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The Need for Development of Meaningful E-Module Teaching Materials to Optimize Mathematics Learning with a Focus on Critical Thinking Skills

Andi Alim Syahri[1], Irwan Akib[1], Sukmawati[1]
[1]Universitas Muhammadiyah Makassar, South Sulawesi, Indonesia

Corresponding author e-mail: andialims@unismuh.ac.id

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Abstract: This research aims to develop meaningful e-module teaching materials for Differential Equations course, with a focus on improving students' critical thinking skills. Using the Technological Pedagogical Content Knowledge (TPACK) framework, the e-module is designed to be interactive and flexible, allowing students to learn independently and in more depth. The research method involved student and lecturer needs analysis, observations, interviews, as well as a student survey to identify gaps in current learning. The results showed that the use of conventional teaching materials did not support the development of critical thinking skills. Therefore, the developed e-module includes various interactive features such as simulations, quizzes, and case studies to assist students in understanding abstract concepts in Differential Equations course. This e-module is expected to increase students' active involvement and provide a more meaningful learning experience. The novelty of this research lies in the integration of technology in a complex mathematics learning process, which has not been done much in previous studies.

Keywords: Critical Thinking Skills, E-modules, Differential Equations, Interactive Learning, TPACK

A. Introduction

Higher education has a great responsibility in preparing students to face global challenges, especially in the Society 5.0 era which emphasizes the importance of critical thinking skills. This skill is very important because it helps students in analyzing, evaluating and solving complex problems (Azizuddin & Hossain, 2020; Prihanto et al., 2018). However, students' critical thinking skills in various fields of study, including mathematics, are still low. Courses such as Differential Equations, which contain abstract concepts, are often a big challenge for students (Prihanto et al., 2018). Students need more than just theoretical understanding; they need strong critical thinking skills to succeed in these courses (Seventika et al., 2018).

Teaching mathematics in higher education tends to focus on theoretical approaches, which often do not provide enough space for the development of students' critical thinking skills. Traditional teaching methods that predominantly use printed books have also not been able to provide interactive and meaningful learning (Kimianti & Prasetyo, 2019). In complex courses such as Differential Equations, a more flexible learning approach is needed, where students can interact with the content in more depth.

Along with the development of technology, the world of education now has a great opportunity to integrate digital technology into learning. E-modules, as technology-based teaching materials, offer a dynamic solution that is more interactive than printed teaching materials. E-modules can help students develop critical thinking skills through various interactive media, such as simulations and quizzes that are relevant to the learning material (Raharjo & Lestariningsih, 2018). This technology also makes it easy for students to learn independently and at their own pace.

Integrated educational technology through e-modules allows students to get a more in-depth and meaningful learning experience. E-modules can be accessed anytime and anywhere, thus providing flexibility in the learning process (Beldarrain, 2007). This is very beneficial in learning mathematics which often requires additional time for students to really understand abstract concepts such as Differential Equations. Therefore, an interactive and well-designed e-module can be a very effective tool in improving students' critical thinking skills.

The main problem faced in learning Differential Equations is the low critical thinking skills of students. Based on a preliminary study conducted on 20 students at Universitas Muhammadiyah Makassar, the results show that students' critical thinking skills in the aspects of evaluation and inference are still very low (Seventika et al., 2018). The lack of these skills suggests that existing teaching methods have not been successful in helping students develop these abilities. One common solution that can be applied to improve critical thinking skills is to integrate technology into learning. Technology allows for more interactive learning and gives students the opportunity to be more involved in the learning process. E-modules, as a form of digital teaching materials, have great potential in creating a learning environment that supports the development of critical thinking skills (Beldarrain, 2007; Sachdeva & Eggen, 2021).

The specific solution proposed in this research is the development of meaningful e-modules integrated with the Technological Pedagogical Content Knowledge (TPACK) framework. This e-module will be designed with interactive elements such as simulations, quizzes, and case studies that can help students think critically and understand the Differential Equations material more deeply (Koehler et al., 2017; Mishra & Koehler, 2006). In addition, the module will be accompanied by a self-study

guide that encourages students to develop their interpretation, analysis, evaluation, and inference skills (Ennis, 2011; Facione, 1994).

The module will not only present learning content passively, but will also encourage students' active involvement in the learning process. Through various interactive activities designed to trigger reflection and analysis, students will be encouraged to develop the critical thinking skills needed to solve complex mathematical problems. This e-module is expected to be an effective tool in improving students' critical thinking skills in Differential Equations courses.

Previous research shows that the use of TPACK-based e-modules in learning has provided positive results in improving students' critical thinking skills and learning motivation (Wijayanto et al., 2023). For example, (Sobari, 2024) found that technology-integrated e-modules can increase student engagement and facilitate more interactive learning. However, specific studies on the development of meaningful e-modules in mathematics courses, especially Differential Equations, are still limited. Therefore, this research aims to fill the gap and provide new contributions in the development of more relevant and effective teaching materials.

This research aims to develop meaningful e-modules integrated with the TPACK framework, designed to improve students' critical thinking skills in Differential Equations course. The novelty of this research lies in the development of teaching materials specifically focused on complex courses, as well as the integration of interactive technology that allows students to be actively involved in the learning process. This e-module is expected to provide a more meaningful and relevant learning experience for students in today's digital era (Mishra & Koehler, 2006).

B. Methods

This research uses the needs analysis method as the initial stage in the development of meaningful e-modules for Differential Equations courses integrated with the TPACK framework. The needs analysis aims to identify gaps between current conditions and expected ideal conditions, especially in terms of technology use and the development of students' critical thinking skills. This stage is very important to ensure that the development of e-modules is in accordance with the needs of students and lecturers, and is able to achieve the learning objectives set. This research ensures that the e-modules developed are truly relevant to the real conditions faced by students and lecturers in learning Differential Equations. This needs analysis also provides a strong basis for the development of modules that fit the TPACK framework, which integrates technology, pedagogy, and content effectively. The following are the results of the needs analysis related to the development of meaningful e-modules for the Differential Equations course:

1. Field Study and Learning Process Analysis: Researchers conducted a field study to analyse the learning process by directly observing the use of teaching materials in the classroom. The results of this observation were used to identify improvements needed to create a more conducive learning environment. This analysis revealed that the use of conventional textbooks is still less effective in facilitating interactive learning that can support the development of students' critical thinking skills.
2. Analysis of Teaching Materials: Through a questionnaire given to students, an evaluation was made of the suitability of the teaching materials used with the curriculum and learning needs. The analysis showed that the materials lacked depth and did not fully support the competency achievements expected in the curriculum. In addition, the materials are not interactive enough to increase student engagement.
3. Student Needs Analysis: Conducted using the Student Analysis Questionnaire (LAAM). From the survey results, it was found that students find it difficult to understand the concepts taught in the Differential Equations course. They also have limitations in critical thinking and lack of resources that can help them learn independently. In this case, the proposed e-module is expected to address these issues by providing interactive and in-depth teaching materials.
4. Literature Analysis: An analysis of the academic literature was conducted to ensure that the developed e-module is relevant to the latest trends in digital learning. The reviewed literature also helps to identify effective e-module design principles, including the integration of the TPACK framework that enables the development of e-modules that combine technology, pedagogy, and content.

The results of this needs analysis stage will be the basis in designing meaningful e-modules integrated with the TPACK framework. The e-modules developed must be able to answer the needs of students and lecturers, both in terms of content, technology, and pedagogy. In addition, the results of this analysis will also be used to determine the interactive features that will be included in the module, such as simulations, quizzes, and visual materials that support the understanding of complex concepts. Thus, the resulting e-module is expected to improve students' critical thinking skills and provide a more meaningful learning experience.

C. Results and Discussion

In the needs analysis stage for the design of meaningful e-modules integrated with the Technological Pedagogical Content Knowledge (TPACK) framework, this study identified several main problems faced by students and lecturers in the learning process of Differential Equations course. The results of the needs analysis obtained through observations, interviews, questionnaires, and literature studies revealed the main challenges, namely the lack of interactivity in the teaching materials used and the low critical thinking skills of students. This leads to an urgent need to develop e-

modules that are interactive and in accordance with technological developments. Findings from the Needs Analysis were below.

Students today face increasingly complex learning challenges, especially in developing critical thinking skills needed in the digital information age and 21st century learning. Teaching materials used in learning, such as traditional printed books, are considered inadequate to support an active, independent learning process, and orientated towards the development of higher order thinking skills. Students need more interactive and technology-based teaching materials to answer this challenge. Conventional teaching materials, such as printed books, often do not provide interactive features that allow students to be actively involved in the learning process. This causes students to be more passive, only receiving information without processing or analysing it critically. In addition, printed books do not support flexibility in learning, which is one of the important needs for students in the digital era. This need is in line with the findings of (Kimianti & Prasetyo, 2019), which show that traditional teaching materials are not effective enough to support the development of critical thinking skills, which is one of the key competencies in 21st century learning. With these limitations, there is an urgent need to develop teaching materials that are technology-based, interactive, and support active learning.

Based on observations and interviews with lecturers, it was revealed that most of the teaching materials used in the learning process in higher education have not been integrated with digital technology. This is an obstacle in aligning teaching materials with modern curriculum developments that demand the use of technology to support a more interactive and effective learning process. Many lecturers reveal that they have difficulty finding teaching materials that are in accordance with the curriculum that are also able to utilise technology as a learning tool. This situation indicates an urgent need to provide teaching materials that can integrate digital technology into the teaching-learning process. In the context of higher education, the use of technology-based interactive e-modules becomes very important, as highlighted by Dexter, (2023).

Technology-integrated interactive e-modules not only facilitate lecturers in delivering curriculum-relevant materials, but also play a major role in increasing student engagement and motivation to learn. The existence of teaching materials that do not fully support the integration of technology has an impact on the low motivation of students and their involvement in the learning process. In contrast, technology-based teaching materials are able to create a more dynamic and interesting learning experience, which in turn can significantly increase student engagement. Through interactive e-modules, students can access richer information, interact with content directly, and learn in a more independent way.

The questionnaire results show that students have low critical thinking skills, especially in the aspects of interpretation, analysis, evaluation, and inference. The low

ability in these aspects indicates that students face difficulties in solving problems that require logical and critical thinking. This is a serious challenge, especially in courses that rely heavily on critical thinking skills such as Differential Equations. As stated by Facione (1994), critical thinking skills are an essential element in solving complex problems, especially in the field of mathematics. This gap in critical thinking skills requires a new approach in the preparation of teaching materials, especially modules that are more focused on developing these skills. The designed module should specifically include relevant exercises and be designed to improve students' ability in this aspect:

1. Interpretation: Training students in understanding and explaining concepts or data they encounter, especially in a mathematical context.
2. Analysis: Strengthening students' skills in breaking down complex problems into smaller, more understandable parts and recognising relationships between concepts.
3. Evaluation: Helps students assess arguments or solutions with logical and evidence-based criteria.
4. Inference: Encouraging students to make appropriate conclusions based on available data or information, as well as being able to consider the implications of the conclusions drawn.

Exercises provided in the module should focus on real problems that require critical and logical thinking, such as case-based problems or applications of Differential Equations in real-world contexts. This will enable students to not only understand the concepts theoretically, but also be able to apply them in solving relevant problems.

Students in the digital era need flexible teaching materials, which allow them to learn anytime and anywhere, and can be adjusted to the learning speed of each individual. This is becoming increasingly important given the characteristics of students who have varying schedules and learning speeds. Conventional teaching materials, such as printed books, do not provide this flexibility and adaptivity, so they are unable to accommodate individual learning needs optimally. E-modules designed with accessibility and adaptivity features offer an ideal solution to this need. As shown in Mai & Giang (2019) research, educational technology, including interactive e-modules, can facilitate independent and adaptive learning, allowing students to learn according to their learning style and pace. This is very important in improving learning effectiveness, because each student can access teaching materials according to their needs and time availability. Considering the questionnaire results that show this need for flexibility, the development of an interactive e-module that can be accessed flexibly and adaptively is an appropriate solution to improve student engagement, motivation and learning outcomes. It also enables students to develop self-learning skills that are essential for their success in lifelong learning.

Based on the results of the needs analysis, it is important to develop an e-module integrated with the TPACK framework. The module is expected to not only passively present teaching materials, but also encourage students' active participation through the use of technology, pedagogy, and well-structured content. Technology integration in e-modules has been shown to increase student engagement and learning effectiveness. In this research, technology will be used to provide various media such as simulations, videos, interactive quizzes, and animations that help students understand abstract concepts in Differential Equations. The use of technology in education, as stated by Serrat et al. (2014), can increase learning motivation and provide a richer learning experience.

In addition, the TPACK framework used in the development of this e-module allows lecturers to integrate technology with appropriate pedagogical strategies, so that learning becomes more meaningful and relevant to students' needs. TPACK provides a foundation for lecturers to select and develop technology-based learning tools that can support students' content mastery and critical thinking skills (Mishra & Koehler, 2006).

In terms of critical thinking, this research emphasizes the importance of developing modules that can encourage students to think analytically, evaluate information, and draw conclusions logically. The designed module should direct students to work on tasks that require continuous interpretation, analysis, evaluation, and inference. This is in line with Facione (1994) research which states that critical thinking is an important ability that must be developed in higher education.

D. Conclusions

From the results of this analysis, it is concluded that it is very clear that there is a need to develop e-modules specifically designed for Differential Equations courses, which are able to integrate technology, pedagogy, and content. This e-module should be interactive, flexible, and designed to support the development of students' critical thinking skills. The use of the TPACK (Technological Pedagogical Content Knowledge) framework will be an ideal solution in meeting these learning needs. This e-module is expected to not only present learning content passively, but also be able to encourage active student engagement through interactive activities designed to hone interpretation, analysis, evaluation, and inference skills. The module should also provide various media, such as simulations, videos, interactive quizzes, and visualisations, which can facilitate students' understanding of abstract concepts in Differential Equations.

The use of the TPACK framework allows lecturers to effectively integrate technology with appropriate pedagogical strategies, so that learning becomes more meaningful and relevant to the needs of students in this digital era. TPACK-based e-modules are

also expected to help increase students' learning motivation by providing a dynamic, engaging, and collaborative learning experience, in line with recommendations from recent literature.

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