had to find the answers myself without much guidance from the lecturer." Nevertheless, this challenge can help improve students' independent and critical thinking skills.

Critical Thinking Skills Test

The critical thinking skills test results showed a significant increase in students after using inquiry-based teaching materials. The following table presents the average pre-test and post-test scores for students' critical thinking skills.

Table 2. Average Pre-test and Post-test Scores of Students

Critical Thinking Indicators	Pre-test Average Score	Post-Test Average Score
Analysis	60	78
Evaluation	62	80
Inference	58	76
Total Average	60	78

The average overall score of students' critical thinking skills increased from 60 on the pre-test to 78 on the post-test. This increase indicates that inquiry-based teaching materials positively influence students' critical thinking skills. The most significant increase was seen in the evaluation indicator, where the score increased from 62 to 80, followed by analysis and inference. This shows that the

inquiry approach applied in the teaching materials can encourage students to hone their evaluation, analysis, and inference skills.

Based on the results obtained, it is known that inquiry-based teaching materials positively impact students' perceptions, involvement, and critical thinking skills. Data from the questionnaire showed that most students felt helped by these teaching materials and felt an increase in their participation in the learning process. The results of observations also support this finding, where students were seen actively participating and demonstrating critical thinking skills that developed during learning.

In addition, interview data provide insight that although students experience challenges at the beginning of the learning process, the inquiry approach encourages them to be more independent and think critically. These challenges are considered a driver that improves their ability to find solutions and argue. The results of the critical thinking skills test showed a significant increase in students' critical thinking skills, which supports the effectiveness of inquiry-based teaching materials in improving critical thinking skills. Overall, this study's results align with previous studies by Ennis (1996) and Paul & Elder (2006), which showed that an inquiry-based approach can improve critical thinking skills and learning independence.

The results of this study provide significant contributions to the understanding and application of inquiry-based learning, especially in the context of mathematics education in higher education, which integrates mathematical literacy and English by developing inquiry-based teaching materials tailored to the needs of mathematics education students. This study aims to deepen the understanding of mathematical concepts and improve students' English skills, which are very important in facing the challenges of globalization and the digitalization of education. Previously, although there have been many studies on the application of inquiry in other fields, such as science or foreign languages, little attention has been paid to the application of inquiry in the context of mathematics education, especially in higher education. Therefore, this study fills the gap by showing that the inquiry approach can increase student engagement, develop critical and analytical thinking skills, and improve their ability to understand and evaluate information in English, which is important for their scientific literacy.

In addition, this study emphasizes the important role of lecturers as facilitators who support students in information-seeking and reflection. By actively involving students in the learning process, this study not only highlights the initial challenges faced by students in adjusting to the inquiry approach but also shows that these challenges serve to improve their independence and critical thinking skills (Johnson & Hall, 2021; Listiyanto & Fauzi, 2016; Palupi et al., 2020; Zion & Sadeh, 2007). The significant increase in critical thinking skills in analysis, evaluation, and inference illustrates the effectiveness of inquiry-based English teaching materials in preparing students to face complex challenges, both in the academic and professional worlds (Sullivan & Andrea McDonough, 2007). Thus, the results of this study not only strengthen previous theories regarding the benefits of inquiry but also provide empirical evidence that this approach can be applied effectively in the context of mathematics education in higher education, especially in Indonesia, which still rarely implements this approach.

It can be seen from the results of this study that the application of inquiry-based teaching materials in English learning for mathematics students in university positively impacts students' engagement, perception, and critical thinking skills. Based on the questionnaire results, more than 80% of students agreed that inquiry-based teaching materials helped them understand the material more deeply and challenged them to think critically. This finding aligns with the research of Schmidt et al. (2020), which states that inquiry-based learning can increase student motivation and involvement, especially in foreign language subjects. According to the theory put Forward, the inquiry approach provides space for students to explore material independently and engage directly in information searches, which creates deeper conceptual understanding.

Students who feel challenged to think critically during learning with inquiry-based teaching materials show that this approach can shape analytical thinking skills. King (2015) stated that the inquiry approach allows students to actively explore the concepts they are learning, thus encouraging them to critically evaluate information and draw conclusions. Increasing student involvement in learning also strengthens the view that inquiry-based learning can foster higher-order thinking skills. Therefore, the results of this study indicate that inquiry-based learning materials effectively increase student active involvement while strengthening their analytical skills.

Furthermore, classroom observations showed that students actively participated in class discussions and demonstrated good collaborative skills in groups. As many as 85% of students participated in group work and demonstrated significant collaborative skills. It supports the findings of Silver (2019), which states that inquiry-based learning develops social and cooperative skills because students are encouraged to exchange ideas, work together, and support each other in achieving understanding. Using the inquiry approach in this English language teaching material encourages individual involvement and increases student collaboration in the learning process.

Interview data with students strengthens the results of the questionnaire and observations, where most students feel that inquiry-based learning materials encourage them to be more independent and active in learning. However, they also expressed challenges, especially at the beginning of the learning process. Some students felt it took time to adjust to this approach, mainly because they had to search for information independently. It shows that the inquiry-based approach requires higher learning independence, where students must direct their learning. As stated by Obeid (2019), lecturers must act as facilitators who support students in the information search process to adapt to the demands of inquiry-based learning. In addition, students who felt challenged by this inquiry approach indicated that this teaching material required high exploration and reflection skills. Some students stated that they had difficulty searching for information or answers independently, but this challenge was considered helpful in increasing their learning independence. It aligns with the findings of Dewi & Nurhadi (2018), who found that an inquiry approach can encourage students to learn independently even though the process is more challenging. The initial challenges students face are essential to improving their critical thinking skills because they learn to find solutions and draw conclusions without strict guidance from the lecturer.

The critical thinking skills test results significantly increased students' analysis, evaluation, and inference abilities. The average student score increased from 60 on the pre-test to 78 on the post-test. This increase indicates that the inquiry approach effectively develops students' critical thinking skills, as outlined by Paul & Elder (2006), which states that critical thinking skills include analysis, evaluation, and inference skills. This study shows that inquiry-based teaching materials help students train to interpret better and critically assess information in these three aspects. Especially in the evaluation aspect, students showed the most significant improvement, from a score of 62 to 80. This improvement indicates that students are more critical in assessing the accuracy of the information they obtain during the learning process. According to Kwan & Wong (2015), evaluation is the ability to determine the relevance and validity of information, which is the basis for the critical decision-making process. The increase in students' evaluation skills shows that inquiry-based teaching materials can encourage them to be more careful in examining available evidence and making decisions.

In the analysis aspect, students also showed significant improvement. In inquiry-based learning, students can analyze information and identify relationships between the concepts learned. This is in line with the findings of Ennis (1996), who states that analytical skills are an essential part of critical thinking, where students must be able to break down complex information into smaller parts and understand their relationships. The inquiry-based teaching materials used in this study have been designed to train students in in-depth analysis to prepare them better to face complex learning challenges. In addition to improving analytical and evaluation skills, inquiry-based teaching materials also boosted students' inference skills, with scores increasing from 58 to 76. Inference skills are the ability to draw logical conclusions from available evidence, an essential critical thinking skill. This study supports the findings of Duke et al. (2022), who found that an inquiry-based approach encourages students to construct arguments and draw conclusions based on their analysis. Using this approach, students can build good inference skills in interpreting information.

Overall, the results of this study align with the view that the inquiry approach can develop high-level thinking skills, which are increasingly important in the era of modern education. According to Yang et al. (2019), inquiry-based learning helps students understand the material and develop broader cognitive skills, such as creative and critical thinking. The results of this study indicate that inquiry-based learning materials can enrich students' learning experiences, provide intellectual challenges, and significantly improve their critical thinking skills. This finding also strengthens the importance of implementing an inquiry-based approach in the mathematics study program, especially in teaching English at Universitas Negeri Padang. This approach is rarely applied in Indonesia, although its benefits significantly improve students' cognitive skills. Therefore, this study provides an essential contribution to developing a higher education curriculum that is more adaptive to the needs of mathematics students

in the digital era. Lecturers can integrate inquiry-based teaching materials to encourage active involvement, independent learning, and critical thinking skills in mathematics students' classes.

The practical implication of these findings is that English lecturers need to understand their role as facilitators in inquiry-based learning in mathematics class. According to Obeid (2019), lecturers who act as facilitators help students face the challenges of more independent learning while ensuring they have the guidance needed to achieve learning goals. By becoming a facilitator, lecturers can support students in overcoming initial challenges in the inquiry approach and encourage them to gain a deeper understanding. The results of this study also emphasize the importance of active mathematics student involvement in the inquiry-based learning process. Students in mathematics study programs who are actively involved show significant improvements in their critical thinking skills, reflecting that the inquiry method provides substantial benefits in developing more dynamic and student-centered learning. Following the findings of Johnson & Hall (2021), inquiry-based learning can shape students into more independent, creative, and critical learners, which is very relevant to the needs of education in the digital era.

This study supports that inquiry-based approaches positively contribute to learning English in mathematics study programs, especially in improving critical thinking skills. Using inquiry-based learning materials allows students to explore concepts in depth, think critically, and develop their reflective abilities. Thus, this study provides a solid theoretical foundation and empirical evidence regarding the benefits of inquiry-based approaches in mathematics study programs. This study provides significant theoretical and practical contributions to developing inquiry-based teaching materials. From a theoretical perspective, this study enriches the literature on the effectiveness of the inquiry approach in teaching English to mathematics students, especially in the context of higher education. These findings can guide lecturers in designing effective teaching materials to encourage mathematics students' engagement and critical thinking skills. Through the inquiry approach, students can become more independent learners who can think critically and reflectively and have the ability to face real-world challenges.

As explained above, the novelty of this study lies in the development of inquiry-based teaching materials that are tailored to the specific needs of mathematics education students in higher education, with a focus on improving mathematical and language literacy, especially English literacy related to mastery of technical terms in mathematics. Previously, English literacy in the context of mathematics learning in higher education received less attention, even though this language plays an important role in accessing scientific literature and understanding mathematical symbols and notations that are often conveyed in that language (Lee & Lawson, 1996; Retnowati et al., 2018; Scott, 2016; Walls, 2007). This study fills this gap by developing inquiry-based teaching materials that improve students' understanding of mathematical concepts and their English language skills, which are very relevant in facing the challenges of globalization and the digitalization of education.

In addition, this study fills the gap in the existing literature by exploring the application of inquiry-based teaching materials in mathematics learning in higher education, which is still limited. Many previous studies have examined the application of inquiry in other fields, such as science or foreign languages, but the application of inquiry in mathematics education in higher education is rare (Boud et al., 2016; Budiarti et al., 2022; Maulinda et al., 2023; Susmariani et al., 2022). This study provides empirical evidence that the inquiry approach can increase student engagement in learning and help them think critically and analytically. More than 80% of students felt that inquiry-based learning materials helped them understand the material more deeply and challenged them to think critically. It strengthens the argument that inquiry allows students to explore the material independently and in-depth.

This study also shows the positive impact of inquiry-based learning materials on students' critical thinking skills and literacy, which have not been widely studied in mathematics education. The critical thinking skills test results showed a significant increase in students' analytical, evaluation, and inference abilities, which are key elements in developing critical thinking skills. This increase reflects the effectiveness of inquiry-based learning in training students to analyze information, evaluate data accuracy, and draw conclusions based on existing evidence. In addition, this study emphasizes the role of lecturers as facilitators in inquiry-based learning, where lecturers function as information providers and support students in searching for information and reflecting on the material that has been studied. This finding emphasizes the importance of the role of lecturers in guiding students to overcome initial challenges in inquiry-based learning, where students are asked to learn independently and actively

(Deepwell & Malik, 2008; Fischer & Barabasch, 2023; Kiptiony Kiplangat, 2017; Simatupang, 2022; Widhiastuti et al., 2022). Interviews with students also showed that despite initial challenges in adjusting to this approach, students who successfully adapted felt more independent in learning and more skilled in critical thinking.

This study significantly contributes to higher education, especially mathematics education, by offering a new approach to integrating mathematical and English literacy through inquiry-based teaching materials. The novelty of this research lies in developing inquiry-based teaching materials tailored to the specific needs of mathematics education students in higher education, focusing on improving mathematical and language literacy, especially English literacy related to mastery of technical terms in mathematics. Previously, English literacy in the context of mathematics learning in higher education received little attention, even though this language plays an important role in accessing scientific literature and understanding mathematical symbols and notations often presented in that language. This research fills this gap by developing inquiry-based teaching materials that improve students' understanding of mathematical concepts and their English language skills, which are very relevant in facing the challenges of globalization and the digitalization of education.

Thus, this approach has a direct impact on students both cognitively, affectively, and psychomotorically. The cognitive impact is that the inquiry-based approach to mathematics learning encourages students to think critically, analytically, and independently, which helps them develop higher-order thinking skills such as analysis, evaluation, and inference and improves their understanding of mathematical concepts in depth (Boud et al., 2016). This approach also has the potential to increase student motivation and engagement, strengthen self-confidence, and encourage them to be more independent in learning (Boud et al., 2016; Kori, 2021; O'Brien et al., 2014; Sullivan & Andrea McDonough, 2007). In addition, by involving independent exploration and practical application, students can develop psychomotor skills that support the application of mathematical concepts in real situations, preparing them to face the challenges of education in the era of globalization and digitalization.

This study contributes to improving the quality of mathematics learning in higher education. It paves the way for broader application of the inquiry approach in mathematics education, which is still rarely applied in Indonesia. This approach is very relevant to the demands of education in the digital era, where students need to be more involved in their learning process and develop critical thinking skills that are important in dealing with complex problems in the academic and professional world.

CONCLUSION

This study demonstrates that the inquiry-based learning approach significantly enhances students' engagement, understanding, and critical thinking skills, particularly within the context of mathematics education at the higher education level. It underscores the value of developing inquiry-based teaching materials that not only deepen students' understanding of mathematical concepts but also enhance their English proficiency, a crucial skill in navigating the challenges of globalization and the digitalization of education. The findings reveal that this approach fosters critical thinking skills, such as analysis, evaluation, and inference, while also promoting greater student independence in learning. Despite initial challenges in adapting to the inquiry-based approach, students experienced substantial growth in their critical thinking capabilities, with more than 80% reporting that the materials helped them gain a deeper understanding and encouraged them to think more critically. The notable improvement in higher-order thinking skills emphasizes the effectiveness of this approach in cultivating essential skills for modern education. This study also contributes to the evolution of higher education curricula, particularly in mathematics education, by highlighting the role of lecturers as facilitators who guide students in information retrieval and reflection. Furthermore, the application of inquiry-based methods in English language teaching materials for mathematics students offers a promising model for expanding this approach in mathematics education across Indonesia, where it remains underutilized. In conclusion, this research reinforces the empirical evidence that inquiry-based learning can significantly improve student engagement, critical thinking, learning independence, and literacy in both mathematics and English at the higher education level while also contributing to curriculum development.

ACKNOWLEDGMENTS

My sincere gratitude to my first supervisor and my second supervisor for their invaluable guidance, expertise, and constant support throughout this research. Their insightful feedback,

constructive suggestions, and encouragement have been crucial in shaping the direction and quality of this study. I also extend my heartfelt thanks to Universitas Negeri Padang for providing the necessary resources, facilities, and a supportive academic environment, which played a significant role in the successful completion of this work.

AUTHOR CONTRIBUTIONS

Author 1 create article, contributed to the conceptualization of the study, development of the research instruments, and overall research design. Author 2 was responsible for data collection, analysis, and interpretation of the research findings. Author 3 assisted with the validation of the research instruments, data analysis, and provided critical revisions to the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

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