



Development of a STEM Based E-Module on Motorcycle Electrical Systems to Enhance Creative Thinking Skills in Vocational High School Students

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Abstract

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Facts in the field show the low creative thinking skills of students. Students' difficulties in understanding the material lead to low creative thinking skills. The background of this research in the era of the Industrial Revolution 4.0, students are expected to have creative and solution-oriented thinking skills, so they are able to solve various everyday problems intelligently and productively. The purpose of this research is to develop an electronic module based on Science, Technology, Engineering, and Mathematics (STEM) to improve students' creative thinking skills in motorcycle electrical systems in State Vocational High Schools. The research method used is development research with the ADDIE model. The research subjects were grade XI students in State Vocational High Schools. Data analysis techniques in this study used qualitative and quantitative methods. The results of the creative thinking skills improvement test showed an N-Gain score of 0.45, which is included in the moderate category. Media expert validation results 86.25%, material expert validation 87.50%. The conclusion of this study is that the STEM-based motorcycle electric E-module is feasible to use and can improve creative thinking skills in State Vocational High Schools. This research provides implications that the development of an electronic module based on Science, Technology, Engineering, and Mathematics (STEM) in motorcycle electrical systems can be a reference for teachers in improving creative thinking skills in terms of content, strategies, methods, and teaching approaches.

Keywords:

STEM Education, E-Module Development, Creative Thinking Skills, Vocational Education, Motorcycle Electrical Systems

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INTRODUCTION

Education plays a vital role in shaping graduates who are able to compete in the global era, particularly in meeting the demands of 21st-century competencies (Daryanto & Bambang, 2022). These competencies include the ability to think analytically and solve problems effectively, communicate well, collaborate in interdisciplinary teams, and continuously develop creativity and innovation (Trilling & Fadel, 2009). In response to the ever-evolving dynamics of the times, the education sector must consistently strengthen its commitment to preparing students who are adaptive, relevant, and ready to face real-world challenges (Saifullah et al., 2024). Especially in the era of the Industrial Revolution 4.0, students are expected to possess creative and solution-oriented thinking skills,



enabling them to intelligently and productively address various everyday problems (Kustandi & D., 2020). The Science, Technology, Engineering, and Mathematics (STEM) approach has been recognized as an effective learning strategy for integrating multiple disciplines and encouraging students to solve real-world problems in creative and collaborative ways (Izzania et al., 2024). Through this approach, students not only gain theoretical understanding but are also able to apply their knowledge in practical contexts.

The Revolutionary Era 4.0 is a real challenge that the community in the nation life must face. The era of digitalization and the industrial revolution 4.0 resulted in automation in all fields, including combining real human life with the physical world fundamentally and simultaneously (Tjandrawinata, 2016). Industrial revolution 4.0 has an impact on the world of global and regional education. Educational institutions, including schools and colleges, are required to produce qualified generations who can adapt to various life challenges (Gardiner, 2017). One of the emphases in the current education system in Indonesia, apart from cognitive abilities, is creating a generation that can think critically and creatively (Fitriah et al., 2024). Higher-order thinking skills, especially critical thinking skills and creative thinking skills, are needed in utilizing students' knowledge for problem-solving and decision-making in various areas of life (Retnawati et al., 2018).

Vocational High Schools are educational institutions that focus on developing students' knowledge and skills to prepare them as competent mid-level workers (Aini & Yasid, 2022). Vocational High Schools graduates are expected to be work-ready individuals who are intelligent, skilled in their chosen fields, professionally competitive, and have strong character traits aligned with industry demands (Fajra & Novalinda, 2020). In today's digital era, students are required to master various skills, one of which is creative thinking (Halimah & Marwati, 2022). Creativity and innovation have become crucial aspects for students to face the dynamic and challenging future job market (Almuharomah et al., 2019). Creativity is categorized as a soft skill, which refers to the ability to solve problems through new approaches, innovative actions, and relevant solutions (Fitriah et al., 2024). This ability is reflected in both the work process and the final outcomes produced (Indriawati et al., 2019).

The phenomenon does not only happen in Indonesia but also in other countries in the world. A study reported in Newsweek by Bronson & Merryman, (2010) shows that the significant decline in the creativity of American students in recent decades was observed and represented as a creativity crisis. It attributes this decline to the standardization of curriculum, teaching, and assessment in schools. Students seem more pressured to memorize facts and find correct answers than critically analyzing and evaluating the content or exploring creative ideas and innovative thinking. STEM becomes a well-known approach among educators due to the increasing perspective of 21st-century global technology (Shernoff, 2017). STEM is a discipline that requires mathematics as a tool in data processing, technology, and engineering as an application of science. The STEM approach allows students to solve problems better and become innovators, inventors, independent workers, logical thinkers, and technological literacy (Fitriah et al., 2024). Several study results show the success of learning with a STEM

approach to improve concept understanding (Ariyatun & Octavianelis, 2020) and critical thinking skills (Fajra & Novalinda, 2020).

Vocational High Schools, as a vocational education institution in Probolinggo Regency, is committed to producing competent graduates who are ready to compete in the workforce (Purnamawati et al., 2022). However, the learning process in Grade XI, particularly in the Motorcycle Engineering and Business program, still faces several challenges. One of the main obstacles is the lack of contextual learning materials that align with students' needs. In addition, the low integration of the STEM approach in classroom activities and the suboptimal level of student creativity hinder the development of critical and innovative thinking skills. To address these challenges, a STEM-based E-Module for Motorcycle Electrical Systems was developed with the aim of fostering students' creative and analytical thinking through scientific approaches, applied technology, and technical problem-solving.

METHODS

This research is categorized as Research and Development (R&D) (Branch, 2009). The R&D approach is utilized to examine user needs with the goal of developing and producing a specific educational product, while also evaluating its validity during the learning process. The sampling technique uses purposive sampling. As noted by (Sudaryono, 2016), the R&D method is a research strategy aimed at generating new products or refining existing ones by using validated tools and assessing their effectiveness.

The development framework adopted in this study is the ADDIE model, selected for its structured and systematic nature (Widyastuti & Susiana, 2019), making it suitable for creating learning models that are effective, efficient, and innovative. According to (Hidayat & Nizar, 2021), the ADDIE model serves as an instructional design framework focused on enhancing core competencies through learner-centered strategies. The ADDIE model includes five sequential stages: Analysis, Design, Development, Implementation, and Evaluation, which are outlined as follows:

Analysis

The purpose of the analysis stage is to determine the educational needs and profile of the learners (Megawati et al., 2022). This includes a needs assessment carried out through classroom observations and interviews with vocational TBSM teachers to uncover challenges faced during the teaching of Motorcycle Electrical Systems. The curriculum was also examined, focusing on learning objectives, essential content, and targeted competencies based on the Merdeka Curriculum. Furthermore, student characteristics (Komarudin, 2022; Piaget, 1952) were analyzed in terms of their interests, preferred learning styles, and digital literacy. An assessment of infrastructure was conducted to evaluate the availability of technological tools (such as smartphones or computers) and internet connectivity to support e-module utilization. The findings from this stage revealed the necessity for an interactive digital learning resource that promotes student engagement and stimulates creative thinking within the scope of motorcycle electrical systems.

Design

During this stage, the e-module's structure and content were systematically planned. The learning objectives were formulated based on an analysis of the curriculum and the identified needs of students. A STEM-based approach was chosen to encourage the development of creative thinking through the application of real-life problem-solving scenarios (Ferdiani & Pranyata, 2022). An outline of the e-module was drafted, covering the arrangement of materials, instructional activities, and student worksheets. Assessment tools were also prepared, including pretest and posttest questions, a rubric for evaluating creative thinking (covering fluency, flexibility, originality, and elaboration), (Ningsih & Suciptaningsih, 2024) as well as observation forms. The user interface was designed through initial sketches to ensure the e-module would be visually appealing and easy to navigate.

Development

This stage focuses on the development and validation of the e-module. Key activities include designing an interactive e-module grounded in the STEM approach, using platforms such as microsites (e.g., s.id). The module incorporates multimedia elements such as videos, animations, electrical circuit simulations, and project-based learning tasks (Daryanto, 2013). Content validation was carried out by subject experts to ensure alignment with the curriculum and STEM principles, while media and design specialists reviewed the visual presentation and user interface. (Pratami et al., 2023) The initial version of the e-module was revised according to the feedback provided by these experts. A small-scale pilot test was also conducted with a limited number of students to detect any technical problems and to collect preliminary user feedback.

Implementation

The implementation phase is intended to evaluate the practical effectiveness of the e-module within an actual classroom environment. This stage involved several key activities: selecting participants for the trial, specifically students from class XI TBSM 1 at Vocational High Schools; conducting instructional sessions where the teacher utilized the e-module across multiple meetings (Khairunisa et al., 2023); and collecting data through pretests, posttests, and classroom observations throughout the learning process.

Evaluation

The evaluation phase is designed to assess both the effectiveness and overall quality of the e-module. This phase includes two components: Formative evaluation, which takes place during the development stage and involves expert reviews, product revisions, and limited testing (alpha testing) (Simbolon et al., 2023); and Summative evaluation, carried out after the implementation stage, where pretests and posttests were used to evaluate students' improvement in creative thinking skills. The effectiveness of the e-module was analyzed using the N-Gain method.

The validation sheet instrument is in the form of a questionnaire that will be given to material experts and media experts containing selection options and a blank

column at the bottom to provide comments and suggestions on the material outlined in the developed product. The questionnaire uses a Likert scale.

The rating scale of the developed product is determined based on the following validation levels.

Table 1. Learning media product assessment scale

No	Score scale %	Level of Validation
1	81 – 100	Very worthy
2	61 – 80	Worthy
3	41 – 60	Fairly worthy
4	21 – 40	Less worthy
5	0 – 20	Not worthy

Source: Riduwan (2020)

The learner response instrument was carried out by giving a questionnaire to students of XI TSM Vocational High Schools 2 Krasaan. The questionnaire was given to students after the use of learning media. Students simply provide a checklist in the column of the answer options “Yes” and “No” on each aspect measured.

The scale of student responses to the products developed is determined based on the following categories.

Table 2. Learner Response Category

Interval (%)	Category
95 – 100	Very positive
75 – 94	Positif
60 – 74	Moderately positif
55 – 59	Poor
0 – 54	Very Poor

Source: Lestari (2023)

Instruments in the form of pretest and posttest questions were given to students to measure students' critical thinking skills. The test was given before and after giving STEM Based E Module media which previously measured its validity and reliability. The validity test is reviewed by comparing the value of r count and r table where the question can be said to be valid if r count is greater than r table. The reliability test is reviewed from the Cronbach's alpha value which if the Cronbach's alpha result is less than 1, it can be said that the measuring instrument is reliable or reliable (Marthiani, 2024). The pretest and posttest questions are in the form of a multiple choice test of 20 questions. In accordance with the opinion of Suarjana et al (2020) that the instrument used to measure critical thinking skills in the context of high school is a multiple choice objective test. The classification of gain in normality is shown in the following table 3.

Table 3. Criteria for Normalized Gain Score

Normalized Gain Score	Category
$g < 0,30$	low
$0,30 \leq g < 0,70$	Medium
$g \geq 0,70$	High

Source: Sugiyono (2017)

RESULTS & DISCUSSION

This part outlines the results of designing and applying a STEM-oriented e-module for the Motorcycle Electrical Systems topic, following the stages of the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) (Cahyani & others, 2020). Data were gathered using methods such as classroom observations, expert assessments in media, content, and language, as well as questionnaires and analysis of students' performance before and after the intervention (pretest–posttest).


Analysis

This stage was carried out to identify learning needs, student characteristics, and infrastructure conditions. The analysis revealed that teaching Motorcycle Electrical Systems in vocational schools requires interactive media to enhance student engagement and stimulate creative thinking skills. (Adella & Dalimunthe, 2024) Observations and interviews with teachers indicated a gap between the instructional content and the media used, particularly in the context of digitalized learning.

Design

At this stage, the researcher developed the design of the STEM-based e-module, which included the structure of the material, learning activities, and assessment components. The elements designed consisted of (Gurusinga & Eddiyanto, 2025):

Tabel 4. E-module display

Elements	e-Module Display
<ol style="list-style-type: none"> 1. Cover 2. Author Page 3. Preface 4. Table of Contents 5. Glossary 6. Introduction 7. Concept Map 8. Learning Activities 9. Evaluation and Assignment Link 10. Jobsheet 11. whatapp 	

Development

At this stage of the development process, the STEM-based e-module was constructed in alignment with the detailed design formulated during the earlier phase. The development involved translating the planned structure, content, and instructional strategies into a functional digital learning product. (Nazifah &

Asrizal, 2022) The e-module was enriched with a variety of multimedia components aimed at enhancing interactivity and student engagement. These components included educational videos that explain key concepts, animated illustrations to visualize abstract ideas (Fitriana & Dewi, 2024), simulations of motorcycle electrical circuits that allow learners to experiment virtually, and project-based tasks that challenge students to apply their knowledge in practical, real-world scenarios.

To ensure the quality and appropriateness of the content and design, the developed e-module underwent a thorough validation process involving two subject matter experts (Mulyasari & Sholikhah, 2021). One expert focused on the material content, reviewing it for its alignment with the curriculum and relevance to the STEM approach, while the other expert examined the design and functionality of the media elements. These validation activities were essential for identifying areas that required improvement and for ensuring that the final product met educational standards and effectively supported the learning objectives (Fitria & Dumiyati, 2023).

Media Expert Validation Results.

The media validation was conducted by Dr. H. Bambang Winarto, M.Pd. The following is the assessment result from the validator:

Table 5. Validation Results by Media Expert

Aspect	Score Obtained	Maximum Score	Criteria
Media	69	80	Very Valid

The validity percentage of the STEM based e-module media can be determined as follows:

$$P = \frac{\text{Score Obtained}}{\text{Maximum Score}} \times 100\%$$

$$P = \frac{69}{80} \times 100\%$$

$$P = 86.25 \%$$

Validation Results by Subject Matter and Language Expert

The material validation was conducted by Sigit Prasetyo, S.T., M.Pd. The following is the assessment result from the validator:

Table 6. Validation Results by Subject Matter Expert

Aspect	Score Obtained	Maximum Score	Criteria
Media	70	80	Very Valid

$$P = \frac{\text{Score Obtained}}{\text{Maximum Score}} \times 100\%$$

$$P = \frac{70}{80} \times 100\%$$

$$P = 87.50 \%$$

Implementation

The implementation phase involved conducting a trial of the developed e-module with students from class XI TBSM 1 at Vocational High Schools 2 Krasaan. During this phase, the teacher integrated (Herpratiwi, 2019) the e-module into classroom instruction and facilitated a series of structured learning sessions spread across multiple meetings. The instructional process was designed to fully utilize the features of the STEM-based e-module, (Jaiz, 2022) including interactive content,

multimedia components, and project-based learning activities. Throughout these sessions, data collection was systematically carried out to assess the module's impact on student learning. (Kumalaretna & Mulyono, 2017) Pretests were administered before the use of the e-module to establish a baseline of students' creative thinking skills, while posttests were given afterward to evaluate the learning outcomes and improvements achieved. In addition to these assessments, classroom observations were conducted to gather qualitative insights into student engagement, participation, and responses during the learning process. These comprehensive data collection efforts provided a well-rounded understanding of the e-module's effectiveness in a real classroom environment (Kosasih, 2021).

Evaluation

The evaluation process for the development of the STEM-based e-module was conducted through two primary approaches:

Formative Evaluation

This type of evaluation took place during the development phase of the e-module. It included several important steps such as validation by experts, which involved a thorough review by specialists in media, material content, and language (Sukendra, 2023). Based on their feedback, necessary revisions and improvements were made to the initial product to enhance its quality and usability. In addition, limited trials or small-scale testing were conducted with a select group of students to identify technical issues and gather preliminary insights into user experience and engagement (Nafiyanto & Pebriana, 2023).

Summative Evaluation

After the implementation of the e-module in the classroom, a summative evaluation was carried out to measure its overall effectiveness in enhancing students' creative thinking abilities. This was done by administering both a pretest (before using the e-module) and a posttest (after its use). The data obtained from these assessments were analyzed using the N-Gain formula to determine the degree of improvement (Fauziyah & Wijayanti, 2024). The results showed an N-Gain score of 0.45, which falls into the "moderate" category. Based on the effectiveness criteria defined by (Arikunto, 2010), this score indicates that the use of the STEM-based e-module had a fairly effective impact. It contributed significantly to the improvement of students' creative thinking skills in learning the subject of motorcycle electrical systems.

Overall, the evaluation results support the conclusion that the developed e-module is a valuable and moderately effective tool for enhancing learning outcomes, particularly in fostering students' ability to think creatively within a vocational education context.

Tabel 7. The Results of the Validity Test for Creative Thinking Questions

Question	Result	Validity	Level of validity
1	1,035 > 0,389	Valid	Very Strong
2	1,035 > 0,389	Valid	Very Strong
3	0,403 > 0,389	Valid	Moderate
4	1,034 > 0,389	Valid	Very Strong
5	1,034 > 0,389	Valid	Very Strong

6	0,412 > 0,388	Valid	Moderate
7	1,035 > 0,389	Valid	Very Strong
8	1,035 > 0,389	Valid	Very Strong
9	0,413 > 0,388	Valid	Moderate
10	1,034 > 0,388	Valid	Very Strong
11	0,413 > 0,389	Valid	Moderate
12	1,035 > 0,389	Valid	Very Strong
13	1,035 > 0,389	Valid	Very Strong
14	1,034 > 0,389	Valid	Very Strong
15	0,619 > 0,389	Valid	Strong
16	1,034 > 0,389	Valid	Very Strong
17	0,412 > 0,389	Valid	Moderate
18	0,450 > 0,388	Valid	Moderate
19	0,413 > 0,388	Valid	Moderate
20	0,412 > 0,389	Valid	Moderate

From these results it can be seen that all creative thinking indicator questions from numbers 1-20 can be said to be valid because $r_{count} > r_{table}$. With r_{table} worth 0.3889 and a significance level of 0.05.

The reliability test was carried out as a whole for all question items contained in the creative thinking indicator questions. The following are the results of the reliability test.

Tabel 8. Reliability Test Results of Creative Thinking Questions

Reliabilitas	
Cronbach's Alpha	Item
0,905	20

Based on the results of the reliability test, it can be seen that the Cronbach's Alpha result obtained is 0.905 on 20 question items. Then all items of creative thinking questions are declared reliable.

The next stage is implementation, where products that have been declared valid, practical, and effective are implemented in learning in class class XI TSM with a total of 34 students. Students access learning media outside of learning activities after the implementation of learning activities on cell structure material in the classroom has been taught. Students do a pretest before using STEM Based E Module media and do a posttest after finishing accessing STEM media. This was done to determine the increase in students' creative thinking skills. The implementation results are presented in table 6.

Tabel 9. Creative Thinking Tes Result

Description	Pretest	Posttest
Average score	65,28	95,87
Classical Mastery	20,26%	90,67%

The evaluation stage includes analysing the improvement of STEM Based E Module media on creative thinking skills. The test results at the implementation stage in class XI TSM were analysed using the N-Gain test to determine the improvement of creative thinking skills. The calculation results are as follows:

Table 9. N-Gain Test Result

Description	Creative Thinking Skill
Average pretest score	65,28
Average posttest score	95,87
N-Gain skor	0,45
N-Gain Percentage	45 %
Category	Medium

The results of validation by media experts showed a score of 86 %, which is included in the very feasible category. This indicates that the STEM Based E Module media has fulfilled technical criteria such as ease of access, attractive visual appearance, clear navigation structure, and compatibility with various devices. Meanwhile, validation by material experts reached a score of 100%, indicating that all content in the media was very much in line with the curriculum, learning objectives, and 21st century learning principles. The material was presented in a coherent and interactive manner, and contained elements that supported the development of creative thinking skills. This finding shows that the developed media is not only visually appealing, but also strong in substance.

The N-gain test results showed an N-gain value score of 0.45, which is included in the moderate category. This means that there is an increase in students' creative thinking skills after using STEM Based E Module media. The increase that occurred still shows that STEM Based E Module media contributes to the development of students' creative thinking skills. The results of this study are in accordance with the research of Sari & Susilowati (2020) which states that website-based media can help students build higher-order thinking skills because it provides flexible and interactive access to learning.

Discussion

This study is a research and development project focused on a STEM-based e-module aimed at improving students' creative thinking skills in the subject of Motorcycle Electrical Systems. During the analysis phase, the results of observations and interviews indicated that the media aspect validation scored 86.25%, categorized as very valid. The material aspect validation scored 87.50%, also categorized as very valid. These validation results show that the e-module falls into the very valid category, with an average score of 86.87%, indicating that the e-module is suitable for use in learning. The result of the creative thinking improvement test administered to 34 students in class XI TSM using the N-Gain Test was 0.45, which falls into the very Creative Category.

The Success of Developing STEM-Based E-Modules on Motorcycle Electrical Systems to Improve Creative Thinking Skills in Vocational High School Students, the developed e-modules are valuable and quite effective tools to improve learning outcomes, especially in fostering students' creative thinking skills in the context of vocational education to improve learning innovation in training creative thinking skills. However, further research needs to consider further research on students whose creative thinking skills are still relatively low. Although showing

flexible thinking, students' creative thinking skills are still at the stage of providing simple explanations (Ariyatun & Octavianelis, 2020).

This study shows that students have creative thinking skills. In accordance with previous studies, students with high analytical skills will have the ability to carefully describe and connect between parts to conclude correctly (Aini & Yasid, 2022). Although students still need to be given more time to practice their creative thinking skills in explaining real problems, they are enthusiastic about participating in learning. Izzania (2024) stated that this process can increase students' interest in learning, make learning more meaningful, help students solve real-life problems, and support future careers. Therefore, student-centered learning must continue to be developed, and student involvement in learning must always be a top priority.

CONCLUSION

The results of this research and development titled "Development of a STEM-Based E-Module to Improve Students' Creative Thinking Skills in Motorcycle Electrical Systems at Vocational High Schools 2 Krasaan " employed a Research and Development (R&D) approach using the ADDIE model, which consists of the following stages: Analysis, Design, Development, Implementation, and Evaluation.

The feasibility of the e-module was assessed through expert validation and a test measuring students' creative thinking skills. The validity of the STEM-based e-module in the Motorcycle Electrical Systems subject, based on expert evaluations, resulted in scores of 86.25% from the media expert and 87.50% from the subject matter expert, with an average validity percentage of 86.87%, categorized as Very Valid. Meanwhile, the improvement in students' creative thinking skills reached an N-Gain score of 0.367, which falls under the Moderately Creative category. It can be concluded that the STEM-based e-module development effectively enhances the creative thinking skills of Grade XI TSM students at Vocational High Schools.

This research provides implications that the development of electronic modules based on Science, Technology, Engineering, and Mathematics (STEM) in the motorcycle electrical system can be a reference for teachers in improving creative thinking skills in terms of content, strategies, methods, and teaching approaches. The development of electronic modules based on Science, Technology, Engineering, and Mathematics (STEM) in the motorcycle electrical system is very feasible, practical and effective in improving critical thinking skills of vocational high school students and can be applied to other schools.

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