Integrating Deep Learning into STEM-Based E-Modules: Advancing Quality Education (SDG 4) in Junior High School Science

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Abstract: The rapid evolution of digital technology in the 21st century necessitates innovative teaching materials that foster deep conceptual understanding. This study aims to develop and evaluate a STEM-based electronic module (e-module) integrated with a deep learning approach for Grade IX junior high school science, specifically focusing on static and dynamic electricity. Using the Research and Development (R&D) method with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), the e-module was designed to incorporate interactive multimedia, STEM-based activities, and deep learning principles—emphasizing understanding, application, and reflection. Results from expert validation (media, material, and language) yielded an average score of 90.73%, indicating very high validity. Practicality testing involving students and teachers resulted in an average score of 91.82%, categorizing the module as very practical. Furthermore, the effectiveness test showed a significant improvement in student learning outcomes, with the average score rising from 62.50 to 85.63 and an N-Gain value of 0.62 (medium category). These findings demonstrate that the STEM-based e-module with a deep learning approach is a valid, practical, and effective tool for enhancing students' conceptual mastery in the digital era.

Keywords: Development; Deep learning; E-Modules; Science; STEM.

Introduction

The rapid evolution of digital technology in the 21st century has shifted the educational paradigm towards interactive, multimodal, and flexible learning resources (Mertala et al., 2024; Ramadan et al., 2025). For the digital native generation, conventional printed teaching materials are no longer sufficient to bridge the gap between abstract scientific concepts and real-world applications. As a result, the transformation of teaching materials into interactive electronic modules (e-modules) is no longer an option, but a necessity to encourage independent and meaningful learning (Harahap et al., 2024; Yersi et al., 2025).

In science education, topics such as Static and Dynamic Electricity present significant pedagogical challenges due to their abstract nature, involving the flow of invisible electrons, as well as complex mathematical relationships. Traditional learning often leaves students stuck in a "surface approach," where they simply memorize formulas like Ohm's Law without understanding the underlying physical phenomena (Agustina et al., 2022; Dewi et al., 2020; Wardani et al., 2023).

This creates a critical gap: even though schools have a digital infrastructure, available resources that are often limited to static PDF files fail to visualize those abstract concepts or engage students in the high-level thinking necessary for conceptual mastery. To address this, the integration of STEM (Science, Technology, Engineering, and Mathematics) approaches is essential, as it provides a contextual framework for problem-solving and

engineering design in electrical systems (Kelley & Knowles, 2016) Taufiq et al., 2020).

In addition, the Ministry of Primary and Secondary Education of the Republic of Indonesia, through Regulation Number 13 of 2025, has mandated the implementation of Deep Learning (Mindful, Meaningful, and Joyful learning) starting from the 2025/2026 school year. This policy aims to shift the focus from the broad scope of the material to the depth of understanding. Although classical deep learning theory emphasizes cognitive processing (Chen & Lin, 2014; Liu et al., 2022; Marton & Säljö, 1976), The 2025 policy specifically demands a simplification of the curriculum that allows for fun reflection and engagement. This research is in line with the national mandate by embedding the "Mindful" stages, "Meaningful" activities (STEM-based projects), and interactive elements of "Joyful" in the e-module, to ensure that students not only "know" about electricity but can also "reflect" on its applications. (Kelley & Knowles, 2016; Saprudin et al., 2022; Sureni et al., 2023), there is still a lack of research that specifically synthesizes STEM with the "Mindful-Meaningful-Joyful" framework of the Deep Learning 2025 policy.

The novelty of this research lies in the development of STEM-based e-modules that are specially designed to meet Indonesia's new curriculum standards in 2025, providing a practical solution for teachers to transform from conventional teaching to deep learning-oriented instruction. Therefore, this study aims to develop and evaluate STEM-based e-modules with a Deep Learning approach to improve the conceptual mastery of junior high school students.

Method

This research is a research and development (R&D) that aims to produce and test the quality of learning products (Ardina et al., 2020; Saprudin et al., 2022). The product developed is in the form of a STEM-based electronic module (e-module) with a deep learning approach in science subjects in grade IX junior high school, especially in static electrical materials and dynamic electricity. R&D research is used because it is oriented towards product development as well as testing its validity, practicality, and effectiveness in learning (Sugiyono, 2014).

The development model used in this study is the ADDIE model, which consists of five stages, namely analysis, design, development, implementation, and evaluation (Andriani & Dwiningsih, 2024).
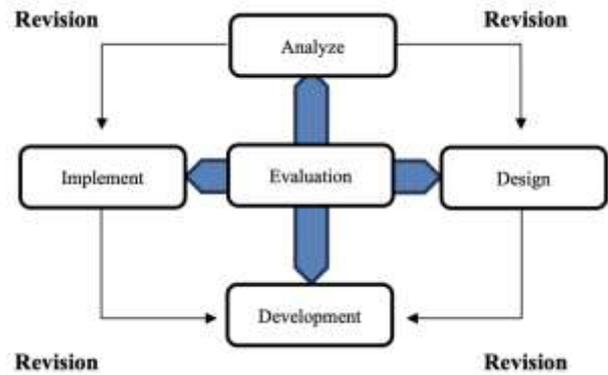

Figure 1. ADDIE Model

The analysis stage was conducted to identify learning needs, student characteristics, and curricular alignment through interviews with science teachers and observations of grade IX students, while the design stage focused on developing the e-module's initial framework and interactive interface. During analysis, the curriculum was adjusted to Learning Outcomes and Learning Goal Flows, and students' characteristics were assessed using essay questions on static and dynamic electricity based on deep learning indicators. Subsequently, the design phase translated these findings into a structured e-module comprising learning flows, STEM-based activities, assessments, and reflections, while also optimizing the UI/UX through the strategic selection of colors, text, and multimedia to ensure the module is both accessible and engaging for junior high school students

The development stage is the stage of realization of the design into an interactive e-module product using the Flip PDF Professional software (Nugroho et al., 2023; Putri, 2023; Rahman et al., 2021), at this stage, learning content is created, integrating STEM activities with deep learning approaches, and preparing formative and summative assessments (Durovic, 2020). The resulting product is then validated by material experts and media experts to assess the feasibility of content, display, and suitability of learning, then revised based on the validator's suggestions.

The implementation stage is carried out by implementing e-modules that have been declared valid in science learning in grade IX junior high school. At this stage, a practicality test was carried out to determine the ease of use of the e-module by teachers and students through questionnaires, as well as an effectiveness test to measure the improvement of student learning outcomes using pre-test and post-test designs. The research instruments used are media, content, language, and practicality validation instruments. Data collection techniques include interviews, observations, tests, and

questionnaires, while data analysis techniques use validity tests and practicality tests.

$$P = \frac{\Sigma x}{N} \times 100\% \qquad (1)$$

Description:
P = Percentage of validation results obtained
ΣX = Total score obtained
N = Maximun Score

The criteria for interpreting the validity percentage of the validity calculation results can be seen in the Table 1 (Nila & Mustika, 2022).

Table 1. Validity Assessment Criteria

Percentage (%)	Validity category
100	Valid without revision
81-99	Valid with light revision
61-80	Valid with moderate revision
≤ 60	Unusable

Analysis of the Practicality of Learning Media

$$Vs = \frac{\Sigma x}{\Sigma y} \times 100\% \qquad (2)$$

Vs = Validation score percentage
ΣX = Total score obtained
ΣY = Maximun Score

The practicality categories of e-modules based on the practicality score obtained can be observed in the Table 2.

Table 2. Practicality Categories

Percentage (%)	Validity category
0 -54	Very Impractical
55-64	Impractical
65-76	Practical
80-100	Very Practical

The evaluation stage is carried out to assess the quality of e-modules comprehensively based on aspects of validity, practicality, and effectiveness. Evaluation is carried out through expert assessment, user responses, and analysis of student learning outcomes. The results of the evaluation are used as a basis for product improvement so that the resulting e-modules meet the criteria for being suitable for use in science learning in grade IX junior high school.

To evaluate the effectiveness of E-Modul in improving student learning outcomes, the assessment was carried out through tests with an objective question format

$$\text{Final score} = \frac{Score\ obtained\ by\ the\ student}{maximum\ score} \times 100 \qquad (3)$$

To determine the improvement in student learning outcomes, the difference between the pre-test and post-test scores is calculated. The difference between the two tests is called the Gain. The formula for calculating the N-gain is as follow (Andini & Fitria, 2021).

$$\text{N-Gain} = \frac{Posttest\ Score - Pretest\ Score}{Score\ Ideal - Pretest\ Score} \qquad (4)$$

The next step, the results of the N-Gain calculation are presented using the following criteria :

Tabel 3. N-Gain Interpretation

N-$gain$ value	Category
N-$Gain$ > 0.7	High
$0.3 < N$-$Gain < 0.7$	Medium
N-$Gain < 0.3$	Low

Result and Discussion

Analysis

At this stage of analysis, there are three parts that need to be analyzed, first, namely the analysis of basic needs, based on the results of the questionnaire analysis of basic needs given to the respondents, with an overview that the development of STE<-based E-Modules with a deep learning approach is needed in science learning. The second is the curriculum analysis, based on the results of the curriculum analysis, it was found that the curriculum used at the UNP Laboratory Development Junior High School has used the Independent curriculum and the subjects chosen are Science subjects in Static Electricity and Dynamic Electricity. In the third part, namely the analysis of student development, based on the results of the analysis that has been carried out in the field, students in grade IX of junior high school are at the stage of cognitive development, where they are beginning to be able to think abstractly but still need concrete examples to understand scientific concepts. In static electrical matter and electric field, most students have not had direct experience so their initial understanding is still limited to everyday phenomena such as standing hair or balloons sticking to walls. The last part is material analysis, Based on the analysis conducted by the author, static electrical matter and electric field are basic parts of the electrical concept that students need to master before learning more complex electrical circuits and electrical concepts. In this section, there are several fundamental concepts that are abstract so that they require gradual explanations, visualizations, and experimental activities to support students' understanding.

Design

The design stage is a strategic step in the development of STEM-based E-Modules with a deep learning approach. At this stage, the researcher prepares the initial design of the product to be developed, starting from the structure of the e-module, presentation materials, learning activities, and evaluation instruments. The design is carried out based on the results of needs analysis, curriculum analysis, and student characteristics so that the resulting e-modules are relevant, attractive, and support the achievement of competencies (Akramova et al., 2025).
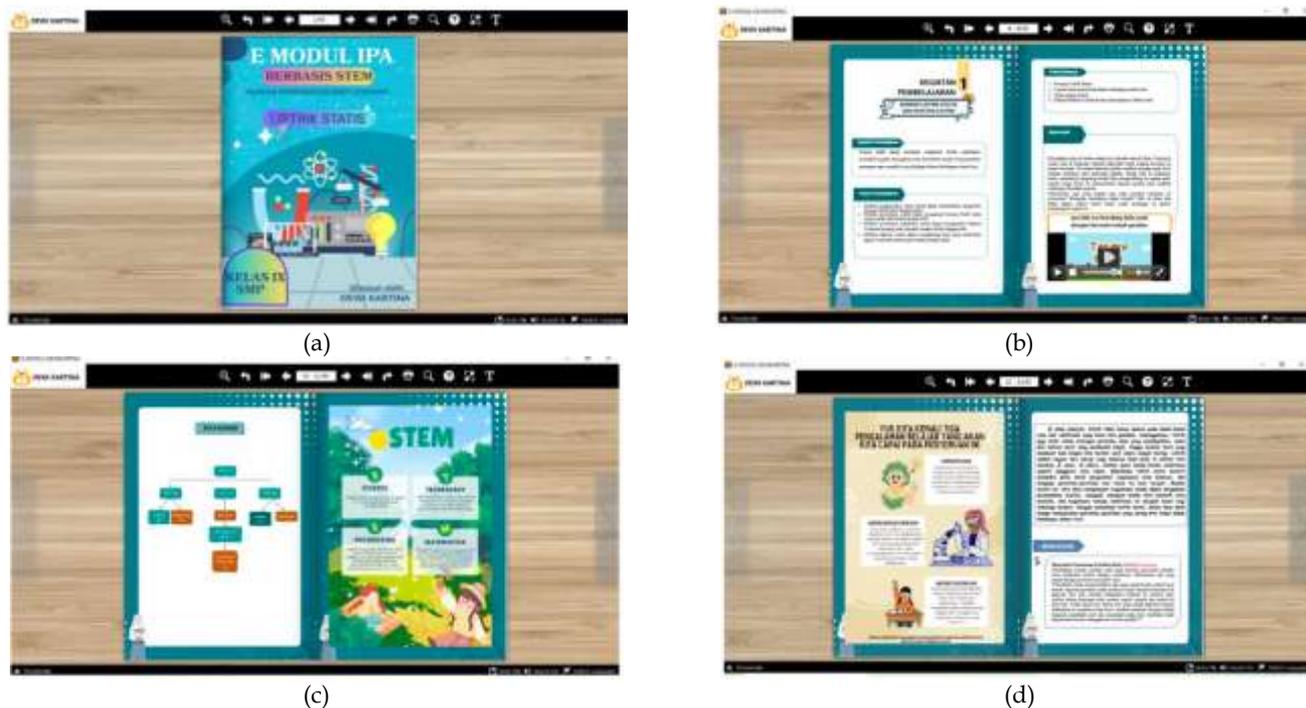

(a)　　　　　　　　　　　　　　　　　　　(b)

(c)　　　　　　　　　　　　　　　　　　　(d)

Figure 2. E-Module design: (a) Cover page; (b) CP and TP pages; (c) STEM Elements; and (d) Deep learning elements

Development

After the STEM-based E-Module with a deep learning approach is designed, the validity test will be carried out by media experts, subject matter experts, and linguists to make further improvements to the product so that its feasibility can be tested in the field.

Table 4. Results of the media, language and material validity test

Aspects	Percentage %	Criteria
Media	90.40	Worthy
Language	85.00	Very decent
Material	96.80	Very decent
Average	90.73	Very decent

Based on the results of the media, language, and material validity test, an average of 90.73% was obtained, this shows that STEM-based E-Modules with deep learning approaches are very valid to be tested at the practicality stage. This is in accordance with research conducted by Taufiq et al. (2020) the development of the STEM module was validated by media and material experts with a percentage of >85%, which indicates the product is very valid and worth testing at the practicality stage
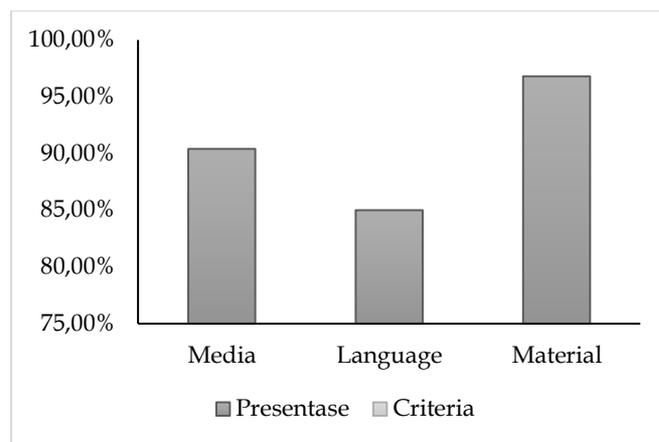

Figure 3. Graph of the results of the media, language and material validity test results

Implementation

The implementation was carried out on junior high school students who had been determined as test subjects. E-modules are used directly in learning activities according to the learning scenarios that have been designed, so that students can interact optimally with the developed e-modules.
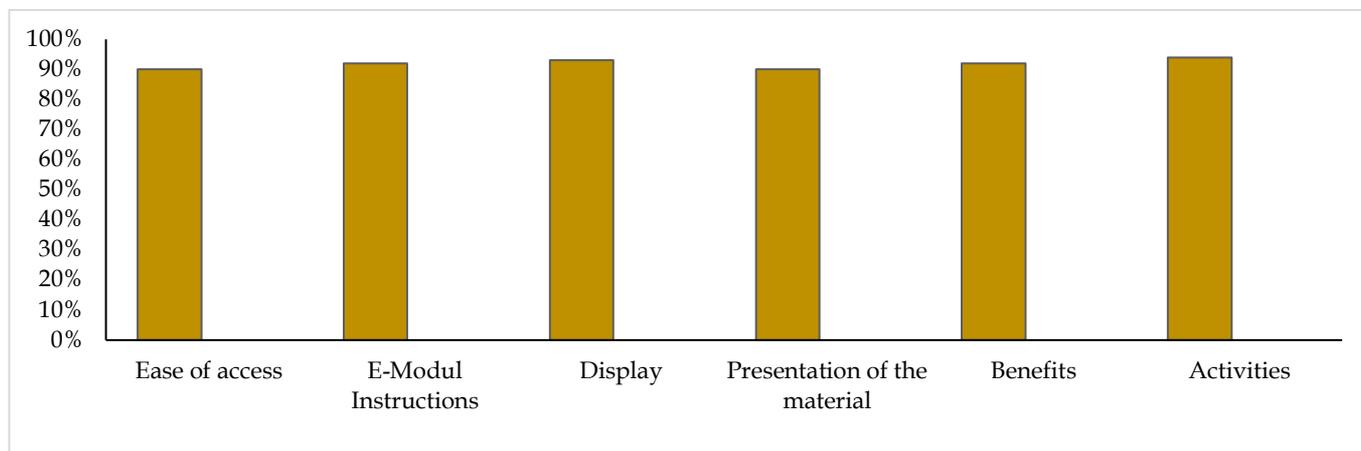
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Figure 4. Graph of the results of the student practicality test

Table 5. Practicality of Student E-Modules

Data	Percentage %	Criteria
Ease of access	90	Very practical
E-Modul Instructions	92	Very practical
Display	93	Very practical
Presentation of the material	90	Very practical
Benefits	92	Very practical
Activities	94	Very practical
Average	91.82	Very practical

Based on the results of the practicality test with students, the results of the practicality test with an average of 91.82% with the category of very practical, it can be concluded that STEM-based E-Modules with a deep learning approach are very practical to be used in the learning process, this is after research conducted by (Santhosh et al., 2023), STEM learning media and tools received a very high positive response from students, demonstrating an excellent level of practicality as they are easy to use, engaging, and support meaningful learning based on real problems.

The effectiveness of STEM-based E-Modules with a deep learning approach

At this stage, STEM-based modules with a deep learning approach are used in broad groups, namely in the classroom. The effectiveness of the product can be determined by the way students are given a Pre test before using the E-module and a Post Test after using the E-module. This effectiveness analysis uses the Ngain (Normalized Gain) value.

Table 6. Comparison of Pre-Test and Post-Test Results

Components	Pre test	Post test
Number of students	32	32
Highest score	80	95
Lowest value	45	75
Average score	62.50	85.63
Percentage %	2813	90.63

Table 7. N-Gain Results

Average Pre Test	Average Post Test	N-Gain	Category
62.50	85.63	0.62	Medium

Based on the results of the N-Gain calculation, an average N-Gain value of 0.62 was obtained which was in the medium category. These results show that the use of STEM-based e-modules with a deep learning approach is able to provide a significant improvement in learning outcomes for students' understanding of the eyes Science lessons.

This increase in learning outcomes can be seen from the increase in students' average scores, from 62.50 in the pre-test to 85.63 in the post-test, as well as an increase in the percentage of learning completeness from 28.13% to 90.63%. This shows that the e-modules developed are effective in helping students understand the material more deeply.

Evaluation

The evaluation stage of the ADDIE model was carried out to assess the quality and effectiveness of STEM-based e-modules with a comprehensive deep learning approach. Evaluations include student learning outcomes, user perception, and product assessments. The results of the analysis showed a significant increase in student learning outcomes, as shown by an increase in the average score from 62.50 (pre-test) to 85.63 (post-test), an increase in learning completeness from 28.13% to 90.63%, and an N-Gain score of 0.62 in the medium category. The perception of teachers and students shows that e-modules are considered practical, attractive, easy to use, and able to increase involvement, motivation, and understanding of science concepts. In addition, product evaluation through validation of material, media, and language experts produces input that is followed up through revisions on aspects of material depth, media display, accessibility flexibility, and linguistic consistency, so that the e-module is declared

valid, practical, and effective for use in science learning at the junior high school level.

Conclusion

Based on the results of the research and discussion, it can be concluded that the development of STEM-based e-modules with a deep learning approach in science subjects in grade IX junior high school using the ADDIE model has been carried out systematically and produced quality products. The e-modules developed are declared very valid based on the assessment of material, media, and language experts, with materials that are in accordance with the curriculum, attractive appearance, clear navigation, and communicative and easy-to-understand language. The results of the practicality test show that the e-module is classified as very practical according to the perception of teachers and students because it is easy to use, attractive, and able to support learning oriented towards the development of critical thinking. In addition, the effectiveness test showed that the use of STEM-based e-modules with a deep learning approach was able to significantly improve student learning outcomes, as shown by the increase in pre-test scores to post-tests and N-Gain scores in the medium to high category. Thus, the e-modules developed are valid, practical, and effective, and have the potential to be an alternative to digital teaching materials that support meaningful, contextual, and skill-oriented science learning in the 21st century.

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Conceptualization, D.K and R.; methodology, D.; software, D.; validation, M.F., M.A. and Y.T.; formal analysis, D.K; investigation, D.K; resources, D.K.; data curation, D.K; writing—original draft preparation, D.K.; All authors have read and agreed to the published version of the manuscript."

Conflicts of Interest
The authors declare no conflict of interest.

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