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DEVELOPMENT OF A TPACK-BASED E-MODULE TO SUPPORT STUDENTS' MATHEMATICAL LITERACY SKILLS

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Abstract

Mathematical literacy is very important in the industrial era 4.0, but international surveys such as PISA show that Indonesian students have poor mathematical abilities. Therefore, new teaching materials are needed. Developing a TPACK-based e-module to promote mathematical literacy is the goal of this study. A 4D development model—define, design, develop, and disseminate—is used in the study. Analyzing learning demands is part of stage define, and designing technology-based e-modules is part of stage design. Following validation by specialists in language, media, and materials, the develop stage produces an e-module that is prepared for testing through adjustments based on validator suggestions. The disseminate stage involves limited testing and distribution to students. Researchers used descriptive analysis techniques in processing the data obtained. The validation results show that the e-module is very valid with a score of 95% for language, 92% for media, and 100% for material. Teacher responses were in the " Highly good" category (95%), while student responses were in the "good" category (73%). This research proves that TPACK-based e-modules are effective in supporting learning, providing solutions to improve students' mathematical literacy, and are relevant for application in technology-based learning.

Keywords: E-Module; literacy; Mathematics; Development; TPACK

INTRODUCTION

The development of students' thinking abilities is closely related to mathematics learning. Mathematics learning plays a crucial role in shaping an individual's thinking character. Bruner (1966) argued that mathematics learning plays an important role in developing abstract and logical thinking abilities. He stated that the goal of mathematics education is not just to master arithmetic skills but also to help students understand concepts more deeply, which form the foundation for creative and innovative thinking patterns. Boaler (2016) stated that mathematics learning can develop critical thinking skills and creativity, as well as help students face challenges with more confidence and without fear of failure. Therefore, it can be concluded that the goal of mathematics education is to develop logical, rational, critical, creative, systematic, and practical thinking patterns. However, these goals have not been fully realized. This remains a challenge, considering that students have been learning mathematics since elementary school (Surat, 2016).

The five components that encompass the standards of mathematics learning processes are problem-solving ability, connections, communication, reasoning, and representation (NCTM, 2020). To meet these components, it is necessary to be accompanied by students' mathematical literacy, as mathematical literacy is very important in preparing students to face various problems (Kusumawardani et al., 2018). The capacity to apply mathematical ideas in various real-world contexts is another aspect of mathematical literacy, which goes beyond just simple arithmetic skills. According to Dinni (2018) research, the ability to comprehend, evaluate, and interpret mathematical information so that pupils can form sound conclusions is known as mathematical literacy. It is desired that students will be able to think critically and creatively when presented with difficult and unstructured problems.

Students must have mathematical literacy abilities, particularly in the age of Industry 4.0, when technology is used for everything (Baiduri, 2019). Students are expected to apply mathematical literacy and its concepts effectively, both in academic environments and in daily life (Lively & Machromah, 2024). According to Putra, et al. (2016), mathematical literacy among students in Indonesia is still at a low level. This is reflected in the results of various international surveys, such as PISA (Programme for International Student Assessment). Based on the 2015 PISA results in mathematics, out of 69 countries participating in the test, Indonesia ranked 63rd (Pratiwi, 2019). The PISA test results prove

that many Indonesian students struggle with solving problems that require a deep understanding of mathematical concepts and creative application in everyday life situations. The dearth of modules that can foster the growth of critical and creative thinking abilities is one of the elements behind the low level of mathematical literacy.

Both within and outside of the classroom, modules are crucial to the learning process (Herawati & Muhtadi, 2018). As teaching materials, modules play a crucial role in supporting students to learn independently or in groups. Modules allow students to learn at their own pace, encourage active participation in the learning process, and provide more focused and effective feedback for students (Sudjana, 2017). In the age of Society 4.0, digital tools and technology play a critical role in helping students reach their full potential. Teachers might leverage the increasing usage of technology as an alternative in the classroom. Teachers can create learning media and modules as teaching resources for students by leveraging technology and digital media (Rahmadhani et al., 2021). Therefore, the growing development of e-modules today has become a breakthrough for educators in supporting student learning.

Students' mathematical literacy can be improved through the creation of e-modules. Research conducted by Rizqiyani, et al. (2022) shows the need for useful and efficient e-modules as well as materials that enhance mathematical literacy. The creation of this mathematics learning e-module, according to Widiantari, et al. (2022), is a solution to provide relevant teaching materials in the form of electronic modules that meet the learning needs in the era of Society 4.0, thus enabling access to learning even when students are not in the classroom.

The utilization of e-modules, which are accessible via electronic devices such as smartphones, laptops, computers, tablets, and similar tools, significantly enhances students' learning experiences. Supporting this, a study conducted by Susanto & Susanta (2022), highlights the effectiveness of e-modules in the learning process. Their research demonstrates that students using e-modules exhibit a higher improvement in mathematical literacy compared to those who do not. The post-test results revealed that students who used e-modules achieved an average score of 81.25, while those who did not scored an average of 62.91.

Based on the aforementioned issues, the researcher aims to design a TPACK-based e-module with the following objectives: (1) to develop a TPACK-based e-module that

supports students' mathematical literacy on the topic of the System of Three-variable Linear Equations for grade X students at MAN Kota Mojokerto, and (2) to evaluate the feasibility and effectiveness of the TPACK-based e-module on the same topic for grade X students at MAN Kota Mojokerto.

METHODS

This study is a type of development research, namely R&D (Research and Development). This research focuses on the creation of teaching modules as the final product, which will then be evaluated for its effectiveness. In order for the module to be a useful tool in the learning planning process, it must be thoroughly examined based on the findings of the needs assessment. It is expected that this module will function well in the Senior High School educational environment. The goal of this project is to create a TPACK (Technological Pedagogical Content Knowledge)-based e-module that will help students improve their mathematical literacy.

The research was conducted at MAN Kota Mojokerto over the course of one month. The study was carried out during the odd semester of the 2024/2025 academic year, specifically 4 - 22 November 2024. The subjects of the research, who were used to test the product's use, were the mathematics teacher of grade X and the grade X students of MAN Kota Mojokerto. The initial design refers to the 4D research and development model (Define, Design, Develop, Disseminate), as shown in Figure 1

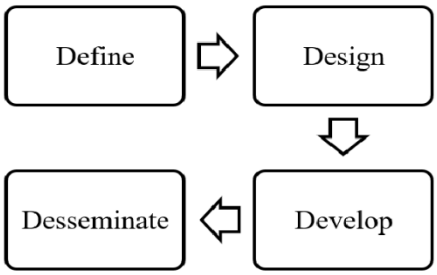

Figure 1. The Research Flow of The 4D Method.

In the first step, Define, a needs analysis is conducted, which includes an initial analysis of students, the curriculum, and the establishment of learning objectives, with a focus on integrating technology to enhance mathematical literacy. The second stage, Design, involves the development of the e-module with a focus on technology, pedagogy, and mathematical content. This design also includes selecting technology-based learning

resources and determining learning methodologies that can be applied in daily life. In the third step, *Develop*, the e-module is created as a tangible product and undergoes validation by three experts: a language expert, a subject matter expert, and a media expert. This approach includes expert assessments, which result in recommendations to improve the provided learning tools. The tools are then modified based on the experts' suggestions. After validation, modifications are made to refine the e-module. The final stage, Disseminate, involves limited trials with teachers and students. This research is expected to result in an e-module that effectively enhances students' mathematical literacy skills, while also offering suggestions to teachers on how to integrate technology, pedagogy, and mathematical content.

The tools utilized in this study include an expert validation sheet and a student response questionnaire. The validation sheet was designed by three experts: a media expert, a language expert, and a subject matter expert. Descriptive-analytic techniques were employed to evaluate the module's validity. The proportion of the validated e-module is presented in Table 1.

Table 1. Percentage of Validity Level of TPACK-Based E-Module

Percentage	Category
$80\% < x \leq 100\%$	Highly Valid
$60\% < x \leq 80\%$	Valid
$40\% < x \leq 60\%$	Adequate
$0\% \leq x \leq 40\%$	Invalid

(Sudjana, 1995)

Alongside the validation test, the researcher distributed questionnaires to teachers and students to gather objective feedback. These responses were utilized to evaluate the alignment of learning activities for both students and teachers with the provided questionnaire. The percentage of teacher and student responses is presented in Table 2.

Table 2. Percentage of Teacher and Student Responses

Percentage	Category
$81\% \leq x \leq 100\%$	Highly Good
$61\% \leq x \leq 80\%$	Good
$41\% \leq x \leq 60\%$	Adequate
$21\% \leq x \leq 40\%$	Poor
$0\% \leq x \leq 20\%$	Highly Poor

(Riduwan, 2012)

RESULTS

The 4D research methodology was used in this work to create a TPACK-based e-module that supports students' mathematical literacy. The four phases of the 4D research model's development are definition, design, development, and dissemination. The researcher selected the System of Three-variable Linear Equations topic for the developed TPACK-based e-module because it can help students improve their mathematical literacy.

Stage I Define

In this stage, the researcher will define or identify the problems in students' learning. After the problems are identified, the researcher will provide effective solutions that can be applied in the learning process. The researcher analyzes four aspects in the problem definition stage, which are Front-End Analysis, Learner Characteristics Analysis, Task Analysis, and Concept Analysis.

Front-End Analysis is the initial step in creating a product that can meet the learning needs. The researcher will determine the problems, needs, and objectives of the product development. The researcher observes the learning problems during the pre-observation activities, supported by three months of teaching assistance experience. Several issues were found in students' mathematical understanding during the learning process. Learning that only uses books as modules is one of the factors causing students to struggle in understanding the lessons. The assignment of tasks that do not provide prior knowledge also affects students' mathematical understanding. Students are sometimes confused when given problems in the form of real-life story problems. The researcher concludes from these issues that students' mathematical literacy is still lacking, thus requiring a module that can support students' literacy.

Analyzing learner characteristics comes next. Every kid has a unique learning style, according to the researcher's findings made at MAN Kota Mojokerto. While some students prefer to move around during class, others pay little attention to the teacher's explanations, while still others are highly attentive and engaged when the teacher presents the content. Nonetheless, during the learning process, the students share a shared understanding. When learning films are used to illustrate the content, students find it easier to understand. To aid pupils in understanding the course, a module that has access to video learning materials is therefore required.

The third stage is Task Analysis. The assignments given to the students are in accordance with the independent curriculum policy. Students will be given problems and will analyze concepts based on the material being taught, which is the System of Three-variable Linear Equations. The assignments are aligned with Learning Achievement and Learning Objectives. Each problem provided also has indicators developed through the CP and TP material on the System of Three-variable Linear Equations.

Concept Analysis is the final stage of problem analysis. The concept in learning refers to Learning Achievement and Learning Objectives in the algebraic elements of phase E. The learning achievement is that students should be able to solve problems related to systems of three-variable linear equations and systems of two-variable linear inequalities. Students should be capable of solving problems involving quadratic equations and functions (including imaginary roots), exponential equations (based on equivalence), and exponential functions. Accordingly, the learning objectives are as follows: (1) Students are able to model problems into a system of three-variable linear equations, and (2) Students are able to solve contextual problems related to systems of three-variable linear equations.

Stage II Design

The researcher uses the second step, also known as the design stage, to develop solutions based on the learning challenges and findings from the analysis conducted in the first stage. In this stage, the researcher performs several planning activities, including the selection of media to be developed according to the research needs, choosing the concepts and format of the media in line with students' characteristics, and designing the product to make the learning process more engaging for students. Three elements are included in the validation sheet that the researcher creates: the media, the content, and the language. The researcher performs this validation to make sure the module is more suitable for use in the educational process. The developed module can be referred to as an e-module because it integrates information technology to make it more engaging and interactive.

The issues that were examined in the earlier phase served as the basis for the development of the e-module. Because students need to become more tech-savvy in the Industry 4.0 age, the e-module is also built on TPACK. To facilitate the construction of the TPACK-based e-module, a number of platforms and media are available to support the e-module. Table 3 lists a few of the media and platforms that were utilized in the creation of the e-module.

Table 3. Platforms and Media Used in the Development of TPACK-Based E-Modules

Platform	Description
Heizine	Main Platform for Developing TPACK-Based E-Modules
Microsoft Word	Platform that assists in creating the framework for TPACK-based e-modules
Youtube	Platform that supports video presentation to make learning easier for students to understand
Internet	Access for searching images as learning resources

The researcher chooses the design offered in the TPACK-based e-module after identifying the media and platforms that facilitate TPACK-based development. Table 4 will display the design that is displayed in the product.

Table 4. Designs Presented in the TPACK-Based E-Module

Design	Description
File Type	A web-based platform that can be accessed through a browser on various devices
Material	System of Three Linear Equations
Language	Indonesia
Font Type	Times New Roman
Size	Paper Size: 21 x 29,7 cm (A4) Font Size: 12-18
Appearance	1. Cover 2. Preface 3. Table of Contents 4. Glossary 5. Concept Map 6. Introduction 7. Presentation of Material 8. Evaluation 9. Bibliography
Source	Every resource within the TPACK-based e-module is registered with copyright.

The design display of the TPACK-based e-module developed using the Heyzine platform is presented in Figure 2.

Figure 2. Cover of the TPACK-Based E-Module

Stage III Develop

The development stage aims to produce a refined TPACK-based e-module based on input from experts and the results of trials with students. This process involves three main steps: preparing product assessment instruments designed for validation testing, conducting the e-module validation test which is submitted to language, media, and subject matter experts to assess the quality and suitability of the module in meeting effectiveness standards. A revision process is carried out to refine the TPACK-based e-module based on the notes and recommendations from the validators. The final result is a TPACK-based e-module that has been adjusted according to expert input and is ready for use. The validation results can be seen in Table 5.

Table 5. Expert Validation Results

Type	Results
Media	92%
Language	95%
Material	100%

Table 5 indicates that the subject material expert provided a validation score of 100%, the media expert scored 92%, and the language expert scored 95%. The e-module satisfies the "very valid" requirements based on all of these values. All of these findings demonstrate how extremely valid the TPACK-based e-module is for use with students.

Stage IV Disseminate

The final stage of this research is the dissemination to students. The implementation of the TPACK-based e-module was conducted with grade X students of MAN Kota Mojokerto during the learning of the System of Three-variable Linear Equations. The distribution was carried out through a QR Code link provided to the students. The QR Code link shared with the students is shown in Figure 3.

Figure 3. QR Code Link for TPACK-Based E-Module

There are several reasons why the dissemination of the TPACK-based e-module was only conducted in grade X at MAN Kota Mojokerto:

1. This TPACK-based e-module only presents the material on the System of Three-variable Linear Equations that is taught to grade X students.
2. The time limitations faced by the researcher is one of the factors restricting the distribution.
3. The financial constraints the researcher had during the research process.

Both the teacher and students provided positive feedback on the TPACK-based e-module, even though its dissemination was limited to grade X at MAN Kota Mojokerto. By distributing a questionnaire to the instructor and students, the researcher was able to obtain this positive feedback. Table 6 displays the results of the teacher's responses.

Table 6. Teacher Response Results

Aspects	**Percentage**	**Category**
Product Use	100%	Highly Good
Learning Content	93%	Highly Good
Media Components	93%	Highly Good
Mean	**95%**	Highly **Good**

From the table above, it can be concluded that the teacher's response to the TPACK-based e-module is categorized as *Highly Good* for implementation.

In addition to the teachers, students also provided positive feedback regarding the TPACK-based e-module. The results of the students' responses are presented in Table 7.

Table 7. Student Response Results

Aspects	Percentage	Category
Practicality of the E-Module	73%	Good
Effectiveness of the E-Module	73%	Good
Mean	**73%**	**Good**

Based on Table 7, it can be concluded that the students' response to the TPACK-based e-module falls into the good category for implementation.

DISCUSSION

The research developed a TPACK-based e-module aimed at addressing students' mathematical literacy problems on the material of the System of Three-variable Linear Equations. The TPACK e-module product was created using the Heyzine Platform, which is currently available on the internet. The development of the product required validators who are experts in their fields, such as language experts, content experts, and media experts. This is in line with the research by Sary & Isnawati (2023), which found that product creation requires the involvement of language experts, content experts, and media experts for product verification. A validation procedure is necessary to obtain comments and feedback from experts. The research conducted by Syamsuddin, et al. (2024), states that feedback from validation experts can improve the quality of the product we are developing.

After the validation process, the TPACK-based e-module was distributed to students. The distribution was conducted with grade X students at MAN Kota Mojokerto. Both the teacher and students provided very positive responses, as seen from the questionnaires given to the teacher and students. The teacher's questionnaire showed a 95% response rate, which falls under the " Highly good" category. Meanwhile, the student questionnaire showed a 73% response rate, which falls under the "good" category. The results of the questionnaires indicate that the TPACK-based e-module can effectively support students' mathematical literacy.. This is supported by research conducted by

Tamur & Pantaleon (2023) on e-modules that are able to support students' mathematical literacy skills, proven by the high student response rate of 92.8%. Nanthi & Mutaqin (2023) The development of the e-modules also proved effective in enhancing mathematical literacy skills, as demonstrated by the N-Gain test showing a value of 0.56, indicating moderate improvement. The above explanation shows that innovative learning media is crucial in improving students' mathematical literacy. This aligns with the research by Ulum, et al. (2024), which states that improving mathematical literacy requires learning tools that support the learning objectives themselves.

CONCLUSION

Based on the research findings, the e-module has been refined through a validation and revision process based on input from experts and feedback from teachers and students. The development process includes the preparation of assessment instruments, the implementation of validation tests by language, media, and content experts, as well as improvements based on the recommendations of the validators. The validation results from the experts indicate that the e-module has a very high validity level, with language validation at 95%, media at 92%, and content at 100%. Overall, the e-module is deemed "very valid" and suitable for use in teaching. Additionally, the response from teachers showed a percentage of 95%, while the response from students reached 73%. These results indicate that both the teacher and student responses to the e-module fall into the "good" category.

A suggestion for future researchers is to test the effectiveness of the TPACK-based e-module in improving students' mathematical literacy, as this study did not reach the effectiveness testing phase. Future researchers may also consider measuring learning outcomes or students' learning motivation after using the TPACK-based e-module.

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