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ORIGINAL RESEARCH

Development of a project-based learning e-module incorporating socioscientific issues (SSI) on the topic of energy sources in life: understanding environmental impacts

Muhammad Ridho Syarlisjiswan, Irwandani Irwandani, Susiwiasih Susiwiasih, Anggi Widiarni

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Abstract
Education must be innovative to remain relevant to technological developments. Integrating technology into learning materials can enhance student engagement and critical thinking skills. This study aims to develop and evaluate the feasibility and attractiveness of a Project-Based Learning (PjBL)-based e-module incorporating Socio-Scientific Issues (SSI) on the topic of energy sources. The research method used is Research and Development (R&D) with the ADDIE model. The e-module was revised based on evaluations by content and media experts. The trial was conducted with physics educators and 10th-grade high school students. Data was collected using a Likert-scale questionnaire. The results showed that the e-module is highly feasible, with a score of 84% from content experts and 92% from media experts. Educators rated its attractiveness at 83%, while student responses averaged 85% in small-group trials and 82% in field trials. This e-module has the potential to be an innovative solution in physics education, particularly for topics related to socio-scientific issues. The implementation of this e-module is expected to promote more contextual and meaningful learning for 10th-grade high school students.

Keywords: ADDIE · E-Modul · Project Based Learning (PjBL) · Socio-Scientific Issues (SSI)

INTRODUCTION

The rapid advancement of technology has significantly impacted various aspects of human life, particularly in the field of education (Chen, 2022; Papert, 1987). The integration of digital technology into the learning system has become an urgent need to improve the quality of education, actively engage students, and develop critical thinking skills (Changwong et al., 2018). This has driven major changes in learning models and educational paradigms. Technology-enhanced learning models not only address the challenges of modern learning environments but also align with the demands of the 21st century (Mowery et al., 2010) especially in facing global challenges such as climate change and the energy crisis (Pfenninger et al., 2014) Technology-based learning models such as flipped classroom (Al Faqih et al., 2023; Hwang et al., 2015), blended learning (Xiong, 2023), problem-based learning (Basilotta Gómez-Pablos et al., 2017; Tambouris et al., 2012), and project-based learning (Stouthart et al.,

✉ Muhammad Ridho Syarlisjiswan
syarlisjiswan@radenintan.ac.id
Irwandani
irwandani@radenintan.ac.id
Susiwiasih
susiwiasih18@gmail.com
Anggi Widiarni
anggiwdyb@gmail.com

Physics Education, UIN Raden Intan Lampung, Lampung, Indonesia.

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2023) have become key factors in students' success in absorbing the knowledge delivered by teachers.

One of the technology-integrated learning models that has shown a significant impact on the learning process is Project-Based Learning (PjBL) (Distyasa et al., 2021) PjBL has been proven effective in enhancing student engagement (Hussein, 2015), conceptual understanding (Fini et al., 2018), and higher-order thinking skills (Ali, 2024; Billah et al., 2019). PjBL requires students not only to grasp fundamental concepts but also to develop innovative solutions to the problems presented (Haryani et al., 2021). It fosters the development of collaboration skills (Hussein, 2021) communication (Owens & Hite, 2022), learning experiences (Johnson & Griffin, 2024), critical thinking (Sari & Prasetyo, 2021), and creativity (Chen et al., 2022), which are all essential 21st-century competencies. PjBL enables students to learn actively through in-depth investigations and solving real-world problems relevant to their daily lives.

The Project-Based Learning (PjBL) model places students at the center of the learning process by providing them with opportunities to engage in project-based activities designed to solve real-world problems (Rasyid et al., 2023). The integration of Socio-Scientific Issues (SSI) into PjBL further enriches this approach by offering socially relevant learning contexts (Maolida et al., 2024; Wahono et al., 2021) SSIs such as climate change (Dawson & Carson, 2020; Peel et al., 2017), energy crises (Frilingou et al., 2023; Goodman, 2018), and public health concerns (Foulk et al., 2020; Lee, 2012) encourage students to connect scientific knowledge with societal challenges (Sadler & Donnelly, 2006) Within the PjBL framework, SSI can serve as a project context that motivates students to understand the relationship between science and society (Reswara et al., 2024). This combination fosters critical thinking, encourages the evaluation of diverse perspectives, and promotes the development of science-based, ethical, and relevant solutions to everyday and environmental issues.

The application of PjBL and SSI in education can be further optimized through the integration of technology (Hernández-Ramos et al., 2021). Technology offers interactive, engaging, and efficient media to support both project-based and socio-contextual learning (Afzal & Tumpa, 2025; Wahyudi et al., 2025; Wei, 2023). One practical implementation is through digital learning modules or e-modules (Muda et al., 2025), which are designed to incorporate both PjBL and SSI elements. E-modules provide flexibility in content delivery through various interactive features such as text, images, videos, and simulations which allow students to learn both independently and collaboratively (Holisoh et al., 2023) Moreover, e-modules facilitate more comprehensive assessments through technology-based features such as interactive quizzes, digital project tasks, and student data analytics.

In the context of physics education, the development of SSI-based e-modules has been widely studied, especially in topics related to environmental issues (Chusni et al., 2024; Tullah et al., 2025), global warming (Syarlisjiswan et al., 2024; Utami et al., 2023), and chemical changes using problem-based learning (Fitri & Asrizal, 2023; Muntari et al., 2024) and POGIL models (Rokhim et al., 2023). However, to the best of the researchers' knowledge, no previous studies have explored the development of an e-module based on Project-Based Learning (PjBL) that incorporates Socio-Scientific Issues (SSI) specifically on the topic of energy sources.

Therefore, this study aims to develop and evaluate the effectiveness of an e-module based on Project-Based Learning (PjBL) that incorporates Socio-Scientific Issues (SSI) on the topic of energy sources. This research is expected to produce an e-module that enhances students'

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understanding of energy concepts, as well as their critical and analytical thinking skills in the context of socio-scientific issues.

METHOD

This study employed a Research and Development (R&D) method aimed at determining the feasibility and developing a PjBL-based e-module incorporating Socio-Scientific Issues (SSI) on the topic of energy sources. The development model applied was ADDIE (Analysis, Design, Development, Implementation, and Evaluation). The selection of the ADDIE model was based on its advantages in offering a structured and easy-to-understand process, which allows for evaluation at each stage of development, thus ensuring the final product meets high-quality standards. The research procedures in this study are as follows:

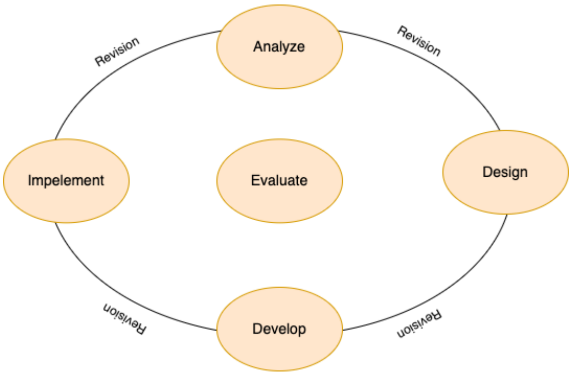

Figure 1. Research procedure adapted from (Branch, 2009)

The initial step of this research was the analysis phase, which aimed to identify potentials and problems, and determine the most appropriate and relevant solutions. The second step, design, involved determining the design ideas for the e-module, starting with the selection of colors, fonts, and cover for the e-module. The product planning stage included compiling the content and planning the structure of the media. The third stage, development, was carried out by developing the e-module product based on the design created in the previous stage. This phase also included product validation by media experts and subject matter experts. The fourth stage, implementation, involved small group trials and field testing. The final stage, evaluation, was conducted in two phases: first, through validation by content and media experts, and second, through small-scale trials in the implementation stage using student response assessments.

Data Collection Instruments

The instruments used in this research were interviews and questionnaires. The questionnaires were divided into three types: (1) expert validation sheets for content and media experts, (2) teacher response questionnaires for field testing, and (3) student response questionnaires for both small group and field testing. The research sample consisted of 29 tenth-grade students from SMA Negeri 1 Ambarawa and 27 students from SMA Negeri 1 Pagelaran.

Data Analysis Technique

The data analysis technique was used to determine the feasibility of the developed e-module product. The data in this study were collected using a Likert scale ranging from 1 to 5, with 1

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being the lowest score and 5 the highest. Table 1 presents the criteria for Likert scale assessment.

Table 1. Assessment Criteria

Criteria	Score
Very Good	5
Good	4
Fair	3
Poor	2
Very Poor	1

After obtaining validation data from the experts, the feasibility percentage for each item was calculated using the Equation 1.

$$P = \frac{\Sigma x}{\Sigma xi} \times 100\% \quad (1)$$

Description : P = Percentage Score; $\sum x$ *= Total response score for an item;* $\sum x_i$ *= Total ideal score for the item;*

The percentage data obtained is then converted into qualitative data based on the assessment criteria presented in Table 2.

Table 2. Score Interpretation Criteria

Score Interval	Criteria
81% ≤ P ≤ 100%	Very Good
61% ≤ P ≤ 800%	Good
41% ≤ P ≤ 60%	Fair
21% ≤ P ≤ 40%	Poor
0% ≤ P ≤ 20%	Very Poor

RESULT AND DISCUSSION

Analysis Stage

The analysis stage aims to identify challenges in physics learning and to explore the potential integration of technology into instruction. Based on surveys and interviews conducted at a public senior high school (SMA Negeri 1 Ambarawa), it was found that 62.3% of students felt less engaged and motivated by the use of conventional printed textbooks. The majority of students expressed the need for innovative digital learning materials to support their understanding of the subject matter. In addition, supporting infrastructure such as projectors, smartphones, and Wi-Fi indicated that the school is ready to implement technology-based learning.

Evaluation at this stage involved an in-depth analysis of both student and teacher needs. The results showed that several topics in printed textbooks tended to be overly theoretical and lacked relevance to real-life contexts. Furthermore, the lack of interactive teaching methods was identified as a contributing factor to students' low engagement. To address this issue, the initial planning focused on developing a digital learning module based on Project-Based Learning (PjBL) incorporating Socio-Scientific Issues (SSI), with the aim of providing more relevant, contextual, and project-oriented learning experiences.

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Moreover, an evaluation of the school's infrastructure ensured that the digital learning tools designed could be effectively implemented. This involved assessing the availability of technological devices and providing teacher training to support the use of digital learning materials. Based on the findings from the analysis and evaluation, improvements were planned by designing an interactive e-module, integrating multimedia, and presenting content that is more applicable to everyday life. This approach is expected to meet students' learning needs and address the demands of 21st-century education. This research is in line with the findings of Widayanti et al., (2022) who analyzed the learning models used by teachers in schools.

Design Stage

The design stage focused on planning a Project-Based Learning (PjBL) e-module incorporating Socio-Scientific Issues (SSI), tailored to the functional and engaging needs of both students and educators. The e-module was designed to cover the topic of energy, ranging from the basic concepts of energy sources to their impacts on the environment and society. Key features designed in the e-module included an attractive and interactive layout, integration of multimedia such as videos, animations, and simulations, as well as project activities grounded in real-world contexts relevant to SSI.

Evaluation during the design stage indicated that adjustments to the module layout and structure were necessary to ensure better readability. Several modifications were made, including changes to colors and font types to enhance reading comfort, the addition of navigation icons to help users explore the module more easily, and a review of the project content to ensure alignment with the Grade 10 physics curriculum. These revisions aimed to enhance user experience and ensure that the e-module effectively supports the learning process.

This study aligns with the findings of Adri & Suwarjono (2023), who evaluated the design of their e-module by revising its front page to improve user-friendliness and usability.

Developmet Stage

The product resulting from the research is an e-module titled "Energy Sources in Life: Understanding Environmental Impacts" which is designed for Grade X high school students. The e-module contains learning materials about non-renewable and renewable energy sources, as well as the social issues arising from these energy sources. The e-module is also equipped with relevant images and videos that align with the material presented. Below is the display of the e-module, as shown in Table 3.

Table 3. Energy Source E-Module

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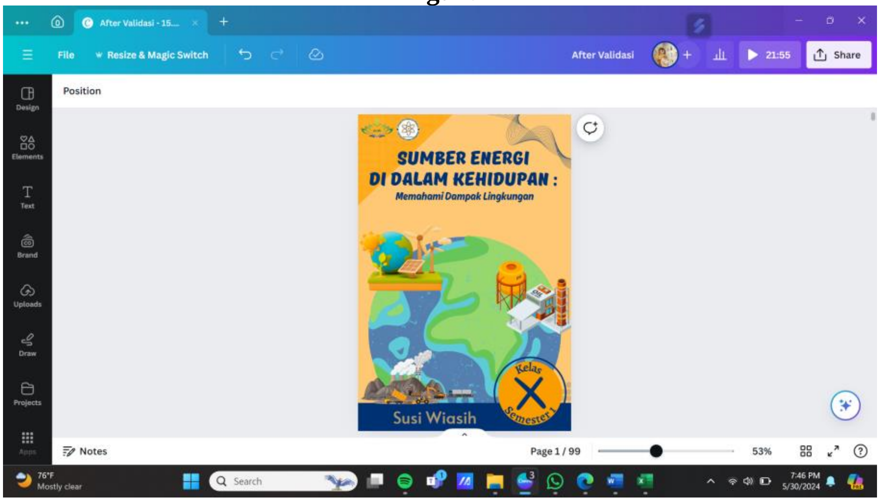
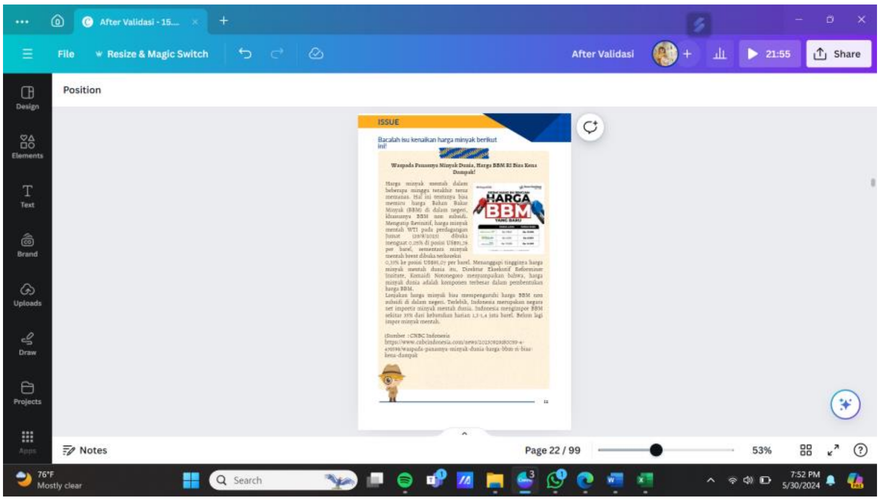
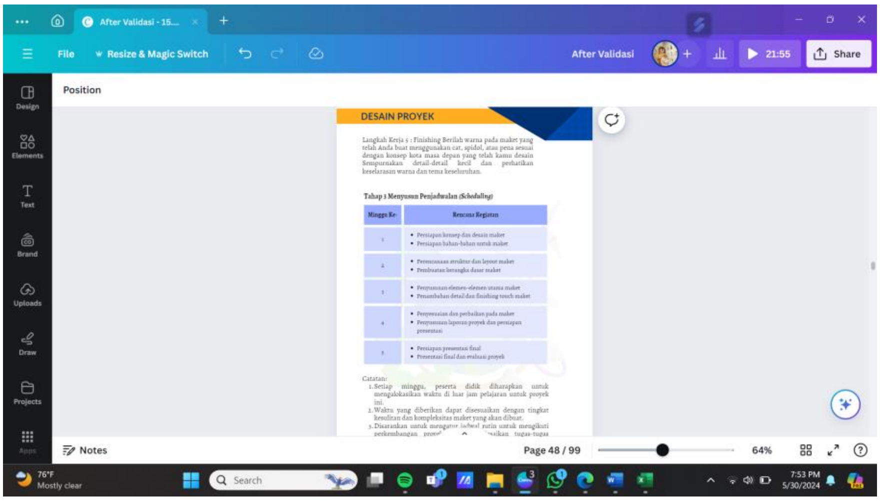
Name	Figure
Front Display	
Content Featuring Fuel Price Illustration	
Final Project Material	

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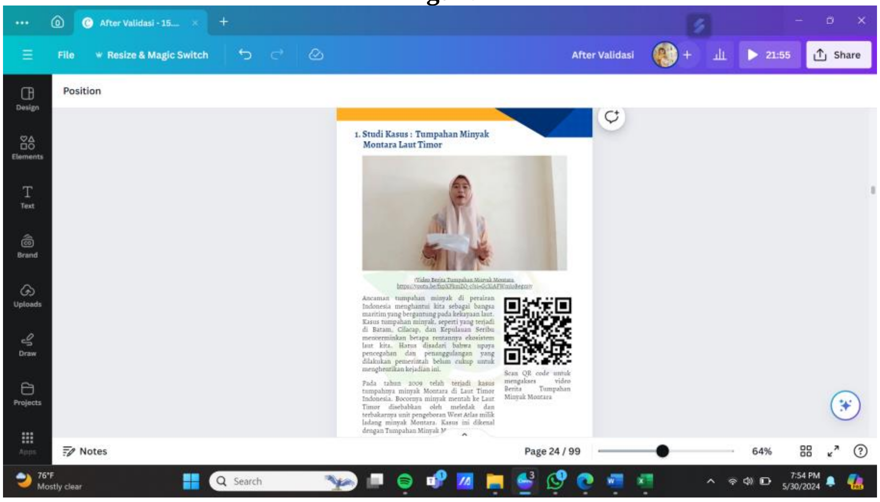
Name	Figure
Video Display	

The product has undergone a validation process by subject matter and media experts. The results of the subject matter validation are as in Table 4.

Table 4. Results of Subject Matter Expert Validation

No.	Assessment Aspect	Assessment Percentage (%)
1	Content Validity	85%
2	Presentation Feasibility	84%
3	Language Accuracy	82%
4	Alignment with PjBL Stage	83%
5	Alignment with SSI Aspects	85%
Average Percentage (%)		84%
Criteria		**Very Good**

Table 5. Results of Media Expert Validation

No.	Assessment Aspect	Assessment Percentage (%)
1	Cover Design	93%
2	Content Design of the E-Module	91%
3	Usability	93%
Average Percentage (%)		92%
Criteria		**Very Good**

The product was then subjected to validation by subject matter and media experts to ensure its feasibility and relevance. The subject matter expert validation showed an average score of 84% (Very Good), with feedback and recommendations to add more in-depth explanations in certain sections, such as the environmental impact of energy use. Meanwhile, the media expert validation resulted in an average score of 93% (Very Good), with feedback and suggestions to improve the quality of animations and add interactive elements, such as video-based quizzes. Based on these evaluations, several revisions were made, including content updates, the addition of interactive simulations, and the enhancement of multimedia elements to improve the student learning experience and ensure the e-module can be optimally used in physics learning.

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Implementation Stage

The implementation stage is divided into two parts: teacher response testing and student response testing. Teacher response testing involved one physics teacher from each school, while student testing included both small-scale trials and field trials. The small-scale trial involved 15 students from SMAN 1 Ambarawa and SMAN 1 Pagelaran. The field trial was conducted at SMAN 1 Ambarawa and SMAN 1 Pagelaran, with 56 students participating, divided as follows: 29 students from Class X.5 at SMAN 1 Ambarawa and 27 students from Class X.1 at SMAN 1 Pagelaran. Table 6, Table 7, and Table 8 are the results of teacher responses, small-scale trials, and field trials.

Table 6. Average Teacher Response Results

No	Aspect	Percentage
1.	Content Quality	87%
2.	Linguistic Quality	80%
3.	E-Module Display	88%
4.	Technical Quality	83%
5.	Alignment with PjBL Stages	75%
	Average	83%

Table 7. Results of Small-Scale Trial

No.	Assessment Aspect	Assessment Percentage (%)
1	E-Module Display	85%
2	Content	86%
3	Language	84%
4	Usability	86%
Average		85%

Table 8. Results of Field Trial Based on Student Responses

No.	Assessment Aspect	Assessment Percentage (%)
1	Tampilan E-Modul	81%
2	Content	82%
3	Language	82%
4	Usability	84%
Average		82%

The results from the implementation stage indicate that the PjBL-based e-module with SSI content was very well received by both teachers and students. The teacher response score of 83% affirms that the e-module is suitable for use in learning, although minor improvements are needed concerning its alignment with the stages of PjBL. The student responses from the small-scale trial (85%) and the field trial (82%) show that the e-module facilitates active learning and increases student engagement. These findings are consistent with the research by (Rahmawati et al., 2023), which indicates that SSI-based learning models can enhance critical thinking and student participation.

Evaluation Stage

The evaluation stage is the final process aimed at measuring the success of the e-module and refining it based on feedback received during the research. Evaluation is conducted through two main approaches. Formative evaluation is carried out at each stage of the ADDIE model

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analysis, design, development, and implementation to ensure that the product produced is of high quality and relevant to the users' needs. Summative evaluation is conducted after the trial runs to assess the overall effectiveness of the e-module in supporting Project-Based Learning (PjBL) and Socio-Scientific Issues (SSI) based learning.

The results of the summative evaluation indicate that the e-module is highly effective in enhancing student learning. Based on the trial results, students showed a significant increase in learning engagement, critical thinking skills, and understanding of energy concepts. Teachers also reported improvements in classroom dynamics, with students becoming more actively involved in discussions and context-based projects.

Research Contributions

The results of this study support the existing literature on the effectiveness of digital learning tools in education. The integration of PjBL, SSI, and this e-module aligns with global educational trends that emphasize contextual and interdisciplinary learning. Studies by Sadler & Donnelly (2006) and Chang & Chiu (2022) confirm that SSI can foster critical thinking skills and ethical decision-making, while PjBL has been proven to enhance student engagement in collaborative projects (Andriyani & Anam, 2022) This e-module expands these findings by demonstrating how digital platforms can effectively operationalize this approach.

Implications

The development of this e-module represents a significant step in contextualizing science education, particularly on the topic of energy. By integrating PjBL, SSI, and digital technology, this e-module provides an innovative tool to enhance students' understanding of environmental impacts. This approach is not only relevant to physics but can also be adapted to other scientific disciplines, supporting interdisciplinary learning and equipping students with the skills necessary to address global challenges. Additionally, this e-module offers a practical solution for educators to integrate technology into their teaching practices.

Limitations and Sugeesions

Although the results of this study demonstrate success, there are several limitations. The relatively small sample size limits the generalization of the findings to a broader population. Furthermore, the success of the e-module implementation is highly dependent on the availability of adequate technological infrastructure, which may not be evenly distributed across all schools. Future research should involve a larger and more diverse sample to further validate these findings. Longitudinal studies are also needed to evaluate the long-term impact of the e-module on student learning outcomes and attitudes toward environmental issues.

CONCLUSION

This study developed an e-module based on Project-Based Learning (PjBL) that integrates Socio-Scientific Issues (SSI) on the topic of energy sources using the ADDIE development model, which includes the stages of analysis, design, development, implementation, and evaluation. The developed e-module was deemed highly feasible by experts, with an average feasibility score of 84% from subject matter experts and 92% from media experts. Furthermore, the e-module was also considered highly engaging by both educators and students, with an

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average score of 83% from educators and an average student response score of 85% from the small group trial and 82% from the field trial. Thus, this e-module is expected to enhance students' understanding of energy sources in the context of socio-scientific issues and can be implemented in Physics education at the high school level.

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