



Construction of Teaching Materials To Facilitate 21st Century Learning on Critical and Creative Thinking

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Abstract: This research aims to produce teaching materials based on 21st century learning for prospective teacher students that are valid and effective. The method of this research was research and development (R&D) using the Thiagarajan 4D model. This model consists of several stages, namely definition, design, development, and dissemination. The test subjects of this research were 27 third-semester mathematics education students at the University of Mataram. Data was collected using a validation questionnaire for teaching materials for material experts, media, practitioners and lecturer and student response questionnaires. Meanwhile, effectiveness data was obtained from student scores on ability tests at the end of using teaching materials. The data was analyzed descriptively to categorize the classical completeness from the scores. The results of the research showed that the teaching materials for teaching critical and creative thinking skills met the criteria valid according to the assessment of material experts, media experts, practitioner experts, lecturers, and students, and their effectiveness has been tested so that it can be concluded that this module meets the requirements for use in learning to build creative thinking and critical thinking skills. These teaching materials can be references for teachers to study how to stimulate student's critical and creative thinking.

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Introduction

The skill to think creatively and critically has become key skills that are critical to acquire in the twenty-first century (National Education Association, 2012). The ability to think critically and creatively is vital for pupils to acquire other skills, such as decision-making and problem-solving abilities. The ability to think critically and creatively does not appear by chance; rather, it is the result of a process that facilitates the development of these skills. Critical and creative thinking must be taught through active learning so that students can experience solving problems from diverse perspectives and deal with complicated events in society. Critical thinking abilities in mathematics can be fostered by introducing students to new and contradictory challenges, allowing them to construct their reasoning to identify unambiguous truths and reasons (English & Kirshner, 2015).

Even though they appear to be the same, creative, and critical thinking talents can be distinguished by definitions, with each definition emphasizing a distinct aspect (Park et al., 2021). According to Kampylis & Berki critical thinking is the ability to think in a way that generates imagination, new ideas, alternative hypotheses, and evaluative abilities (Kampylis & Berki, 2014). Critical thinking in mathematics is defined as the capacity and cognitive tendency to combine knowledge, reasoning, and cognitive methods in reflectively generalizing, proving, and assessing unexpected mathematical problems (Firdaus et al.,

2015). The basic skills for critical thinking include interpretation, analysis, inference, evaluation, explanation, and self-regulation (Facione, 2020).

While critical thinking focused on evaluate the ideas, creative thinking tend to rise new idea. Creative thinking is a method that is employed when producing or giving rise to a new concept, such as merging previously unimplemented ideas (Octaviyani et al., 2020). One widely accepted definition of creativity is a person's ability to generate ideas or products that are regarded novel and suitable (Scott & Bruce, 1994). Munandar states the features of creative thinking talents are fluency, flexibility, originality, and thorough thinking skills (elaboration) (Munandar, 2009).

Based on the results of discussions and researchers' experiences, many mathematics education students at FKIP University of Mataram still have low critical and creative thinking skills. The data of 27 student's performance on algebra tests shows that more than 70% of students got score 60/100. One of the problems from the test is "one of the roots of $2x^2 - 5x + p = 0$ is the inverse of the other root. Evaluate the value of p and all the roots. " This problem facilitates students to interpretate the meaning of roots, analyse the formula to solve the problem, make a judgement of the formula and evaluate the value of p that already gave from that formula. Meanwhile, the test also contains the problem "how many ways to find two numbers whose sum is 200 and have maximum product of multiplication". This question facilitates students to raise new idea of these two numbers.

Furthermore, according to interview with the lecturer, another fact that influences students' critical and creative thinking abilities is that there are no teaching materials that develop students' critical and creative thinking skills. It is essential if there is a module which contains several sub questions to enhance student critical and creative thinking skill. Teacher questioning skill also contributes to students critical thinking performance (Edgar & Baylon, 2014).

Based on these issues, it is essential to create teaching materials to help students enhance their critical and creative thinking skills. Teaching materials can be defined as any type of content that is systematically arranged and created in accordance with the applicable curriculum with the goal of enabling students to study independently (Magdalena et al., 2020). They are items used by teachers or students in the learning process that might include information concerning knowledge, abilities, and attitudes that students must develop in order to acquire specific basic competencies (Kosasih, 2021). There are two sorts of teaching materials, according to Sadjati (2012), printed teaching materials (modules, handouts, worksheets) and non-printed teaching materials (display teaching materials, overhead transparency, audio, video, computer-based teaching materials). The printed teaching materials that will be generated as part of this research.

Several researchers have worked on developing educational materials to include 21st century abilities, such as employing class VIII Pythagorean content to construct mathematics teaching materials centered around 21st century competencies (Maryamah, Anriani, & Fathurrohman, 2019). Cahyaningsih and Nahdi (2020) creating elementary mathematics teaching materials based on the RME (Realistic Mathematics Education) paradigm in order to increase critical thinking skills. Another study created competency-based handouts for class IV 21st century students utilizing the TPS (Think-Pair-Square) learning approach ((Utami, Irianto, & Muryaningsih, 2020)

According to these studies, there has not been much development of textbooks for mathematics education students that are focused on 21st century learning and notably emphasize components of increasing critical and creative thinking abilities. Therefore, researchers are interested in conducting research to develop teaching materials based on 21st

century to enhance student critical and creative thinking. This research aims to produce teaching materials based on 21st century learning on critical and creative thinking for prospective teacher students that are valid and effective.

Research Method

This was R&D (research and development) research utilizing the Thiagarajan 4D model. This model is divided into four stages: define, design, development, and dissemination (Thiagarajan et al., 1974). This study's test subjects were 27 third semester Mataram University mathematics education students. The subjects were chosen because they were prepared to participate in school internships, thus it is intended that this research would provide students with ideas on how to develop their critical thinking abilities and creativity.

This study's instruments include material expert validity sheets, media expert validity sheets, and practitioner validity sheets, as well as student and lecturer response questionnaires and tests for teaching critical and creative thinking abilities. The critical thinking learning test is designed to assess students' critical thinking abilities who study utilizing modules developed by researchers. The exam is in the form of essay questions that refer to indications of critical thinking abilities, such as analyzing, synthesizing, and evaluating the material in the questions in order to solve problems and establish plans for working on the questions. Meanwhile, the test teaches creative thinking skills through essay questions that refer to creative thinking markers such as fluency, flexibility, originality, and elaboration.

The data obtained from this research are as follows: a) validation results from material experts, media experts, and practitioners, b) student response data, c) lecturer response data, d) critical thinking ability data of students who study using modules, and e) creative thinking ability data of students who study using modules. The validation data was analyzed descriptively using the mean score. Meanwhile, the critical and creative thinking of students to measure the effectiveness of the module was analyzed descriptively using the classical completeness.

The data collected via expert validation is then summed up and averaged. The average score is then transformed into categories, as shown in Table 1 (Ratumanan & Laurens, 2016).

Table 1. The Category of Module's Quality

| Score Interval | Category | Information |
|-------------------------|--------------|--|
| $1 \leq P \leq 1.75$ | Very invalid | Not yet usable and still in need of consultation |
| $1.75 \leq P \leq 2.75$ | Invalid | Can be used with multiple revisions |
| $2.75 \leq P \leq 3.25$ | Valid | Can be used with enough revisions |
| $3.25 \leq P \leq 4.0$ | Very valid | Usable with minor revision |

Note: P= average score from three validators

Meanwhile, the information gathered from the questionnaires distributed to students and instructors was evaluated using the classification shown in Table 2 (Widoyoko, 2016).

Tabel 2. Formula to Determine the Quality of Module

| Formula | Classification |
|---|----------------|
| $X > \bar{X}_l + 1,8 \times sb_l \Leftrightarrow X > 27,2$ | Very good |
| $\bar{X}_l + 0,6 \times sb_l < X \leq \bar{X}_l + 1,8 \times sb_l \Leftrightarrow 22,4 < X \leq 27,2$ | Well |
| $\bar{X}_l - 0,6 \times sb_l < X \leq \bar{X}_l + 0,6 \times sb_l \Leftrightarrow 17,6 < X \leq 22,4$ | Enough |
| $\bar{X}_l - 1,8 \times sb_l < X \leq \bar{X}_l - 0,6 \times sb_l \Leftrightarrow 12,8 < X \leq 17,6$ | Not enough |
| $X \leq \bar{X}_l - 1,8 \times sb_l \Leftrightarrow X \leq 12,8$ | Very less |

Note:

$$\bar{X}_i = \frac{1}{2} (\text{maximal idela score} + \text{minimal ideal score}) = \frac{1}{2} \times (32 + 8) = 20$$

$$sb_i = \frac{1}{6} (\text{maximal ideal score} - \text{minimal ideal}) = \frac{1}{6} \times (32 - 8) = 4$$

ΣX = the sum of all scores

Data on students' critical and creative thinking abilities who learnt utilizing teaching materials were assessed by checking for average student scores. The percentage of students who receive a score of at least 75 on a scale of 100.

Results and Discussion

Study has been conducted using Thiagarajan 4D step, namely define, design, develop and dissemination. The result and explanation for each step provided below.

a) Define

This stage consists of front-end analysis, learner analysis, task analysis, concept analysis, and specifying instructional objectives (Ekantini & Wilujeng, 2018; Thiagarajan et al., 1974). An analysis of student challenges and needs is performed during the front-end analysis stage. Data for analysis was gathered through the process of documenting past test results from students, classroom observations, and interviews with the class's lecturer. Based on classroom observations, it was discovered that there were no teaching materials available to train student critical and creative thinking skills. In the meantime, interviews with course lecturers reveal that teaching materials with this goal are required in class to assist students in constructing learning that can stimulate students' critical and creative thinking abilities.

Learner analysis was used to examine the characteristics of the students who will be assessed using the educational materials. The teaching materials were tested on students from the Capita Selektta Mathematics course in the third semester. There were 27 pupils in all, including 17 women and 10 men. Students had studied various courses that helped them gain critical and creative thinking abilities, such as Teaching and Learning and Basic Mathematics.

A task analysis was performed to define the major objective for creating this module, such as the character or skills that students would gain after learning to utilize this module. The results of this stage's analysis propose that students will gain capacities to learn skills in creativity and critical thinking after studying the teaching materials that will be created. In this case, students can split down classroom learning difficulties into multiple sub-questions that aid in the development of indicators of critical and creative thinking abilities.

The next analysis is concept analysis. This analysis is used to analyze the concepts used to achieve the main objectives of the materials created, for example the materials that will be used in learning. At this stage, the researcher determined that the teaching materials would contain four parts, namely 1) theory regarding critical and creative thinking skills 2) how to teach critical thinking skills, 3) how to teach creative thinking skills and 4) how to evaluate critical and creative thinking skills.

The final analysis is specifying instructional object. In this activity, researchers write the final objectives more specifically and measurably so that they can be included in learning activities. The specific objectives of each part of the material are as follows.

- 1) The learning objectives of the section regarding theories regarding critical and creative thinking abilities are that students understand definitions from experts regarding critical and creative thinking abilities, analyze indicators of critical and creative thinking abilities and understand how to reveal indicators of critical and creative thinking

- 2) The learning objective of the section on how to teach critical thinking skills is that students are able to teach critical thinking skills to student teachers in algebra, numbers, geometry and statistics.
- 3) The learning objective of the chapter on how to teach creative thinking skills is that students are able to teach creative thinking skills to student teachers in algebra, numbers, geometry and statistics.
- 4) The learning objective of the chapter on how to evaluate critical and creative thinking abilities is to analyze the level of students' critical thinking abilities based on the answers to the test and analyze the level of students' creative thinking abilities based on the answers to the test.

b) *Design*

The design stage includes all activities to design the initial product. This stage consists of construction criterion-referenced test, media selection, format selection, and initial design (Rizki & Linuhung, 2016). In the construction criterion-referenced test activity, researchers create a reference test that is used to measure the achievement of the main objective of making the module. This test refers to the results obtained in the specifying instructional object activity. The test consists of essay questions that ask students to create sub-questions to explore students' critical and creative thinking abilities. In media selection, researchers choose the media to use the module, which can be in print or digital form. In this stage, the researcher decided to create modules in print and digital form. The digital form in question is a soft file that all students can access. The next stage is format selection, which determines the required module format. The format employed in this study is the instructional material module format adopted by FKIP Mataram University in 2016.

Activities continue to initial design. In this phase, researchers design teaching materials based on an analysis of previous activities. A snapshot of the initial design is shown in Figure 1. After the initial design is completed, the research then enters the development stage.



Figure 1: Snapshot of Initial Teaching Material Design

Figure 1 shows how to build critical thinking skills in algebraic areas of the subject. The critical thinking skills honed are those of Facione (2015) in the areas of interpretation, analysis, inference, evaluation, explanation, and self-regulation. "Suppose the function f is contained in the equation $5f(x) + 3f\left(\frac{1}{x}\right) = 12x$. Find the value of $f(6)$!" The module includes question development to assist students in developing critical thinking skills with questions such as:

- 1) What do you understand from this question? (This quiz is meant to help students improve their interpreting skills.)
 - 2) Which x values are appropriate for determining $f(6)$? (Inference)
 - 3) For the x value acquired in step c), how many equations are formed? (Evaluation)
 - 4) Can the equation obtained in d) be used to calculate $f(6)$ and $f(1/6)$? Give the explanation. (Explanation)
- c) *Develop*

This stage includes expert validation, product revision, and preliminary trials. Expert validity is assessed in three areas: material, media, and practitioner. Five mathematics education lecturers at FKIP Mataram University with the functional designations of lecturer and associate professor validated these three aspects. Four mathematics education lecturers with the functional role of head lecturer validated teaching materials in terms of resources, media, and practitioners. Table 3 displays the validation findings.

Table 3: Teaching Material Validation Results from the Material, Media, and Practitioner Perspectives

| Perspective of Validator | Average score from each validator | | | | Average of all scores | Information | Feedback |
|--------------------------|-----------------------------------|-------------|-------------|-------------|-----------------------|--|--|
| | Validator A | Validator B | Validator C | Validator D | | | |
| Material | 4 | 3.19 | 3.84 | 3.5 | 3.63 | Teaching material can be used with minor revisions | <ul style="list-style-type: none"> Add sample question to develop student self-regulation The word "after attending lectures in learning" might be better to change to "after reading or observing teaching materials" |
| Media | 4 | | 3.875 | | 3.94 | Teaching material can be used with minor revisions | <ul style="list-style-type: none"> It will be great if the writer reduces the number of people in cover |
| Practitioner | 4 | | 3.92 | 3.38 | 3.76 | Teaching material can be used with minor revisions | <ul style="list-style-type: none"> Need some adjustment in language used in materials Give a brief explanation about the specific topic that is related to the question. For example, the question about algebra can be taught in the topic about functions or systems of linear equations in two variables. |

Table 4 shows the average score of 3.25 to 4.00 for student response surveys and validation questionnaires for journalists, practitioners, and subject matter experts. Table 1 indicates that instructional materials are usable with a few slight adjustments. The approved instructional materials have been revised according to the validator's recommendations.

After validation was carried out, the researcher revised the teaching materials according to input from the validator. The next step is to carry out a trial. The trial was carried out in one of the third semester Capita Selektta Mathematics classes at Mathematics Education, FKIP, Mataram University. The trial was carried out over four meetings, namely on 14 August 2023, 21 August 2023, 28 August 2023, and 3 September 2023. At the end of

the meeting, lecturers and students filled out questionnaires to see their responses to the modules used. The results of the lecturer questionnaire are shown in Table 5. Meanwhile, the results of the student questionnaire were analyzed using Table 2. The results of this analysis are shown in Table 4.

Table 4. The result of student's response

| Average score | Interval | Classification |
|---------------|---|----------------|
| 25,56 | $24 < X \leq 27,2$ X is the total score of student's responses | Good |

Based on the findings of the examination of the responses from the students, the instructional materials are rated as good in Table 4. Students also provided feedback on what they felt this instructional resource needs to be improved upon in the provided questionnaire. Table 5 displays a summary of the feedback the students provided. The results of this table demonstrate that over half of the students offered feedback on the language employed and the relative importance of each critical thinking ability indicator. Manalo states that language also influences student's critical thinking and the use of critical thinking assessment (Manalo and Sheppard, 2016). Furthermore, critical thinking can be reflected in their critical thinking reading skill (Din, 2020). There is a positive relationship between critical thinking ability and reading comprehension (Talebinejad and Matou, 2012).

Table 5. The summary of result from student's feedback

| The aspects that need to be revised | The number of students that give feedback | Percentage |
|---|---|------------|
| Simplify the language | 11 | 41% |
| The explanation needs to be detailed | 3 | 11% |
| The differences between each indicator of critical and creative thinking skill are made clearer | 6 | 22% |
| Add more pictures and illustrations | 2 | 7% |
| Add more problem examples | 3 | 11% |
| Cover needs to be revised | 1 | 4% |
| The module is already good | 1 | 4% |

d) *Dessiminate*

After students have learned how to use the educational materials, researchers conduct effectiveness tests. The details of the test result reported in Table 6 are as follows.

Table 6. The result of effectiveness test

| Average score | The number of students | | | |
|---------------|------------------------|------------------|------------------|-------------|
| | $x < 75$ | $75 \leq x < 80$ | $80 \leq x < 85$ | $x \geq 85$ |
| 70,23 | 23% | 40% | 32% | 5% |

Table 6 reveals that more than 70% of students received a score of 75/100 or higher. It denotes that teaching materials are classified as being used effectively in instructional activities. This result similar to the study by Vong dan KaewuraI (2017) who also developed the ability of prospective teacher to teach critical thinking.

The module was categorized as valid and effective. It revealed that this module provided the contents to facilitate students critical and creative thinking and when this module is used in classroom learning, it is able to enhance students' skills on those two



twenty first century skills. Furthermore, since the module was valid and effective, teacher can use this module as references to study about how to foster students critical and creative thinking skills with suitable question.

Conclusion

The research findings indicate that the teaching materials for teaching critical and creative thinking skills to mathematics education students have met valid criteria based on the evaluation of material experts, media experts, practitioner experts, lecturers, and students, and their effectiveness has been tested, allowing it to be concluded that this module meets the requirements for use in learning to build the ability of prospective teacher to think creatively and critically which associate with 21st century learning.

Recommendation

Several recommendations can be made based on the findings of this study as mentioned in the conclusions:

- a) Educational and curriculum materials are beneficial to students who have acquired teaching materials. As a result, this teaching material is ideal for prospective teacher who will participate in teaching practice or Introduction to School Field activities.
- b) Teacher can use this module as an example module to build student critical and creative thinking skill. The example problem in this module and the sub-problem can be adapted in classroom learning to explore student skills.
- c) Future research can be focused on adjusted the problem example to the specific materials taught in schools. For example, the problem in algebra displays in Figure 1 can be one of the list questions in system of linear equation for two variables for 8th students.

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