

DEVELOPMENT OF E-MODULE BASED STEM EDP ON ELEMENTARY SCHOOL STUDENT'S LEARNING PROCESS

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Abstract

This study aims to develop and determine the feasibility and effectiveness of a STEM (Science, Technology, Engineering, and Mathematics)-based e-module using the Engineering Design Process (EDP) approach in elementary science learning. The research employed a Research and Development (R&D) method using the ADDIE model, which consists of five stages: Analyze (identifying needs and student characteristics), Design (designing the structure and content of the e-module), Develop (developing the digital product and conducting expert validation), Implement (testing with fifth-grade students at SDN Gunung Parang, Sukabumi City), and Evaluate (analyzing effectiveness through pre-test, post-test, and student response questionnaires). The subjects were 21 fifth-grade students. Data were collected through interviews, questionnaires, expert validations (material, media, and practitioners), and learning achievement tests. Validation results showed an overall feasibility score of 88% (very feasible), with 79% from material experts, 90% from media experts, and 95% from practitioners. Effectiveness testing indicated an increase in students' average scores from 59.38 (pre-test) to 90.00 (post-test), with an N-Gain value of 0.75 (high category). Therefore, the STEM-EDP-based e-module is declared feasible and effective for improving students' conceptual understanding and critical thinking skills on the topic Light and Its Properties, serving as an innovative alternative learning medium for elementary science education.

Keywords: E-Module; STEM; EDP; ADDIE; Science Learning

Abstrak

Penelitian ini bertujuan untuk mengembangkan serta menguji kelayakan dan keefektifan e-modul berbasis STEM (Science, Technology, Engineering, and Mathematics) dengan pendekatan Engineering Design Process (EDP) pada pembelajaran IPA siswa sekolah dasar. Metode yang digunakan adalah Research and Development (R&D) dengan model pengembangan ADDIE, yang meliputi lima tahap: Analyze (analisis kebutuhan dan karakteristik siswa), Design (perancangan struktur dan konten e-modul), Develop (pengembangan produk digital dan validasi ahli), Implement (uji coba terbatas pada siswa kelas V SDN Gunung Parang Kota Sukabumi), dan Evaluate (analisis efektivitas melalui pretest–posttest dan angket respon siswa). Subjek penelitian terdiri atas 21 siswa kelas V. Data dikumpulkan melalui wawancara, angket, validasi ahli (materi, media, dan praktisi), serta tes hasil belajar. Hasil validasi menunjukkan tingkat kelayakan rata-rata 88% (sangat layak), dengan rincian: ahli materi 79%, ahli media 90%, dan praktisi 95%. Hasil uji efektivitas menunjukkan peningkatan nilai rata-rata siswa dari 59,38 (pretest) menjadi 90,00 (posttest) dengan N-Gain sebesar 0,75 (kategori tinggi). Dengan demikian, e-modul berbasis STEM-EDP yang dikembangkan dinyatakan layak dan efektif dalam meningkatkan pemahaman konsep dan keterampilan berpikir kritis siswa pada materi “Cahaya dan Sifatnya”, serta dapat menjadi alternatif inovatif dalam pembelajaran IPA di sekolah dasar.

Kata kunci: E-Modul; STEM; EDP; ADDIE; pembelajaran IPA

Received : 2025-07-16

Approved : 2025-10-30

Revised : 2025-10-29

Published : 2025-10-31



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Introduction

The Industrial Revolution 4.0 demands that the education system produce a generation with critical, creative, collaborative, and communicative thinking skills. Within this framework,

students are not only required to understand theory but also to be able to implement concepts in real life. Students' ability to comprehend current material is closely related to mental activities, such as analyzing and evaluating information. This includes cognitive processes such as paying attention, categorizing, selecting, and making decisions. Furthermore, students are also expected to develop other skills, such as higher concentration, in-depth analytical skills, and more effective information processing (Kusyanto et al., 2022: 1-6). One approach that can be used to meet these demands is STEM-based learning integrated with the Engineering Design Process (EDP). Science, technology, engineering, and mathematics (STEM) itself is a popular learning approach globally that is effective in implementing integrative thematic learning because it combines four main areas of education: science, technology, engineering, and mathematics (Nurmala et al., 2021: 5024-5034). Therefore, an approach is needed that can encourage students to develop a deeper understanding of concepts. This approach provides students with opportunities to learn through solving real-world problems by designing solutions based on the principles of science, technology, engineering, and mathematics (STEM). However, based on field findings, the learning process still shows limitations in building optimal student understanding. Initial observations at Gunung Parang Elementary School show that science learning still takes place traditionally and does not involve many students actively in practical activities. Limited laboratory facilities and a lack of supporting learning media also contribute to students' low understanding of science material.

According to (Hidayat et al., 2019: 1-9) states that the learning process of students must gain understanding at a complex and reasonable level in a problem concept which is then evaluated for the purpose of a scientific knowledge by using the process of analysis and evaluation. However, not all learning processes will be optimally achieved because for students need learning activities that provide opportunities for discussion, provide many opportunities for students to express their opinions, encourage cooperation in studying and determining knowledge in students. In this learning process, it is important for students cognitive activities, which are related to the use of the mind, learning to think critically, analytically and evaluatively means using mental processes such as attention, categorization, selection, and assessment (Amalia et al., 2021).

By using an approach that is appropriate to learning, it is expected that students can have a scientific attitude and problem-solving skills, both during the teaching and learning process in class and in facing real problems that they will experience. Therefore, in the learning process it is necessary to use other approaches that are appropriate to the needs of students, with this can use the STEM EDP approach that is appropriate to the STEM EDP-based e-module to increase the effectiveness of the learning process. The learning model that combines the STEM approach with this thinking process aims to improve 21st-century skills such as critical thinking, collaboration, and problem solving. In the STEM EDP-based approach, students are invited to directly design and create real products. Learning is carried out in groups and is practice-based, so that students can experience a contextual and applicable learning process. Some concepts that will be implemented in the learning process can be done by compiling an e-module that includes how the entire learning process uses the STEM EDP approach.

In line with previous research which discussed that STEM integration in learning provides opportunities for students to be actively involved in the learning process through discussion and exploration activities (Siregar et al., 2019: 0549). Implementing STEM in learning activities can facilitate students' ability to analyze and evaluate problems. In line with

this, (Kusyanto et al., 2022: 1-16) stated that the application of STEM in learning can facilitate students to improve their problem- solving and creative thinking skills.

Modules are one part of teaching materials that need to be innovated (Fauzan, 2021: 643- 654). This innovation is not only in terms of content, but also must consider other aspects related to the module. One form of innovation in module development is the existence of digital modules. According to (Herawati & Muhtadi, 2018: 180-191) An e-module is a digital module consisting of text and images containing electronic digital material accompanied by simulations suitable for use in learning. Educators, as policy implementers, are expected to carry out their profession optimally in line with global developments. One of the Ministry of Education and Culture's policies that teachers must implement is the creation of e-modules as teaching materials that can be used in schools. (Triyono, 2021). In line with this understanding (Pakpahan et al., 2022: 440-453) An e-module is a module in electronic format that is run on a computer. Technological advances have also made it possible to display e-modules on smartphones. Based on the definitions above, an e-module is a module that contains learning materials in digital form. This e-module can support classroom learning activities and assist educators in planning their learning processes.

The application of the STEM approach to science learning, in particular, provides a platform for training students to improve their higher-order thinking skills as part of 21st-century skills through the contexts offered by the STEM approach. The STEM approach is often interpreted as the integration of four disciplines, according to its acronym: Science, Technology, Engineering, and Mathematics. (Muttaqiin, 2023: 34-45), so that in its implementation STEM learning often involves the four elements of the discipline. Based on the definitions above, it can be concluded that STEM- based learning will shape the character of students who are able to recognize a concept or knowledge (Science) and apply that knowledge with the skills (Technology) they have mastered to create or design a method (Engineering) with analysis based on mathematical data calculations (Mathematics) in order to obtain solutions to solving a problem. The STEM approach to science learning has been widely applied in the classroom as an effort to support the implementation of the current curriculum in Indonesia. Student-centered learning is used as a method to implement science learning in order to prepare graduates to be able to have various skills that must be mastered in the 21st century.

STEM is an effective approach to implementing integrated thematic learning because it combines four core areas of education: science, technology, engineering, and mathematics. The application of STEM can help develop knowledge by answering questions based on investigation and helping students create new knowledge. Furthermore, the application of STEM can also improve students' critical thinking skills, characterized by the ability to solve problems, make decisions, analyze assumptions, and evaluate (Khoiriyah, 2018). In fact, the application of STEM is also able to encourage students to create something new (Fathoni et al., 2020: 33-42). Furthermore, the Engineering Design Process (EDP) is a pedagogical education that is applied to students (Widiastuti & Budiyanto, 2022). With EDP-based learning, students will enhance their experience of design knowledge. Through the application and skills of engineering with the Engineering Design Process (EDP), students will be able to learn independently and develop design literacy. In elementary schools, EDP learning focuses on idea generation, and teachers focus on redesign. STEM learning involves students in the design process. Design is an integral part of students' thinking in the STEM world. STEM has one characteristic that must be visible in the learning process, namely the Engineering Design Process (EDP). In the opinion of ABET (Accreditation Board for Engineering and Technology), EDP explains that the process of designing a system, component, or process to meet the desired

needs. EDP is a learning method that introduces students to engineering skills. Students are taught to be able to analyze real-world problems using the knowledge they have acquired and then provide solutions in the form of products. (Wibowo et al., 2024: 389-398).

Although the Engineering Design Process (EDP)-based STEM approach is theoretically considered effective in improving 21st-century skills such as critical thinking, creativity, problem-solving, and engineering literacy, the reality on the ground shows that its implementation at the elementary school level is still not optimal. Many teachers still rely on conventional learning methods due to limited understanding of the concepts and stages of EDP. In addition, learning activities in elementary schools are generally not fully integrated with the engineering design process, so the essence of the EDP-based STEM approach has not been fully achieved, as well as the diversity of student readiness in participating in the project-based learning process. On the other hand, project-based learning activities as a form of real application of EDP are still rarely carried out due to limited learning time, facilities, and available resources, and the minimal availability of STEM EDP-based teaching modules also hinders effective implementation. Furthermore, a systematic review by Sutisnawati et al. (2025) shows that although the STEM-based EDP approach has great potential in improving STEM literacy, its implementation in elementary schools still faces various challenges, especially in terms of teacher readiness and limited resources. Therefore, there needs to be a systematic effort to develop learning models and supporting media that can facilitate the effective implementation of EDP in elementary school environments.

According to (Ulum et al., 2021: 50-55) With STEM, this consists of six stages: define, learn, plan, try, test, and decide. Combining the STEM approach in EDP aims to improve students' EDP skills in solving problems and providing solutions. This approach allows students to develop their own critical and creative thinking through a structured learning process using teaching materials in the form of modules. According to (Widiastuti & Budiyanto, 2022) The EDP (Engineering Design Process) approach in the learning process can create new activities that teach students about engineering design concepts. (Khasanah et al., 2023: 682-290) "Define" is the process of defining the phenomenon that occurs. "Learn" is the application of scientific concepts to solve problems. "Plan" involves formulating a solution by connecting scientific concepts. "Try" includes implementing a solution based on information relevant to the problem, while "Test" involves re-evaluating the design based on that information. "Decide" refers to the process of drawing conclusions about the strengths and weaknesses of a design based on previously obtained information. Although theoretically, the Engineering Design Process (EDP) stages in the STEM approach, such as define, learn, plan, try, test, and decide, are designed to create a structured, problem-solving-oriented learning process, their implementation in the field is still not optimal. In practice, these stages are often not fully implemented. Teachers tend to focus on the initial stages, such as define and learn, while more advanced stages, such as test and decide, are often neglected due to time and resource constraints. Furthermore, teachers' understanding of each EDP stage is still limited, so its implementation is not fully achieved. Teaching materials used in schools are also not fully structured according to the EDP flow, so learning tends to be instructional rather than exploratory, and this is due to limited time and supporting resources. Therefore, it is necessary to develop teaching materials that can facilitate the implementation of the EDP stages as a whole, such as the development of STEM-EDP-based e-modules designed according to the characteristics and needs of students at the elementary school level.

Science learning prioritizes cultivating and empowering students as lifelong learners. Learning must take into account the ever-evolving conditions and demands of the environment and align with the direction of holistic human development. This STEM-based approach does not have a specific syntax or steps for implementation, as STEM is an approach, not a learning model. According to (Widiastuti & Budiyanto, 2022), STEM has a pattern known as EDP (Engineering Design Process), or a process for designing a work. Students are taught to analyze real-world problems using the knowledge they have acquired and then provide solutions. By using this STEM approach, students' hard and soft skills can be developed, because learning using this STEM approach is carried out actively, namely with a method of problem solving, collaboration, creativity, critical thinking, and how to communicate between groups. (Zulfa et al., 2022: 43-49). By engaging students in learning activities, the EDP approach can provide opportunities to apply STEM knowledge and skills in real-life contexts, strengthening their understanding of science concepts and increasing their engagement in learning. EDP should not only be adopted in STEM teaching, but also has great potential to positively influence students' cognitive and non-cognitive characteristics that are crucial for achieving STEM literacy. Efforts are needed to integrate EDP in schools, aiming not only to improve student achievement but also to address the limited STEM awareness among teachers.

An e-module is a digital module containing learning materials. This e-module can support classroom learning activities and assist educators in planning their learning processes. Furthermore, learning using the STEM approach is carried out actively, using problem-solving methods, collaboration, creativity, critical thinking, and communication between groups (Zulfa et al., 2022: 43-39). By involving students in learning activities, this EDP approach can provide opportunities to apply STEM knowledge and skills in real contexts, strengthening understanding of science concepts, especially in the material of Chapter 1 topic A "light and its properties." Similar research has been conducted by several previous researchers, including (Utami et al., 2018: 165-172) namely the development of a mathematics module with a science, technology, engineering, and mathematics (STEM) approach on the subject of quadrilaterals. The results of the study indicate that the assessment from experts is very appropriate, and the responses of students and teachers are very interesting. It can be concluded that in this study, the measured results show that the assessment from experts is in the very appropriate category, and the measured responses from students and teachers are in the interesting category. These findings strengthen the basis of the current research, as well as being a reference for the preparation of this research. The difference between previous research and the research to be conducted is that the researcher developed an electronic module (e-module) based on STEM EDP in the learning process of elementary school students on the subject of light and its properties.

Research Methods

The research conducted by the researcher is a type of Research and Development (R&D). According to Sugiyono (2019, p. 297), research and development methods are used to produce specific products and test their effectiveness. Research and Development (R&D) is the process or steps taken to develop a new product or improve an existing one. Research and Development is a research method aimed at producing specific products. Through research, solutions to educational problems can be found, allowing for the development and application of more innovative education. One such method is research and development (R&D) (Okpatrioka, 2023: 86-100). Thus, R&D in education is the process of developing a product and determining its validity. Therefore, this research is a type of research and development (R&D)

aimed at developing a product in the form of a STEM- based EDP e-module and testing its effectiveness, or validation. Validation was conducted by subject matter experts, media experts, and fifth-grade teachers, then tested on fifth-grade elementary school students to determine or demonstrate its validity.

The development model used is ADDIE, an acronym for Analyze, Design, Development, Implementation, and Evaluate. This model was developed in the 1970s and is commonly used for product development or instructional design models. According to Mariam & Nam (2019), this model is commonly used in the context of developing performance-based learning products. The stages of the ADDIE model include:

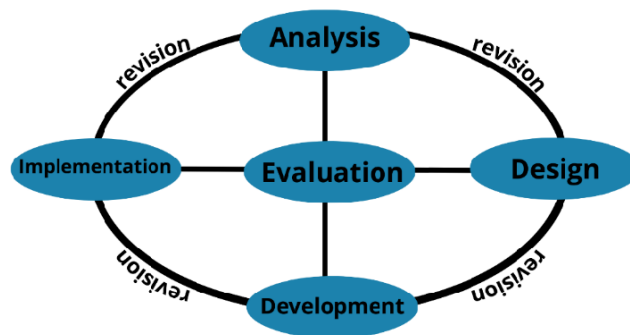


Figure 1. ADDIE Research Stages

This study employed several instruments and indicators to assess the feasibility and effectiveness of an e-module developed for the topic “Light and Its Properties.” The research instruments included expert validation, a student response questionnaire, and learning outcome tests consisting of a pretest and a posttest. Expert validation involved three groups of evaluators: material experts, media experts, and practitioners or teachers. Material experts assessed the suitability of the content with core competencies, the accuracy of scientific concepts presented, and the depth of the material. Media experts evaluated the e-module’s appearance, interactivity, clarity of navigation, and ease of use. Meanwhile, practitioners or teachers assessed the integration of the e-module with classroom learning needs, the appropriateness of the language used, and the ease of implementation in teaching activities.

The student response questionnaire was used to obtain learners’ feedback regarding the e-module. The indicators included attractiveness of appearance, ease of use, clarity of language, relevance of the content to the topic “Light and Its Properties,” and the usefulness of the module in supporting conceptual understanding. The learning outcome test, consisting of a pretest and a posttest, aimed to measure students’ conceptual improvement before and after using the e-module. The indicators measured included the ability to understand the concept of light and its properties, the ability to apply the concept in everyday life, and problem-solving skills based on the Engineering Design Process (EDP) approach. All research instruments were analyzed using a Likert scale (1–5) to determine the e-module’s feasibility. The effectiveness of the e-module was tested using the N-Gain and Paired Sample t-Test to identify improvements in student learning outcomes after the implementation of the e-module. The development of the e-module followed a series of interrelated stages (Waruwu, 2024: 1220–1230). The subjects of this study were 21 fifth-grade students from SDN Gunung Parang, Sukabumi City.

Data collection techniques included both qualitative and quantitative approaches. Qualitative data were obtained through teacher interviews, classroom observations, and

feedback from the validation process conducted by material experts, media experts, and practitioners. Quantitative data were derived from expert assessments, student responses, and pretest–posttest results. The data were analyzed both qualitatively and quantitatively. Qualitative analysis was used to assess the feasibility of the e-module based on expert validation and student responses, while quantitative analysis was applied to determine the effectiveness of the e-module by comparing students' learning outcomes before and after its use in the learning process. The assessment used in this study was a Likert scale with 5 categories which can be seen in the following table:

Table 1. Likert Scale Assessment

Criteria	Score
Very good	5
Good	4
Enough	3
Not enough	2
Very less	1

(Source: Damayanti, A. E., Syafei, I., Komikesari, H., & Rahayu, R. 2018)

Calculate the percentage score using the following formula:

$$\text{Percentage score (P)} = \text{Total Score} / \text{Maximum Score} \times 100\%$$

Calculate the average validation score using the following formula:

$$\text{Average of percentage (P)} = \text{Total percentage} / \text{Number of validators}$$

The calculation of the feasibility value from the percentage score results obtained in the research is interpreted in the following criteria:

Table 2. Eligibility Criteria

Percentage Score	Criteria
80%-100%	Very Eligible
60%-80%	Eligible
40%-60%	Quite Eligible
20%-40%	Less Eligible
0%-20%	Very Less Eligible

The N-Gain calculation is obtained from the pretest and posttest scores, to calculate the N-Gain using the formula and assessment categories for the N-Gain score can be seen as follows:

$$\text{Formula: N-Gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}}$$

Table 3. N-Gain Categories

N-Gain Value	Category
$g > 0,7$	High
$0,3 < g < 0,7$	Medium
$g < 0,3$	Low

(Source: Wahab, A., Junaedi., & Azhar, M. 2021)

Result And Discussion

This study aims to describe the feasibility and effectiveness of a STEM (Science, Technology, Engineering, and Mathematics)-based e-module using the Engineering Design Process (EDP) approach in Natural Science (IPA) learning in elementary schools. The

development model used in this study is the ADDIE (Analyze, Design, Development, Implementation, and Evaluate) model.

The analysis phase served as the basis for determining the development needs for STEM-based e-modules in the EDP. Through interviews with fifth-grade teachers and direct field observations, it was discovered that the learning process remained conventional and did not actively engage students in practical activities. The dominant approach was scientific and problem-based learning (PBL), which was not fully effective in developing 21st-century skills such as critical thinking, collaboration, creativity, and communication (Kusyanto et al., 2022). In addition, the limitations of learning media and facilities and infrastructure also become obstacles in the process of students' understanding of science material, especially on the topic of "Light and its Properties". Therefore, a learning innovation is needed through learning that can answer these challenges to increase the effectiveness of learning in the classroom, one of which is through an e-module based on the STEM approach integrated with the Engineering Design Process (EDP). This is appropriate because it emphasizes the active involvement of students in solving real problems in the learning process (Widiastuti & Budiyanto, 2022).

After conducting the needs analysis, the next stage is planning, which involves the initial design of the e-module to be developed. This design is conceptual and includes the development of an e-module content framework, the selection of key materials, and a structured presentation scheme. At this stage, the e-module framework is developed, focusing on the fifth-grade science material, Chapter 1, Topic A, "Light and Its Properties." Each section of the e-module is designed to align with the EDP stages: define, learn, plan, try, test, and decide, so that students can actively engage in the learning process. (Ulum et al., 2021). (Khasanah et al., 2023: 682-690), In addition, the module framework design is also designed by considering the characteristics of elementary school students, so that the presentation of the material uses simple language, attractive visuals, the presentation of the material in the e-module considers the integration between the fields of science, technology, engineering, and mathematics, and pays attention to the characteristics of students at the elementary school level so that the material is easy to understand and interesting. This approach is believed to be able to improve students' conceptual understanding and encourage the achievement of 21st century skills as a whole (Khoiriyah, 2018) dan (Zulfa et al., 2022: 43-49). Planning as shown below:

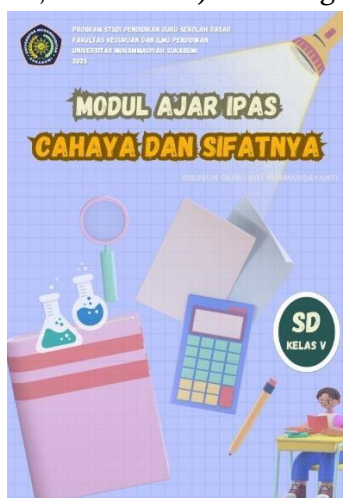


Figure 2. Cover Page

The development stage is the process of realizing the conceptual design of the e-module into a digital product ready for testing and validation. The e-module is developed using STEM

principles integrated with the Engineering Design Process (EDP) stages. At this stage, researchers develop all learning components, from content and visualizations to project-based and collaborative learning activities. The e-module product encompasses the EDP steps from define to decide, ensuring students not only understand the concept but also apply it in real-world contexts. (Khasanah et al., 2023: 682- 690). This module is also divided into three main chapters that are arranged systematically and thematically according to the desired objectives. Each chapter contains material presented in an interesting and easy-to-understand manner, also complemented by simple practical activities along with steps that can be done by students in groups. The goal is to increase active student involvement in the learning process, as well as help provide a deeper understanding through direct experience. At the end of the chapter in the module, multiple-choice practice questions are provided as a means of evaluation to determine the achievement of students' understanding of the material that has been studied previously. And also equipped as part of the closing is presented a summary of the material that discusses the explanation of the material in each chapter. This aims to help students review their understanding of the material more concisely.

After the development process, the e-module was validated by material experts, media experts, and practitioners (grade V teachers) to assess its suitability in terms of content, presentation, and usability in the context of elementary school learning. The assessment was conducted using a validation sheet instrument that covered several aspects, including clarity, suitability, presentation, and readability of the module. The validation results showed that the e-module obtained an average feasibility score of 88% (very feasible), with the following breakdown: material experts 79% (feasible), media experts 90% (very feasible), and practitioners 95% (very feasible). This score falls into the "very suitable" category (Damayanti et al., 2018), Thus, the e-module is declared ready to proceed to the implementation stage. The validation results are also presented in the table below:

Table 4. Expert Validation Results

No.	Name	Score	Ideal Score	Presentation	Expert Validation Results	Category
1	Expert Validation 1	38	48	100%	79%	Feasible
2	Expert Validation 2	36	40	100%	90%	Very Feasible
3	Practitioner Validation	38	40	100%	95%	Very Feasible
	Amount	112	128	100%	88%	Very Feasible

After expert validation, the e-module was revised based on their suggestions, criticisms, and input. The results of the revisions are presented in the following table:





Figure 3. Slide module

E-modules can be visited and viewed via the following link: <https://www.edustemedp.site/cahaya>

After being declared feasible, the e-module was implemented in science lessons for fifth-grade students at Gunung Parang Elementary School, involving 21 students, specifically on the topic "Light and Its Properties." The implementation phase aimed to assess student responses, the effectiveness of the e-module, and student engagement during the learning process. The implementation process was carried out through a series of lessons that followed the EDP structure in the e-module. Students followed the process from defining the problem (define), learning the concept (learn), designing a solution (plan), creating and testing the solution (try and test), and evaluating the results (decide). This process integrated project-based activities, group discussions, and real-life problem-solving. This phase began with a brief discussion of the learning activities and filling out a test sheet with the instructions provided to gauge student understanding of the material before more detailed explanations were provided. Next, students were given an initial understanding of the learning process consistent with the module. Afterward, students and researchers conducted the learning process, consistent with the module design, from beginning to end. After the learning activities, students were asked to complete the test sheet again to assess changes in their learning achievement. Pre- and post-learning data were analyzed to determine the effectiveness of the module development. The implementation results showed an increase in student engagement and enthusiasm in participating in the learning process. Furthermore, students also completed a student response questionnaire to assess the feasibility of the developed e-module, with very positive results, according to the student responses, which obtained a score of 88%, in the very feasibility category, mainly because the e-module was designed with attractive visuals, communicative language, and was easy to understand. (Zulfa et al., 2022: 43-49).

The evaluation stage, after field implementation, is conducted to measure the level of achievement of learning objectives and the effectiveness of the e-module in supporting the learning process. This evaluation stage generates data obtained through pre- and post-tests administered to students, as well as questionnaires. The data collected was analyzed using SPSS version 25. The assessment consisted of 10 questions covering six aspects of the EDP indicators: define, learn, plan, try, test, and decide. The analysis was as follows:

Table 5. Normality Test Results

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	,113	21	,200*	,944	21	,264
Posttest	,198	21	,031	,927	21	,119

Based on the results of the Shapiro-Wilk normality test, the significance value for the pretest was 0.264, while the posttest was 0.119. Both values are greater than 0.05 ($0.264 > 0.05$ and $0.119 > 0.05$), indicating that the pretest and posttest data were normally distributed. Furthermore, to determine whether there was a significant difference in improvement between the pretest and posttest from the use of e-modules in the STEM EDP-based learning process, a paired sample t-test was conducted using SPSS version 25, as follows:

Table 6. Paired Sample Statistics Test Results

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	59,38	21	7,560	1,650
	Posttest	90,00	21	4,074	,889

Based on the data in the table above, the average score before (pretest) using the STEM EDP- based e-module in the learning process was 59.38, while after (posttest) it increased to 90.00, with a difference of 30.619. This statement indicates an improvement in learning outcomes.

Table 7. Paired Sample T-Test Results

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Pretest	-30,619	6,492	1,417	-33,574	-27,664	-21,613	20	,000
	Posttest								

Based on the data obtained above, the significance value is $0.000 < 0.05$. This statement indicates a significant increase between the scores before (pretest) and after (posttest) the use of the STEM EDP-based e-module. Thus, this proves that the use of the e-module has a significant impact on student learning. Furthermore, the data from the pre- and post-questionnaire were analyzed using the N-Gain test with SPSS version 2. The following table shows:

Table 8. N-Gain Test Results

<i>Descriptive Statistics</i>					
	N	Minimum	Maximum	Mean	Std. Deviation
NGain	21	,56	,87	,7544	,09077
Valid N (listwise)	21				

Based on the trial results, there was an increase in the average student score from 59.38 in the pretest to 90.00 after the posttest. The effectiveness of the STEM EDP-based e-module was measured through an N-Gain analysis, which compared scores before and after module use. The results obtained an average N-Gain score of 0.7544 or 75.44%, which is classified as

high (Wahab et al., 2021: 112–121). Furthermore, a paired-sample t-test showed a significance value of less than 0.05, indicating a significant difference between the pretest and posttest scores. These findings indicate that the STEM EDP-based e-module is effective in improving students' mastery of science concepts and critical thinking skills. Student responses to the use of the e-module were also very positive, as they felt the module facilitated understanding of the material. Overall, the e-module proved to have a positive impact, and teachers also provided feedback in the form of evaluations that included feedback from students and teachers to improve the content, visual appearance, and activities in the module for future optimization.

The research shows that the STEM-based e-module using the Engineering Design Process (EDP) approach is highly feasible and effective in supporting science learning in elementary schools. The module's feasibility was demonstrated through validation results by subject matter experts, media experts, and practitioners, with an average score of 88% (very feasible). This indicates that the e-module's content, presentation, and usability meet appropriate learning standards for elementary school students. Developing the e-module, which considers student characteristics and integrates STEM elements into each stage of the EDP, is a key factor supporting this feasibility.

Empirically, the e-module's effectiveness was evident in the improvement of student learning outcomes on the topic “Light and Its Properties.” The average pretest score of 59.38 increased to 90.00 in the posttest, with statistical significance at $p < 0.05$, indicating a significant improvement in learning outcomes. The N-Gain test result of 0.75 (high category) further confirms the e-module's effectiveness in improving students' conceptual understanding and critical thinking skills. Furthermore, student responses to the use of e-modules were very positive, as evidenced by a questionnaire score of 88%, showing that students found the engaging visualizations, communicative language, and hands-on learning activities helpful in understanding the material.

The findings of this study are consistent with those of Wahab et al. (2021) and (Wibowo et al., 2024), which demonstrated that the STEM–EDP approach significantly enhances higher-order thinking skills and student learning outcomes. This alignment indicates that integrating scientific inquiry and engineering design provides meaningful learning experiences by involving students directly in solving problems and creating designs.’

However, these results differ slightly from the study by Utami et al., (2018), who developed a STEM-based mathematics module and found a smaller improvement in critical thinking skills. This difference may stem from the contextual nature of science subjects, which allow direct application of STEM–EDP principles through simple experiments. Hence, the high effectiveness observed in this study suggests that science, as a contextual and experimental field, is more suitable for EDP integration compared to abstract disciplines like mathematics.

The increase in learning outcomes also supports Kusyanto et al., (2022), who argue that STEM-based learning promotes 21st-century competencies—particularly critical, creative, and collaborative thinking—because it offers structured opportunities for exploration, experimentation, and reflection. Therefore, the STEM–EDP-based e-module not only meets technical feasibility standards but also has strong pedagogical relevance for developing higher-order thinking skills (HOTS) among elementary students.

This research provides several practical implications for teachers, especially in schools with limited laboratory facilities. The STEM–EDP-based e-module serves as an interactive and innovative learning medium that replaces laboratory experiments with easily implemented project-based activities. Through simple engineering design projects, students can engage in

scientific exploration using readily available materials, reducing dependency on costly laboratory equipment.

Furthermore, the e-module offers a structured guide for teachers to implement project-based learning aligned with the EDP stages—from defining the problem to evaluating students' design outcomes. This structure simplifies lesson planning and helps teachers conduct active, inquiry-based learning more effectively. Consequently, the e-module supports the creation of participatory, contextual, and problem-solving-oriented classrooms.

In conclusion, the STEM-EDP-based e-module not only enhances students' conceptual understanding but also provides teachers with a practical, low-cost solution for delivering engaging science lessons in resource-limited contexts. Future studies are encouraged to apply the module across different topics and school environments to broaden its impact and generalizability.

The sample size of this study was relatively small, consisting of only 21 fifth-grade students from one elementary school. This may limit the generalizability of the research results to a broader context. Therefore, further research is recommended to involve more schools and diverse participant characteristics to enhance the external validity of the research results.

Conclusion

Based on the research and analysis conducted, it can be concluded that the e-module based on the STEM (Science, Technology, Engineering, Mathematics) approach integrated with the Engineering Design Process (EDP) stages is highly feasible and effective in supporting Natural Science (IPA) learning in elementary schools. Validation by subject matter experts, media experts, and practitioners showed an average score of 88%, categorized as "very feasible," reflecting the module's suitability in terms of content, presentation, and usability in the learning context. Implementation of the e-module demonstrated a significant improvement in student learning outcomes, as evidenced by pretest and posttest results, with an average score increasing from 59.38 to 90.00. The Paired Sample t-test showed a significance level of 0.000 ($p < 0.05$), confirming a statistically significant difference. Furthermore, the N-Gain analysis of 0.7544 (high category) supports the effectiveness of the e-module in improving students' conceptual understanding. Furthermore, student responses to the e-module were very positive, with a feasibility score of 88%. This reflects student preference for the e-module due to its engaging visuals, communicative language, and actively engaging learning activities. Thus, this e-module not only improves learning outcomes but also fosters critical thinking, collaborative learning, and problem-solving skills, essential for 21st-century learning.

Similar e-modules are recommended for other materials or themes in science subjects, to expand the application of the STEM-EDP approach and strengthen the overall quality of learning. Educators and education practitioners are expected to utilize this e-module as an innovative learning medium that supports the development of 21st-century skills, particularly through the application of project-based learning and contextual problem-solving. Improvements to the e-module's visuals and interactivity are needed, such as the addition of animations, simulations, or interactive quizzes, to further engage students and increase their engagement in the digital learning process. Further research is recommended to be conducted involving more diverse subjects, both in terms of number and school background, so that the findings have broader generalizability and are able to provide a greater contribution to the development of STEM-EDP-based digital learning media.

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