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Digital Green Economy Module to Foster Green Behavior in Grade X Students

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Abstract: Global environmental crises, driven by unsustainable economic practices, highlight the urgent need for a transition toward a green economy. Education plays a crucial role in this transition by fostering green behavior among the younger generation. However, a significant gap exists in the availability of specific teaching materials that integrate green economy concepts into the economics curriculum within a local context. This study addresses that gap by developing and testing a digital-based Green Economy Module for 10th-grade students in an environmentally vulnerable region. Employing a Research and Development (R&D) approach using the ADDIE model, this study created a learning module that underwent rigorous validation by content, language, and graphics experts, achieving a "very feasible" rating (94.40%). The module's practicality was confirmed with a "very practical" rating from students (97.2%). A quasi-experimental design was used to measure effectiveness. The results showed that the module is significantly more effective than conventional methods in enhancing students' cognitive understanding. Furthermore, the module was found to be effective in shaping students' green behavior, raising the overall average from 59.6% to 70.6%. The findings confirm that a digital-based Green Economy Module, when developed with a contextual approach, can be an innovative and effective solution for improving student understanding and fostering sustainable behavior.

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Introduction

Global environmental crises, such as climate change and the degradation of natural resources, represent pressing challenges driven by unsustainable patterns of economic production and consumption (IPCC, 2023; WMO, 2025). In response, the green economy has emerged as a development paradigm that balances economic growth with environmental preservation (Bondarenko et al., 2023). This concept emphasizes resource efficiency and investment in natural capital to reduce ecological footprints (Zhang et al., 2022). In Indonesia, the green economy has become part of the national development vision, underscoring the vital

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role of society, including the youth, in its implementation (Undang-Undang No. 59 Tahun 2024 Tentang Rencana Pembangunan Jangka Panjang Nasional Tahun 2025-2045, 2024).

Education plays a crucial role in shaping green behavior, which are conscious actions to protect the environment (Nurhidayati et al., 2024). Integrating sustainability issues into educational curricula, particularly in economics, is highly relevant for equipping students with the knowledge and attitudes needed to support the transition to a green economy (UNEP, 2008). Studies show that building a sustainable attitude can foster students' intent for sustainable behavior (Muharlisiani et al., 2021; Surjanti et al., 2019). However, despite the acknowledged importance of environmental education, a literature review reveals a significant gap in the development of specific teaching materials. The majority of research on environmental education focuses on science subjects like biology or geography, and few have deeply integrated green economy concepts into the economics curriculum. Other research on e-module development has proven its effectiveness in improving student learning outcomes (Farenta, 2023; Vianis et al., 2022), but none have specifically developed and tested a digital module focused on a local context to shape students' green behavior through the subject of economics. This indicates a need for a more focused and contextualized approach.

Based on this gap, the scientific novelty of this research lies in the development of a digital-based green economy module that is contextually designed to shape the green behavior of 10th-grade students in regions vulnerable to environmental issues. The focus of this study is on senior high school students (Grade 10, or Phase E) for two key reasons. First, they are at a critical cognitive and moral development stage, allowing them to grasp complex green economy principles and translate them into meaningful action. Second, they are on the verge of becoming independent consumers and future workforce participants, making this intervention crucial for long-term behavioral change. This module not only digitizes printed teaching materials but also integrates green economy principles with relevant local case studies, making it a unique and specific tool for addressing regional environmental challenges. Therefore, the research problem is: How to develop a digital-based green economy module that is valid and effective in shaping the green behavior of 10th-grade students (Phase E)? The purpose of this article is to present the development process, validation results, and effectiveness of the digital-based green economy module in shaping the green behavior of 10th-grade students.

Research Method

This study employed a Research and Development (R&D) approach, adapting the ADDIE model (Analyze, Design, Develop, Implement, Evaluate) (Branch & Varank, 2009).This model was chosen for its systematic framework, which is ideal for producing a learning module that is not only valid and practical but also effective. The entire research flow was meticulously planned, starting from the needs analysis phase all the way to a comprehensive evaluation, as depicted in the research flow diagram. The study began with the Analyze phase, where researchers conducted a deep analysis of student needs, the characteristics of the Phase E curriculum, and local environmental issues in the area around the school. Following this, the Design phase involved the specific design of the digital module, including the formulation of initial material drafts, visual layout planning, and the creation of

IJE
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pp. 306-317
Email:ije@skillerindonesia.com

data collection instruments. In the Develop phase, the designed module was validated by experts, including specialists in content, media, and language, to ensure its quality and feasibility before being piloted. The design of this study is presented in Figure 1.

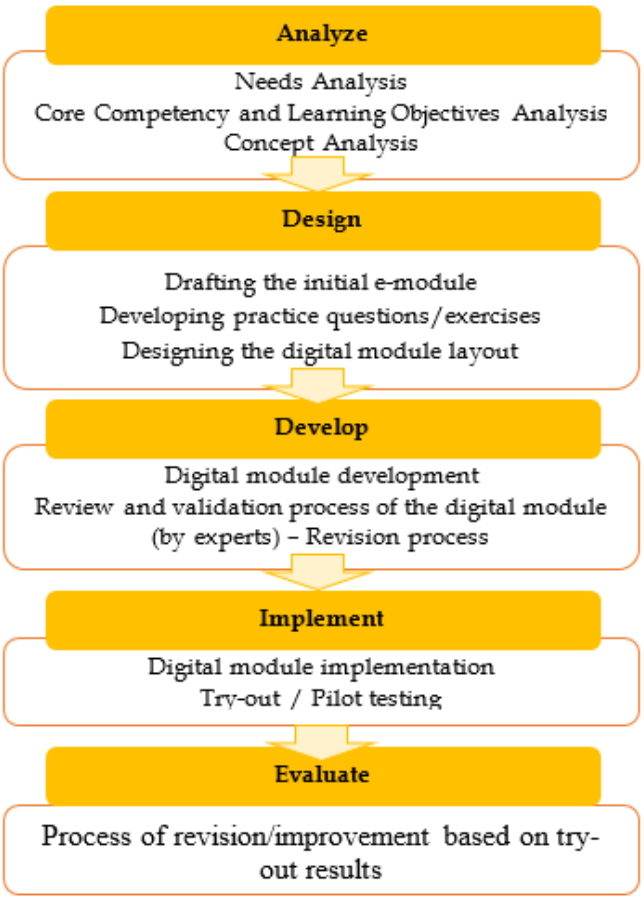

Figure 1. Design of the ADDIE Development Research

This study used a quasi-experimental design with a Nonequivalent Control Group Design to measure the module's effectiveness. The subjects were 10th-grade students at SMA Negeri 1 Porong. The researchers used a cluster random sampling technique to select two classes as the sample: one experimental class (X-12, 34 students) that would use the module, and one control class (X-4, 34 students) that would not. Data collected in this study were both quantitative and qualitative. Quantitative data came from expert validation questionnaires, student response questionnaires, and the results of pre-tests and post-tests administered to both groups. Meanwhile, qualitative data were obtained through interviews with teachers and observations during the module implementation process. Data analysis was conducted in stages. To assess the module's feasibility and practicality, data from the expert validation and student response questionnaires were analyzed using descriptive quantitative analysis based on the Likert Scale. To test the module's effectiveness, pre-test and post-test data were analyzed

IJE
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pp. 306-317
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using inferential statistics. The Wilcoxon Signed-Rank Test was used to test for differences within each group, and the Mann-Whitney U Test was applied to compare the results between groups. The findings from this analysis, both qualitative and quantitative, were used to validate and conclude the effectiveness of the developed module in shaping students' green behavior.

Result and Discussion

1. Validity and Feasibility of the Learning Module

   The product development phase began with a series of in-depth needs analyses, which indicated the necessity for specific learning resources on the green economy. Interviews with teachers and students confirmed that conventional materials were often uninteresting and failed to bridge theoretical understanding with local, relevant environmental issues. The results of the expert validation showed that the developed module has a very high level of validity.

Table 1. Average Validation Results

No.	Validator	Percentage	Category
1.	Content	91.33%	Very Feasible
2.	Language	92.86%	Very Feasible
3.	Graphics	99%	Very Feasible
Average		94.40%	Very Feasible

Source: Researcher-processed data (2025).

Based on Table 1, the average validation percentage from content, language, and graphics experts is 94.40%, placing the module in the "Very Feasible" category. This high validity confirms that the learning product meets educational quality standards and curriculum needs. In addition to expert validation, a small-scale trial was conducted to measure the module's practicality from the students' perspective. The results were very positive, with student responses reaching 97.2%, indicating the module is "Very Practical." This practicality demonstrates that the module's interactive design and visual layout successfully facilitated student engagement and made the learning process more enjoyable, in line with the principles of multimedia learning development (Mayer, 2014).

2. Module's Effectiveness in Improving Learning Outcome

   To measure the module's effectiveness, a comparison of pre-test and post-test results was conducted between the experimental and control classes. Descriptive analysis showed that while the initial abilities of both classes were relatively similar (Table 2), there was a significant increase in the post-test scores of the experimental class.

Table 2. Distribution of Pre-test and Post-test Results for Experimental and Control Classes

Score Interval	Experimental Class				Control Class			
	Pre-test		Post-test		Pre-test		Post-test	
	(f)	(%)	(f)	(%)	(f)	(%)	(f)	(%)
10 - 19	1	0,15	0	0,00	0	0,00	0	0,00
20 - 29	0	0,00	0	0,00	0	0,00	0	0,00
30 - 39	6	0,75	0	0,00	5	0,63	0	0,00
40 - 49	0	0,00	0	0,00	0	0,00	0	0,00

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E-ISSN: 2988-7798
pp. 306-317
Email:ije@skillerindonesia.com

Score Interval	Experimental Class				Control Class			
	Pre-test		Post-test		Pre-test		Post-test	
	(f)	(%)	(f)	(%)	(f)	(%)	(f)	(%)
50 - 59	6	0,75	3	0,39	10	1,24	3	0,39
60 - 69	5	0,63	3	0,39	5	0,63	6	0,75
70 - 79	2	0,27	0	0,00	2	0,27	8	1,00
80 - 89	9	1,12	13	1,60	8	1,00	11	1,36
90 - 100	5	0,63	15	1,84	4	0,51	6	0,75
Total	34	100	34	100	34	100	34	100
Lowest Score	10		60		30		25	
Highest Score	95		100		90		100	
Average Score	65.15		91.18		62.05		80.88	

Source: Researcher-processed data (2025)

The average score of the experimental class jumped from 65.15 to 91.18, far exceeding the increase in the control class, whose average only reached 80.88. This dramatic rise shows that the developed digital module facilitated a deeper conceptual understanding among students. Inferential statistical analysis using the Wilcoxon Signed-Rank Test (Tables 3 and 4) proved that there was a significant improvement in learning outcomes ($p < 0.05$) in both classes, confirming that both learning methods were effective. More importantly, however, the improvement in learning outcomes in the experimental class was statistically more significant than in the control class. This definitively proves that the digital green economy module is more effective in increasing student understanding compared to conventional learning methods. This finding supports previous research stating that interactive e-modules can significantly enhance student learning outcomes (Retnosari & Hakim, 2021; Vianis et al., 2022). Next, to determine if there was a significant difference between the pre-test and post-test scores within each class (experimental and control), the Wilcoxon Signed-Rank Test was conducted. The test results are presented in Table 3.

Table 3. Wilcoxon Signed-Rank Test Results

Ranks				
		N	Mean Rank	Sum of Ranks
PostEks – PreEks	Negative Ranks	0[a]	,00	,00
	Positive Ranks	32[b]	16,50	528,00
	Ties	2[c]		
	Total	34		
PostKon – PreKon	Negative Ranks	1[d]	3,50	3,50
	Positive Ranks	30[e]	16,42	492,50
	Ties	3[f]		
	Total	34		

Source: Researcher-processed data (2025)

In the Experimental Class, 32 students (Positive Ranks) showed an increase in their post-test scores compared to the pre-test, with a mean rank of 16.50 and a sum of ranks of 528.00, with no students experiencing a decrease (0 Negative Ranks). This indicates a consistent increase in learning outcomes after the Green Economy module intervention. Meanwhile, in the Control Class, 30 students (Positive Ranks) also showed an increase in scores with a mean rank of 16.42 and a sum of ranks of 492.50.

IJE
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pp. 306-317
Email:ije@skillerindonesia.com

Although 1 student (Negative Ranks) had a decrease in score, the majority of students still showed improvement with conventional methods. Descriptively, both classes showed an increase in learning outcomes. However, to confirm the statistical significance of this increase, an analysis of the Asymp. Sig. (2-tailed) value is needed. This is presented in Table 4

Table 4. Statistical Test Results of the Wilcoxon Signed-Rank Test

Test Statistics[a]		
	PostEks - PreEks	PostKon - PreKon
Z	-4,942[b]	-4,803[b]
Asymp. Sig. (2-tailed)	,000	,000
a. Wilcoxon Signed Ranks Test		
b. Based on negative ranks.		

Source: Researcher-processed data (2025).

The Wilcoxon Signed-Ranks Test results show a significant increase in both classes. For the experimental class (PostExp - PreExp), the Asymp. Sig. (2-tailed) value of 0.000 ($p < 0.05$) proves a significant increase in learning outcomes after the green economy module intervention. Similarly, in the control class (PostCon - PreCon), the Asymp. Sig. (2-tailed) value of 0.000 ($p < 0.05$) also indicates a significant increase.

Table 5. Mann-Whitney U Test Results

Ranks				
	Class	N	Mean Rank	Sum of Ranks
Result	PostEks	34	39,96	1358,50
	PostKon	34	29,04	987,50
	Total	68		

Source: Researcher-processed data (2025).

Table 5 presents the number of subjects (N) and the mean rank for each class. The experimental class (PostExp) consisted of 34 students with a Mean Rank of 39.96, while the control class (PostCon) also had 34 students with a Mean Rank of 29.04. The higher Mean Rank in the experimental class (39.96 > 29.04) indicates that the post-test learning outcomes of students in the experimental class were likely better than those in the control class. This is strong initial evidence that the green economy module had a positive impact. However, this table alone does not prove whether this difference is statistically significant. For confirmation of significance, the "Test Statistics" results from the Mann-Whitney U Test output are presented in Table 6.

Table 6. Statistical Test Results of the Mann-Whitney U Test

Test Statistics[a]	
	Result
Mann-Whitney U	392,500
Wilcoxon W	987,500
Z	-2,316

IJE
Interdiciplinary Journal of Education
https://skillerindonesia.id/index.php/ije/index
Vol. 3, No 3: November2025
E-ISSN: 2988-7798
pp. 306-317
Email:ije@skillerindonesia.com

Asymp. Sig. (2-tailed)	,021
a. Grouping Variable: Kelas	

Source: Researcher-processed data (2025).

The statistical test results of the Mann-Whitney U Test, presented in Table 6, show an Asymp. Sig. (2-tailed) value of 0.021. With a significance level of 0.05, since 0.021 < 0.05, the Null Hypothesis is rejected. This means there is a statistically significant difference between the post-test learning outcomes of the experimental and control groups. Referring to the mean ranks from the previous table, where the experimental group had a higher rank, it can be concluded that the learning outcomes of students who used the green economy module were significantly better than those in the control group.Hasil Analisis Respons Siswa terhadap Modul Ekonomi Hijau *(Green Economy)* berbasis Digital

3. Results of Student Response Analysis to the Digital-Based Green Economy Module

The practicality of the module was measured by collecting student response data. The respondents filled out the questionnaire in an online Google Forms format after using the module in the learning process. The results of the student responses are presented in Table 7.

Table 7. Distribution of Student Response Results

Description	Yes (f)	No (f)	Yes (%)	No (%)
A. Content Quality	102	0	100%	0%
B. Learning Motivation	33	1	97%	3%
C. Language Quality and Readability	65	3	95,56%	4,4%
D. Visual Quality and Appeal	98	4	96,08%	3,92%
Maximum Score	306	306	100%	100%
Obtained Score	298	8	97,38%	2,62%
Interpretation	Very Practical			

Source: Researcher-processed data (2025).

Table 7 displays the Distribution of Student Response Results to the Digital-Based Green Economy Module. The response questionnaire, filled out by 34 students after using the module, showed very positive results. A total of 97.38% of the total score obtained indicated that most students felt the module's content facilitated their understanding and enriched their knowledge. The language aspect was also rated as easy to understand by the majority of students, and the design layout, font type, and font size generally received positive responses, indicating optimal visual appeal and readability. Nevertheless, there is still a little room for improvement in the layout and appeal of images/illustrations. Overall, the student responses indicate that the Green Economy Module has a very high level of practicality and was well-received by the target users.

4. Student Green Behavior Profile

To answer how the digital-based Green Economy module can shape students' green behavior, data from a green behavior questionnaire were analyzed. The questionnaire was

IJE
Interdiciplinary Journal of Education
https://skillerindonesia.id/index.php/ije/index
Vol. 3, No 3: November2025
E-ISSN: 2988-7798
pp. 306-317
Email:ije@skillerindonesia.com

designed to measure five main indicators of students' green behavior. The results of the quantitative analysis are presented in Table 8 to illustrate the students' green behavior profile before and after using the module.

Table 8. Student Green Behavior Profile Before and After Treatment

Green Behavior Indicator	Pretest		Posttest	
	Average (%)	Criteria	Average (%)	Criteria
Environmental Maintenance	51,9	Fairly High	65,88	High
Waste Reduction	64,76	High	69,47	High
Natural Resource Conservation	62,8	High	67,77	High
Sustainable Mobility and Consumption	58,9	Fairly High	74,9	High
Community Education	59,5	Fairly High	75	High
Overall Green Behavior Average	59,6	Fairly High	70,6	High

Source: Researcher-processed data (2025).

The analysis results show that the digital-based Green Economy module is effective in facilitating the formation and improvement of green behavior among 10th-grade students (Phase E). Before the module's implementation, the students' green behavior profile was in the "Fairly High" category with an average of 59.6%.

After learning with the green economy module, the overall average of green behavior increased significantly to 70.6%, with a "High" criterion. This increase was consistent across all indicators, raising several aspects from the "Fairly High" category to "High" (e.g., Environmental Maintenance increased from 51.9% to 65.88%). This proves the module successfully motivated and facilitated real changes in students' attitudes and practices, actively shaping better green behavior.

5. Discussion of Findings
   a. Module Development Process and Its Relevance

The module's development process began with an in-depth analysis that revealed students' lack of understanding of the green economy in a local context. This gap reflects the need for relevant and specific learning resources (Dick et al., 2001). This finding is supported by Hakim (2023), who also highlighted the need for integrating relevant economic material into the high school curriculum (Hakim et al., 2023). A digital module was chosen because it aligns with the characteristics of digital native students who are more responsive to interactive media (Fibrianti et al., 2025) and is consistent with learning theory that optimizes the combination of visual and textual elements (Mayer, 2009).

The module's development followed the ADDIE model, a systematic and effective approach to ensuring quality (Branch & Varank, 2009; Dilaines et al., 2024). The module underwent revisions and validation by content, language, and graphics experts to ensure its relevance and accuracy. The module's appealing and interactive design, including "Student Green Activities," is in line with constructivist principles, which state that students build knowledge through interaction and experience (Bruner, 2021).

Vol. 3, No 3: November2025
E-ISSN: 2988-7798
pp. 306-317
Email:ije@skillerindonesia.com

b. Feasibility and Practicality of the Module

The module was declared "Very Feasible" with an average expert validation score of 94.40% (content 91.33%, language 92.86%, graphics 99%). These results confirm its quality in content, language, and visuals and are consistent with other research that emphasizes the benefits of e-modules in 21st-century learning (Arif et al., 2024; Eka et al., 2022; Hakim et al., 2023).This expert validation aligns with the findings of Utami et al. (2022) and Calamlam (2021), who affirmed the importance of expert validation to guarantee the quality of learning media (Calamlam, 2021; Utami et al., 2022). The high feasibility score, especially in the graphics aspect (99%), indicates that the module has a strong user experience (UX), which is a crucial factor in user acceptance (Zardari et al., 2021).

In terms of practicality, the module received a score of 97.38% ("Very Practical") from students (Sugiyono, 2013). This positive response shows that the module is easy to understand, engaging, and effective, in line with the principles of accessibility and readability in digital design (Andriansyah et al., 2023; Prakoso et al., 2024). This high practicality score is consistent with similar research on other e-modules (Fitriyawany, 2025; Pixyoriza et al., 2022), proving that modules deemed feasible by experts also tend to be practical for users.

c. Effectiveness of the Module and its Potential in Shaping Green Behavior

The module proved to be significantly effective in improving student learning outcomes. The pre-test and post-test results showed a substantial increase in the experimental class compared to the control class. The Wilcoxon Signed-Rank Test proved a significant increase in both classes, while the Mann-Whitney U Test showed that the increase in the experimental class was far more significant. This effectiveness can be explained by Social Cognitive Theory. The interactive and reflective features in the module enhance students' self-efficacy and self-regulation, which motivate them to learn more diligently and deeply (Efendi & Sholeh, 2023; Tarumasely, 2024). These findings align with research linking interactive modules to improved learning outcomes (Masruroh & Agustina, 2021; Sholikhah et al., 2022).

Additionally, this module has strong potential to shape students' green behavior. The module's design, which integrates "Student Green Activities," supports both social cognitive learning theory (Bandura & Doll, 2005) and the Theory of Planned Behavior (Ajzen, 1991). The module increases students' awareness (the cognitive aspect) and attitudes (the affective aspect), which are important prerequisites for real behavioral change. While empirical measurement of behavior requires further research, the theoretical foundation of this module is very strong in supporting that goal (Anand et al., 2024).

Conclusion

This research successfully demonstrates that the development of a digital-based Green Economy Module not only meets the need for a relevant and sustainable teaching material but also effectively achieves its goal of improving learning outcomes and has the potential to shape students' green behavior. Specifically, the developed module was declared highly feasible and

Vol. 3, No 3: November2025
E-ISSN: 2988-7798
pp. 306-317
Email:ije@skillerindonesia.com

very practical based on expert validation and student responses, which guarantees its quality and ease of use. Furthermore, the effectiveness analysis shows that this module is significantly superior to conventional teaching methods in enhancing students' cognitive understanding. These findings confirm the research hypothesis that integrating contextual green economy content with digital media can be an innovative solution to address environmental challenges through education, while also fostering sustainable awareness and behavior in the younger generation.

Recommendation

This study successfully produced a valid and practical digital-based Green Economy Module. To optimize its future use, it is recommended to continue development by adding more advanced interactive features like simulations or discussion forums, and to create multiplatform or offline versions to increase student accessibility. Additionally, the module can be developed for higher-level materials and grades to ensure the continuity of learning. Improving the visual quality and layout by involving professional graphic designers is also important to make the module's appearance more appealing. To strengthen its effectiveness, it is necessary to diversify evaluation methods and implement real collaborative projects where students can directly apply the concepts they have learned..

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Vol. 3, No 3: November2025
E-ISSN: 2988-7798
pp. 306-317
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