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# Development of TPACK-based e-Modules for Pre-service Mathematics Teacher Using Successive Approximation Model

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**Abstract**

The purpose of this research was to develop valid and practical TPACK-based e-modules for prospective mathematics teachers. The development uses the SAM model which provides a systematic and iterative approach consisting of 3 phases, i.e., preparation, iterative design, and iterative development. The research was conducted at Universitas Samudra with the development of an e-module on one of the differential equation materials, namely homogeneous differential equations. Modules are designed using flipbooks, integrating material, problem solving exercises, and ending with project students compiling instructional designs on material mathematics. The results of the assessment by the validator team (consisting of material experts, linguists and media experts) obtained 82.22% for the level of validity, with a very decent category. On the other hand, the average student response regarding the practicality of the e-module is at 87.01 in the very practical category. Thus, the e-module on TPACK-based differential equation material is feasible and practical for use by pre-service mathematics teachers at Universitas Samudra.

**Keywords:** e-Module, Pre-services teacher, SAM, TPACK

## 1. Introduction

The rapid development of digital technology has significantly transformed learning practices in higher education. Although digital resources such as e-modules have been widely used and proven to enhance student engagement and learning outcomes, many of these resources still focus primarily on content delivery without effectively integrating pedagogical strategies and technological affordances. Technology is constantly evolving, having a significant impact on various aspects of life, including formal education (Nugroho Yanuarto, Mistima Maat and Husnin, 2021). On the other hand, changes triggered by outbreaks due to pandemics have changed the pattern of learning activities. Even though the pandemic is over, there are a number of things that can continue, such as online, hybrid and mixed learning (Fuchs, 2022; Shamail and Chitale, 2022). One form of technological progress that has been widely used in the learning process during the pandemic is the use of e-modules (Nova *et al.*, 2023). Advances in technology have made it possible to use e-modules as effective learning media (Blancaflor *et al.*, 2022; Kamsin *et al.*, 2022), further interactive e-modules can be utilized as learning media in the digital era (Keator, 2020). Likewise, research by Samir Abou El-Seoud et al (2014); Greyling *et al* (2020) in his research stated that e-modules can improve mastery of material and student learning outcomes.

Despite their potential, many e-modules are not designed to support higher-order teaching competencies, particularly in integrating technology into pedagogically meaningful mathematics instruction. In addition, research by Sofroniou (2020) concluded that interactive e-modules are a learning medium that has many benefits. Furthermore E-Modules can help teachers to increase their understanding of technology and the pedagogical skills needed to integrate technology in learning. This indicates a critical gap: the availability of technology does not automatically lead to effective teaching practices. Pre-service teachers often lack the ability to integrate technology, pedagogy, and content in a coherent manner.

Talking about the goals to be achieved in pedagogical content knowledge (PCK) mastery learning activities for prospective teacher students is one of the central themes in teacher education research (Shulman, 1986, 1987; Prasart, 2011). A pre-service teacher must master knowledge about teaching techniques, how relevant learning techniques are, and how to apply learning strategies. Of course, this mastery needs the support of other aspects, one of which is content knowledge. In mathematics teacher education, the development of Pedagogical Content Knowledge (PCK) and Mathematical Knowledge for Teaching (MKT) is essential (Ball, Hill and Bass, 2005; Ball, Thames and Phelps, 2008). However, in the digital era, these competencies need to be extended to include technological integration, which is conceptualized in the TPACK framework.

Although TPACK has been widely recognized as a crucial framework, many existing learning resources, including e-modules, do not explicitly operationalize TPACK components into concrete instructional design. As a result, pre-service teachers have limited opportunities to develop integrated knowledge through authentic learning experiences.

To address this gap, this study develops a TPACK-based e-module that explicitly integrates technological tools, pedagogical strategies, and mathematical content into a unified design. The novelty of this study lies in how TPACK components are operationalized through interactive multimedia, problem-solving activities, and project-based tasks that require students to design technology-integrated lesson plans.

Therefore, this study aims to: (1) develop a valid and practical TPACK-based e-module for pre-service mathematics teachers; (2) describe how TPACK components are operationalized within the e-module design; and (3) evaluate the practicality of the e-module in supporting student learning.

## 2. Methods

This study employed a research and development (R&D) approach using the Successive Approximation Model (SAM). The participants consisted of 23 undergraduate students enrolled in a Differential Equations course at Universitas Samudra. The sampling technique used was purposive sampling, as participants were selected based on their relevance to the study objectives. with the subject of research on mathematics education students at Universittas Samudra, Langsa, Aceh Indonesia. The subjects attended lectures on differential equations. The model used in this study is the SAM (Successive Approximation Model) model involving three main stages: planning, development, and evaluation. Adopted from (Allen and Sites, 2012), where the concept was also adopted by other researchers (Wintarti, Abadi and Fardah, 2019; Ali, 2021; Wolverton and Guidry, 2022), the scheme of the SAM used is as follows

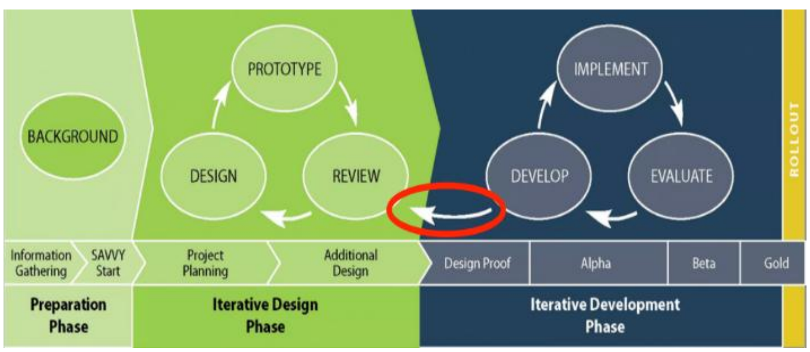


Fig. 1. Successive Approximation Model.

The following describes the SAM process that used:

1. Preparation Phase:

The process begins with an initial evaluation or analysis carried out to identify needs, formulate learning objectives, and learning contexts. This evaluation is carried out by analyzing teaching materials and semester lecture plans (RPS) against the learning objectives to be achieved.

2. Iterative Design Phase:

After the initial evaluation is done, the design phase begins. At this stage, instructional planning is carried out by formulating specific learning objectives and designing appropriate learning strategies to achieve these goals. In design, technology and media are also determined to be used in developing E-Modules, learning objectives are designed according to curriculum developments and student needs, learning strategies are carried out online by utilizing interactive e-modules, e-module designs using the help of the Flipbook Maker Pro application . Flipbook maker is software for making modules that can be integrated with various media, such as images, videos and animations (Dianawati and Suputra, 2022).

3. Itertive Development Phase:

Once the design is complete, the development phase begins. At this stage, the E-Module is created based on a predetermined design, this serves as the basis for further development . E-Module development includes content creation, using a multimedia approach and integrating TPACK with learning content and technology used in e-modules.

The data were analyzed qualitatively and quantitatively in the form of suggestions and input from the validator and research subjects, quantitatively the data were categorized based on the validity of the expert validator and practicality by students. The following are the criteria and indicators for assessing material experts, language experts and media experts.

The instruments were reviewed by experts to ensure content validity, and reliability analysis using Cronbach's alpha was conducted to assess internal consistency.

Table 1: Aspect of Validity Assesment

| | **Assessment aspect** | **Criteria** | **Indicator** |
|---|---|---|---|
| 1 | Material Expert Validation Sheet | Content (30%) | a. Compatibility with learning objectives<br>b. Completeness and concepts presented<br>c. Linkage with curriculum and competency standards |
| 2 | Material Expert Validation Sheet | Organizational Structure (25%) | a. Arrangement of well-structured information<br>b. Use of subsections, headings, or charts to make navigation easier<br>c. The order of the material is logical and easy to follow |

| | | | |
|---|---|---|---|
| 3 | Linguist Validation Sheet | Text readability and alignment (10%) | a. The use of language that is clear and easy to understand<br>b. Consistent use of fonts, sizes and styles<br>c. Correct spelling, grammar, and author errors |
| 4 | Media Expert Validation Sheet | Engagement Interactivity (20%) | a. The use of interactive media (images, videos, animations) that support learning<br>b. Activities or exercises that encourage the active involvement of participants<br>c. Use of questions or tasks that stimulate critical thinking |
| 5 | Media Expert Validation Sheet | Visual Quality (15%) | a. Attractive and easy to read layout<br>b. Appropriate use of colors and graphics<br>c. Page design consistency |

The aspect of the validator expert's assessment of the product is used to measure the feasibility of the e-module that has been developed and adapted to the material, the assessment criteria are using a Likert scale as shown in the following table:

Table 2: Assessment criteria Validator Expert

| Score | Information |
|---|---|
| 1 | Totally diasgree |
| 2 | Don't agree |
| 3 | Simply agree |
| 4 | Agree |
| 5 | Strongly agree |

The results obtained are then calculated to obtain an average percentage score using the following formula:

P=$55\% \times \sum x + 10\% \times \sum y + 45\% \times \sum z$

Where:

P = Percentage

$\sum x$= average score of material experts

$\sum y$= average score of linguists

$\sum z$= average score of media experts

Furthermore, the feasibility of the e-module can be analyzed through the results of the percentage of material experts, media experts and linguists with criteria such as the following table:

Table 3 Criteria of Evaluation

| No | Evaluation | Criteria |
|---|---|---|
| 1 | $81 \leq \bar{x} \leq 100$ | Very Worth it |
| 2 | $61 \leq \bar{x} < 81$ | Worthy |
| 3 | $41 \leq \bar{x} < 61$ | Simply agree |
| 4 | $21 \leq \bar{x} < 41$ | Less Eligible |
| 5 | $0 \leq \bar{x} < 21$ | Very Inadequate |

To see the feasibility of the e-module, it can be analyzed through student responses to e-module development with the following assessment aspects:

Table 4: Student assessment sheet

| No | Criteria | Indicator |
|---|---|---|
| 1 | Content Quality | a. Clear and easy to understand<br>b. Examples and illustrations help understanding<br>c. The relevance of the e-module to the topic being studied |
| 2 | Clarity Presentation | a. Structured and neat<br>b. The language used is easy to understand<br>c. Information through displayed pictures and videos |
| 3 | Engagement and Interactivity | a. Engagement and training<br>b. Think critically<br>c. interaction |
| 4 | Alignment and readability | a. structured and easy-to-read layout<br>b. Colors and graphics<br>c. Spelling mistakes, spelling mistakes |
| 5 | Overall Rating | a. Satisfaction<br>b. Benefit<br>c. Desire to disseminate |

The results obtained from student responses are then calculated to obtain an average percentage score using the following formula:

$$P = \frac{\sum x}{\sum x\, i}$$

Where:

P = Percentage
$\sum x$= Sum of subject scores
$\sum x\, i$= Maximum total score

Furthermore, these results are categorized based on the following assessment criteria:
Table 5: Criteria of Evaluation

| No | Evaluation | Criteria |
|---|---|---|
| 1 | $81 \leq \bar{x} \leq 100$ | Very Practical |
| 2 | $61 \leq \bar{x} < 81$ | Practical |
| 3 | $41 \leq \bar{x} < 61$ | Pretty Practical |
| 4 | $21 \leq \bar{x} < 41$ | Less Practical |
| 5 | $0 \leq \bar{x} < 21$ | Very impractical |

4. Implementation:

After the E-Module has been developed and validated, the next stage is implementation. E-Modules are introduced to educators and students for use in learning. At this stage, the teacher facilitates the use of the E-Module by students.

5. Evaluation and Revision:

The evaluation stage is carried out to collect feedback from educators and students about the experience of using the E-Module. This evaluation involves observation, tests, interviews, and surveys. Based on the evaluation results, the E-Module is revised and improved to correct weaknesses and increase its effectiveness. These improvements may include content, design, navigation, and other interactive aspects. The process in the SAM Model continues iteratively (repeatedly) with continuous evaluation and revision stages to improve the quality of the E-Module. After the evaluation and revision phases are completed, the cycle starts again with a new evaluation/analysis stage for further development of the E-Module.

## 3. Result and Discussion

The results of this study are e-modules, material expert validation, linguist validation, media expert validation, and student responses.

### Results of e-Modules

The e-module used with the help of a flipbook maker on homogeneous differential equation material, along with an overview of the e-module that has been developed

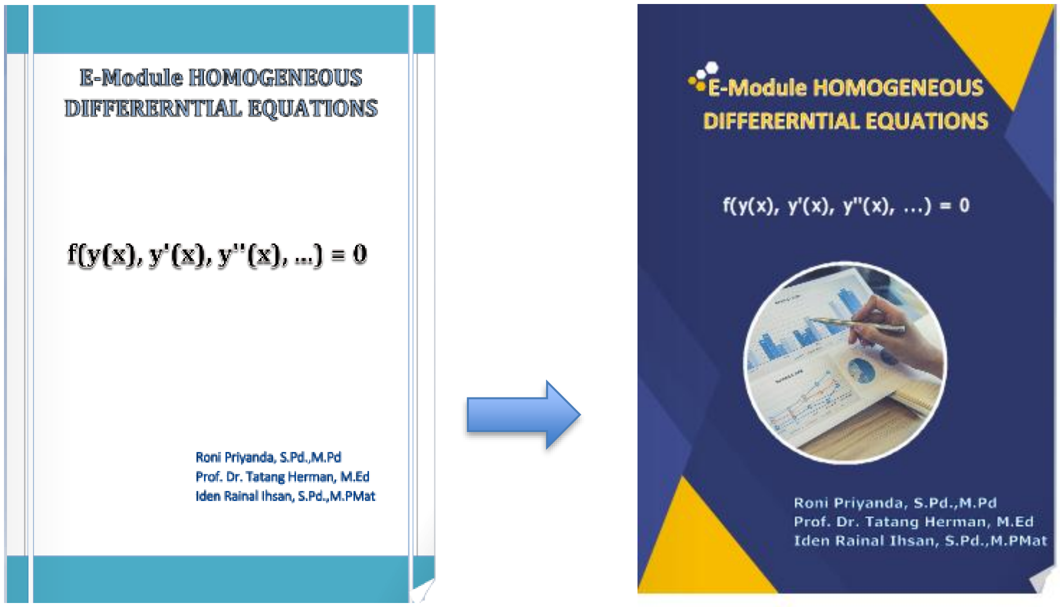


Fig. 2. Display of the e-Module Cover after revision

In accordance with the input and directions of media experts and linguists to improve the cover design to make it more attractive.

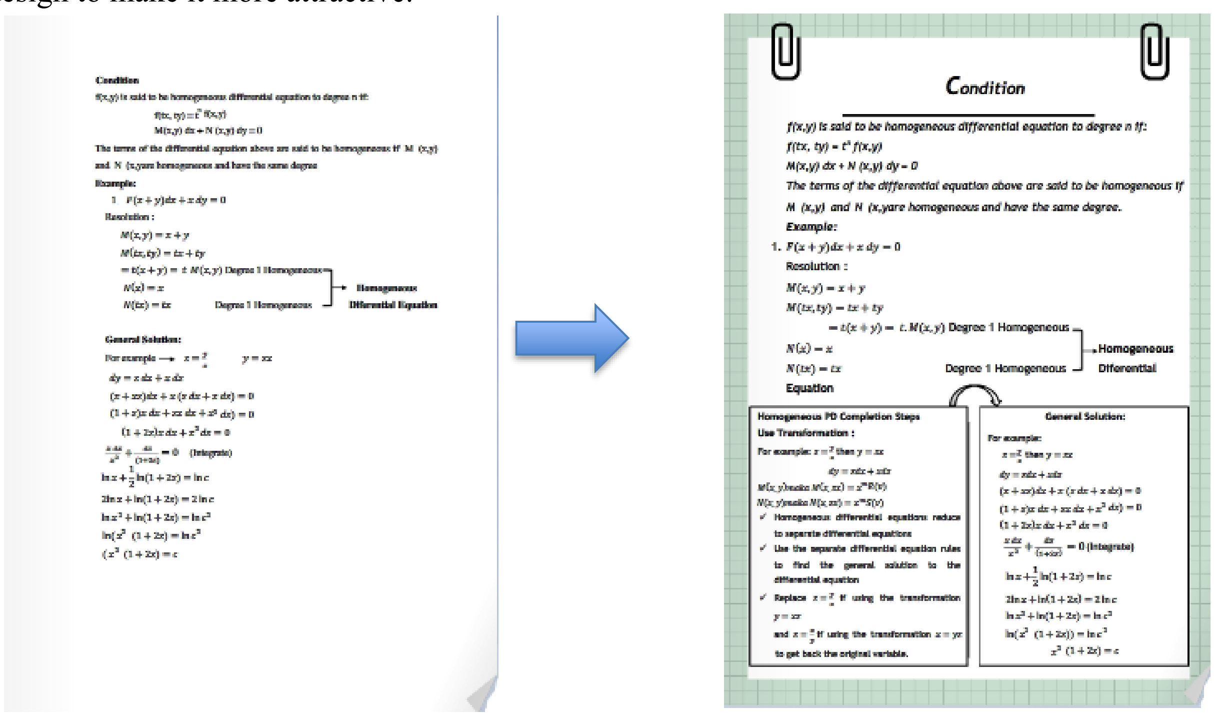


Fig. 3. Content View after revision

According to Material Expert input to add steps and examples of higher difficulty, as well as page design to be colored.

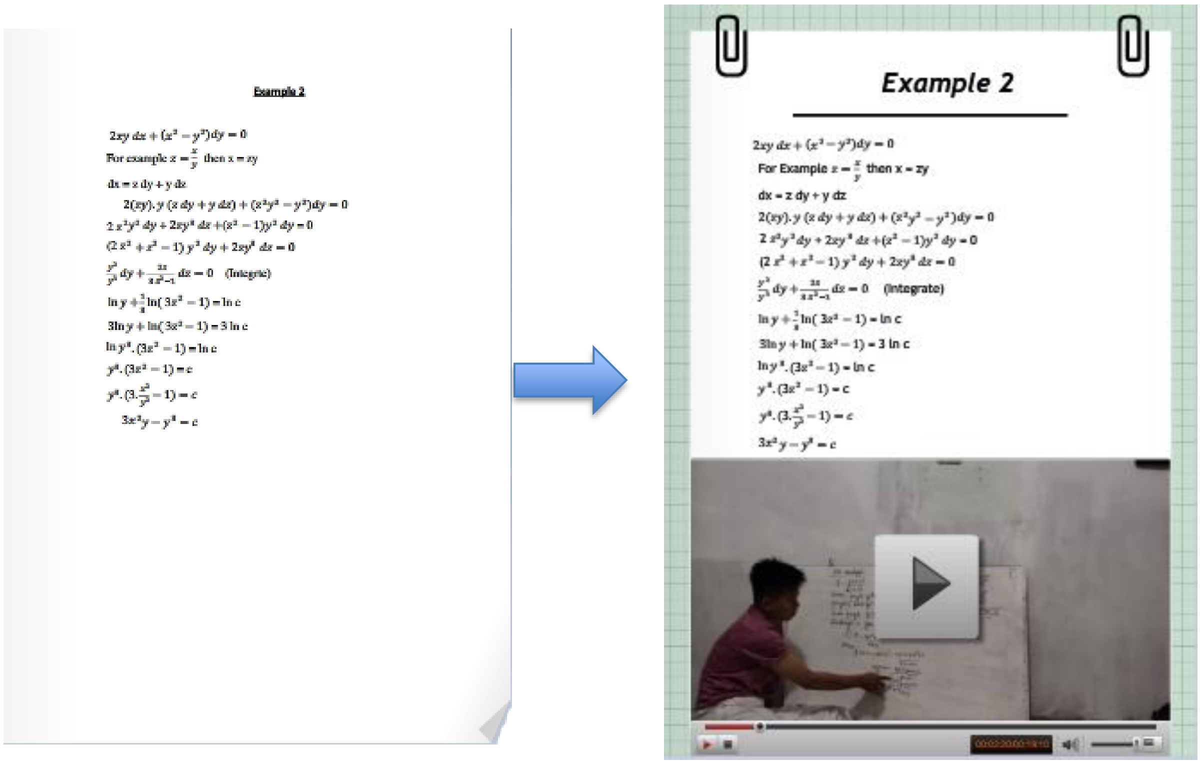


Fig. 4. Display of sample and discussion after revision

Before the revision, the sample questions were only given a discussion with concrete steps, after being revised, in addition to the discussion in writing, it was also supplemented by discussion via video, according to the input of the media expert validator. Then students are given project assignments to make learning plans and implement learning using technology in learning mathematics, this is seen as important to see the level of understanding of students' TPACK in learning mathematics

**Expert Validation Results**

Expert validation was carried out by 3 validators, namely: material experts, linguists and media experts, along with the results obtained in expert validation

Table 6: Expert Validation Result

| Validators | Criteria | Mark | Information | |
|---|---|---|---|---|
| Material | Content | 80 | 76.7 | Worthy |
| | Organizational structure | 73.4 | | |
| Language | Readability and alignment of text | 73.4 | 73.4 | Worthy |
| Media | Engagement | 93.4 | 93.4 | Very Worth it |
| | Interactivity | | | |
| | Visual Quality | 93.4 | | |

P = 55% × 76.7+10% × 73.4+35% × 93.4
P = 82.22%
Based on the total e-module eligibility percentage, it was found that the e-module in the homogeneous differential equations course is very feasible, with an eligibility percentage of 82.22%.

**Student Response Results**

The results of student responses were obtained by giving response questionnaires to students after implementing the e-module in learning, there were 23 students who participated in learning using the e-module on homogeneous differential equation material, the results of student responses can be seen in the following table:

Table 7: Table of Evaluation Criteria and Assessment

| Criteria | Mark | Information |
|---|---|---|
| Content Quality | 86.95% | Very Practical |
| Presentation clarity | 88.69% | Very Practical |
| Engagement and Interactivity | 89.27% | Very Practical |
| Alignment and readability | 80.87% | Very Practical |
| Overall rating | 89.27% | Very Practical |
| **Average** | **87.01** | **Very Practical** |

Based on the average practicality percentage of the e-module, it was found that the e-module in the homogeneous differential equations course is included in the very practical category, with a practicality percentage of 87.01%.

The high validity score indicates that the integration of content, pedagogy, and technology was well-aligned within the e-module design. This supports the TPACK framework, which emphasizes the importance of integrating these three domains in teaching.

The high practicality score suggests that students perceived the e-module as useful and easy to use. This may be attributed to the inclusion of interactive multimedia and project-based tasks, which promote active learning and engagement.

However, this study is limited to a small sample and does not measure the effectiveness of the e-module in improving TPACK competencies. Future research should focus on experimental studies to evaluate its impact on learning outcomes.

## 4. Conclusion

This study contributes to mathematics education by providing a concrete example of how TPACK can be operationalized in e-module design. The integration of multimedia, problem-solving, and project-based tasks enables pre-service teachers to develop technology-integrated teaching competencies. From a theoretical perspective, this study strengthens the implementation of TPACK by linking it with instructional design using the SAM model. From a practical perspective, the developed e-module can be used as a reference for designing digital learning resources in mathematics education.

## 5. Aknowledgments

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