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E-Module Learning Cycle 5E Oriented Education for Sustainable Development on Reaction Rate Material to Increase Sustainable Consciousness

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ABSTRACT

The energy resource crisis and environmental damage continue to be very serious global issues as a result of people's behavior that is not sustainable in terms of the environment. Education through the concept of ESD (Education for Sustainable Development), plays an important role in instilling sustainable consciousness to realize the SDGs, namely by integrating them in learning. The purpose of this study is to generate and determine the effectiveness of using ESD-oriented reaction rate learning modules in increasing sustainability consciousness. This development was carried out using the ADDIE method using readability instruments and pretest-posttests that had been validated by experts. This study has a limitation in terms of the number of participants involved, which was only 36 students. To analyze the pretest-posttest data, the N-gain Score test was used. The resulting product is an ESD-based reaction rate interactive learning module in digital form (website). The developed learning module received a high validation of 82.7% from expert validators, including the "very good" category. The student readability test score was also very high, reaching 86.46%. The results of the implementation of the module obtained an N-gain value of 0.5752, so this module can be categorized as "quite effective" in increasing students' sustainable consciousness.

INTRODUCTION

The energy resource crisis and environmental degradation continue to pose threats worldwide. The initial step toward a solution is to instill sustainable awareness in all members of society. Sustainable awareness is the consciousness that fosters a tendency to protect the surrounding environment (Muthia & Nugraha, 2021). Sustainability awareness refers to a combination of knowledge, attitudes, and behaviors regarding sustainability (Ovais, 2023). Sustainable awareness can be introduced through the education sector. Education plays a very important role because its impact directly affects and determines the quality level of human resources (Perkasa & Aznam, 2016).

The integration of sustainable awareness in learning can be carried out through the Education for Sustainable Development (ESD) approach. ESD is education aimed at creating a more sustainable society. Education for Sustainable Development (ESD) plays a crucial role in achieving Sustainable Development Goal (SDG) number 4, namely "Quality Education." SDG 4 emphasizes the importance of ensuring inclusive and quality education. In this context, ESD becomes an approach that integrates sustainability principles such as environmental responsibility, social justice, and economic development into the education system(UNESCO, 2017).

Burmeister & Eilks (2012) state that the main focus of ESD is to prepare young generations to become responsible citizens in the future. ESD produces learning that encompasses cognitive, socio-emotional, and attitudinal aspects, enabling students to understand sustainability not only through knowledge but also through social skills and attitudes (Rieckmann, 2017). According to research by Berglund et al., (2014), there is a significant difference in sustainability awareness between students taught with the ESD approach in schools and students from regular schools. This indicates that integrating ESD into learning influences sustainability awareness (Michael & Sumilan, 2020)

The implantation of SDGs through ESD can be embedded in chemistry subjects, particularly in the topic of reaction rates. Reaction rates contain everyday life issues that can be connected to SDG problems (Fibonacci, 2020). The concept of reaction rates can be applied to address environmental problems. These environmental issues that can be tackled with the reaction rate concept are closely related to SDG number 12, which is Responsible Consumption and Production. SDG 12 encourages efficient resource management and the reduction of waste and pollution. The reaction rate concept studies the speed of reactions and the factors that affect them. This understanding is essential in addressing environmental problems because many environmental processes such as pollutant degradation, waste treatment, and gas emission control can be managed by regulating the chemical reaction rates involved. Thus, knowledge about SDGs and their relation to reaction rate material can be integrated into learning. The implementation of ESD in Indonesia is not new. However, in practice, it has not been fully optimized (Shantini, 2016). Preliminary studies show that 91.7% of students do not recognize the terms SDGs and ESD. Even among three teachers who were subjects of the study, two did not know these terms. Based on these results, it can be concluded that knowledge about SDGs and ESD is still very limited among students and teachers.

The implementation of ESD in Indonesia can be enhanced through innovation, namely by developing ESD-oriented e-modules for learning. E-modules facilitate the learning process, are attractive to study, and can be accessed independently both inside and outside the classroom (Romayanti, 2020). In line with previous research conducted by Mutmainnah, (2021) it was proven that the use of e-modules in the learning process effectively improves student learning outcomes in the reaction rate material. E-modules can be developed with various supporting software, one of which is Articulate Storyline. Articulate Storyline has many features that support the development of interactive e-modules with content consisting of a combination of text, images, audio, video, and animation (Sapitri & Bentri, 2020)

The Learning Cycle 5E learning model is suitable to be combined in ESD-based learning activities. In line with research by Saputra & Faizah, (2021) the LC 5E learning model with a Science for Sustainability Development approach is a model that combines initial concepts with new concepts through investigations conducted in real-life contexts. The Learning Cycle 5E is a model where students actively engage in various exploratory learning experiences that help them develop new understanding (Rejeki, 2015). This is supported by research conducted by (Djadir et al., 2021) which states that the Learning Cycle 5E model is effective for implementing learning to improve students' new understanding, activity and response, achievement of minimum mastery criteria, and student learning outcomes.

This study has limitations due to the limited sample and focus only on the reaction rate material, so the results cannot be generalized widely. The duration of module usage is also short, and the application of the e-module depends on the availability of technology, which is not yet evenly distributed in schools. However, this study presents novelty by integrating the Learning Cycle 5E model and Education for Sustainable Development (ESD) principles into an interactive e-module. This approach not only enhances understanding of chemical concepts but also fosters students' awareness of the importance of sustainability in daily life.

METHODS

Research Design

This research is a research & development using the ADDIE model developed by Branch, (2009). The model has 5 stages which include analysis, design, development, implementation, and evaluation(Branch, 2009). This research aims to produce an Education for Sustainable Development-oriented learning module on reaction rate material in digital form (website).

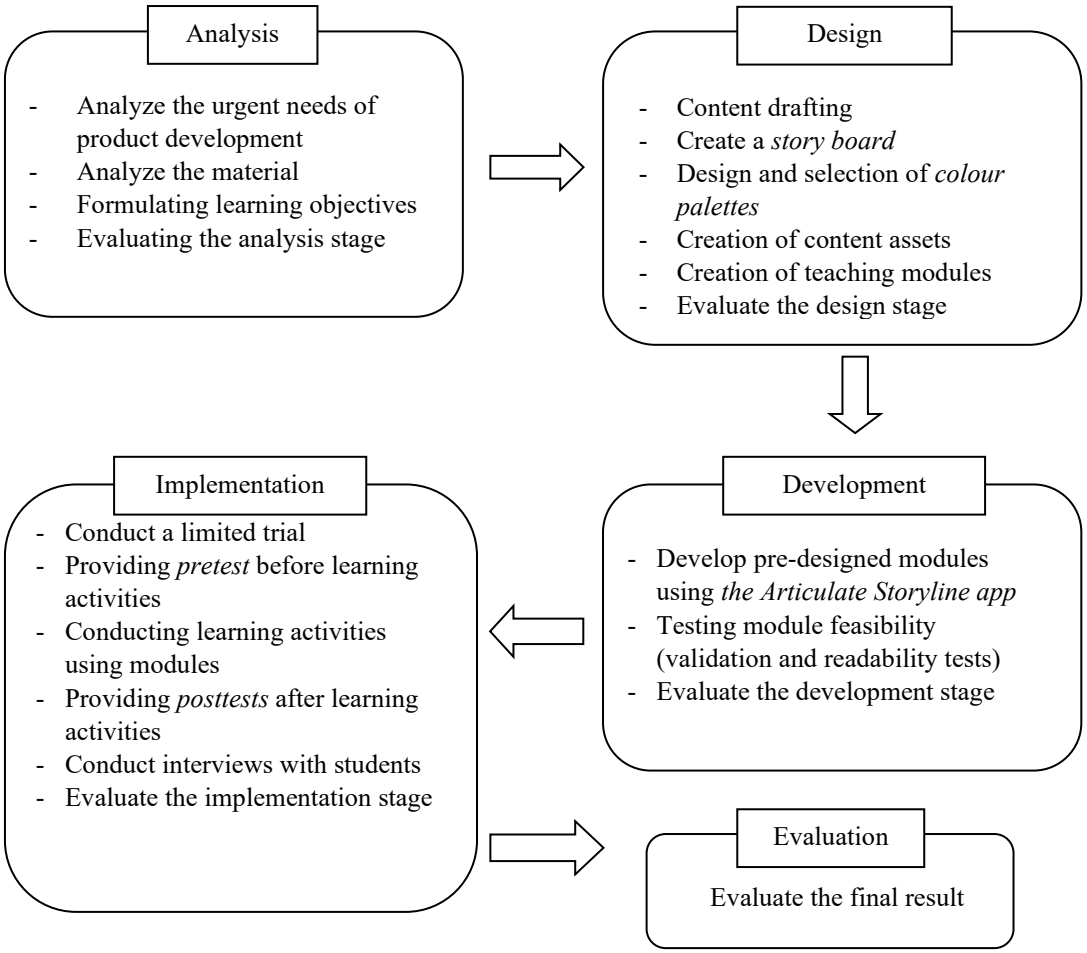

Figure 1. Module development stage chart

Research Target

The research began with a content validity test of both the material and media by experts. The initial product development trial was conducted in a limited trial involving 36 eleventh-grade students from a senior high school in Malang Regency. This study has a limitation in terms of the number of participants involved, which was only 36 students. This number does not yet represent a broader population, so the research findings cannot be fully generalized.

This study employed a pre-experimental method using a one-group pretest-posttest design as the approach in the e-module field testing. The selection of this design was based on the research objective, which aimed to observe the effectiveness of the e-module in improving students understanding after its use, without involving a control group. In this design, the same subjects were given tests before (pretest) and after (posttest) receiving the treatment in the form of e-module usage. The use of the pre-experimental method is considered appropriate because the research is at the early stage of product development. Therefore, the main focus is to evaluate the changes occurring within a single group after the treatment is given. Although this design has limitations in controlling external variables, it still provides an initial overview of the practical and efficient impact of using the e-module in a learning context..

Research Data

The data collection methods used were test and non-test methods. Test used to measure students' understanding of SDGs before and after treatment. Non-test used to assess the feasibility and quality of the developed e-module and evaluate the clarity and accessibility of the learning materials.

Research Instruments

The instruments used in this study included a needs analysis survey, material and media validation forms, a readability test survey using the subjective readability test method, pretest and posttest assessment forms on SDGs understanding, and an interview guide regarding awareness of sustainability. Two data analysis techniques were employed: qualitative and quantitative analysis. Qualitative data were obtained from interviews, and suggestions from validators and students. Quantitative data were collected from validation tests, readability test surveys, and pretest-posttest assessment forms on SDGs understanding. The research instruments are described in detail in Table 1.

Table 1. Research Instruments

Instruments	Instrument Type
Needs analysis	Questionnaire
Material and media validation questionnaire	Closed questionnaire with a likert scale of 1-4
Readability test questionnaire	Closed questionnaire with a likert scale of 1-4
Continuous consciousness *pretest* and *posttest* questionnaire	Closed questionnaire with a likert scale of 1-4
Interview questionnaire	Open Interview

Data Analysis

The measurement of the effectiveness of the use of modules in increasing students' understanding of the SDGs was carried out through the provision of pretest and posttest questionnaires which were tested using google forms. To analyze the pretest-posttest data, the N-gain Score test was used. To see the category of the large increase in N-gain scores and the level of effectiveness of the modules, refer to Sukarelawa (2024).

RESULTS AND DISCUSSION

Analysis

The analysis stage was preceded by conducting a needs analysis using a google form questionnaire addressed to teachers and students in one of the schools at Malang. The teachers and students who participated as samples were selected through a random sampling method. This method was chosen to avoid bias in subject selection and to obtain a sample that is representative of the population. Through this approach, it is expected that the data collected can accurately reflect the condition of the overall population, thereby increase the reliability of the study results and support their generalizability.

Based on the results of the needs analysis, teachers use teaching materials to support the learning process. As many as 2 out of 3 teachers still use teaching materials in printed form. In the learning process, teachers need other learning modules besides those already available at school. Along with the rapid development of the times, learning media innovation needs to be carried out to increase learning variety(Agusti & Solikhin, 2021). Teachers agree that it is necessary to innovate the latest digital learning modules that are packaged in an attractive and more detailed manner as well as their practical use to make it easier for students to learn, especially independent learning at home. The results of the questionnaire stated that only 1 out of 3 teachers had heard the term SDGs and all teachers had never heard of the term ESD and had never found a learning module that discussed the SDGs. Therefore, the development of this

ESD-based module needs to be developed to increase the insight of teachers and students about SDGs and ESD.

The results of the student needs analysis survey administered to eleventh-grade students indicated that 91.7% of the respondents' reported difficulties in understanding chemistry subject matter. This finding suggests that conceptual comprehension in chemistry remains a significant challenge at the senior high school level. Such difficulties may be attributed to the abstract and complex nature of chemistry content, which often requires higher-order thinking skills, as well as the limited availability of supportive instructional media. It was also identified that most students predominantly utilize printed chemistry textbooks provided by their teachers as their main learning resources. While printed materials continue to serve as essential tools in the learning process, they are often constrained by a lack of interactivity, limited visualization, and reduced accessibility—factors that may hinder students' ability to fully grasp the material.

Furthermore, the data revealed that 97.2% of students expressed a preference for learning through digital devices. This indicates a significant shift in student learning preferences toward digital-based media, which are perceived to be more engaging, accessible, and adaptable to individual learning needs. These findings underscore the potential for the development and integration of interactive digital learning tools such as e-modules as an effective strategy to enhance students' motivation and improve their comprehension of complex scientific content.

In an era where technology is increasingly included in every aspect of life, it is not surprising that students tend to prefer to learn using digital devices rather than printed books (Hanikah et al., 2022). In contrast to printed books, digital devices have the advantage of flexibility and easier accessibility so that students can quickly find information, and take advantage of various learning features available in one device more interactively(Yuniastuti, 2021). The results of the questionnaire also showed that students prefer to learn if the material is presented using interesting animations and additional learning videos. So, students need alternative teaching materials other than printed books available to support learning.

The survey results indicated that 91.7% of students had never heard of the term SDGs, and 94.4% were unfamiliar with the term ESD. This finding is consistent with a previous study conducted by Wiyana (2023) which reported that 70% of the research subjects lacked knowledge and understanding of the term SDGs. Therefore, enhancing students' awareness and knowledge of the SDGs represents a critical step toward fostering sustainable development awareness. To achieve this, it is necessary to incorporate SDG-related content into the learning process and to design innovative strategies that expand students' awareness and encourage their active participation in efforts to support the realization of the SDGs. In this regard, the development of an ESD-based learning module presents a promising opportunity to be further explored and implemented. The next stage of analysis is material analysis and formulation of learning objectives.

At this stage, the researcher analyzes the concept of the material that will be included in the learning module by conducting a literature study of various sources of teaching materials about reaction rate materials that are adjusted to the "Kurikulum Merdeka". The formulation of learning objectives is carried out by determining competency achievement indicators that are adjusted to the specific learning goals SDGs, which can be seen in table 2.

Table 2. Learning Objectives

Learning Activity 1	Learning Activity 2	Learning Activity 3
1. Students are able to provide examples of behaviors that reflect SDGs-12 related to the rate of reaction. 2. Students are able to explain the concept of reaction rate.	1. Students are able to provide examples of behaviors that reflect SDGs-12 related to reaction rate 2. Students can determine the reaction rate equation and reaction order	1. Students can explain the concept of SDGs-12 and the embodiment of attitudes in daily life 2. Students can design, conduct, and conclude and present the results of experiments on factors that affect the rate of reaction.

Design

The design stage begins with designing a draft of the content of the learning module. The learning module contains three learning activities including learning activity 1 (Introduction to Reaction Rate), learning activity 2 (Reaction Rate Equations & Reaction Orders), and learning activity 3 (Impact Theory & Factors Affecting Reaction Rate). Each learning activity contains the syntax of the Learning cycle 5e learning model which is equipped with reading materials and learning videos. The module also contains instructions for using the module, competencies, concept maps, references, and supervisor biodata. After the content of the draft content is completed, continue with the creation of a story board. The next stage is creating a design, selecting a color palette, and creating content assets in the Canva application. The design stage continues by making a teaching module that will be used as a guide to the learning flow using the learning module to be developed.

Development

This development stage begins with developing a draft module that has been designed using the *Articulate Storyline application.* The modules developed include learning activities that use the syntax of the Learning Cycle 5e learning model and integrate the concept of SDGs into learning objectives and learning activities. The integration of the SDGs in the module can be seen in figure 2.

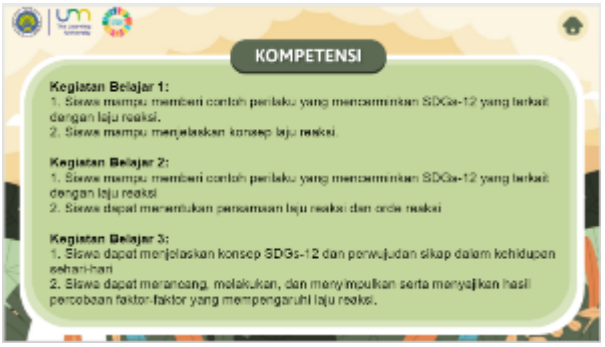

Figure 2. Learning Objectives

The integration of the SDGs concept in the module is listed in the learning objectives section. Learning objectives are arranged based on each learning activity and consist of SDGs learning objectives and reaction rate concept learning objectives. Before entering the learning, it begins with an introduction to the SDGs through learning videos and ends with questions based on the videos that have been seen. The introduction can be seen in Figure 3.

Figure 3. Introduction

The integration of SDGs at the engagement stage is carried out through the reading of texts that discuss issues related to the SDGs, which are then connected to the concept of reaction rate as a solution to these problems. For example, in Figure 4, learning activity 1 involves an engagement text that discusses the problem of food waste and food loss. In this case, frozen food is used as a method that utilizes the concept of reaction rate to reduce food waste and food loss.

Figure 4. Engagement

In the exploration stage, the integration of SDGs is carried out through the presentation of problems which are then explored by students to find solutions. This stage also includes the exploration of reaction rate material, by providing reading materials for students to search for answers. Exploration can be seen in figure 5.

Figure 5. Exploration

The integration of SDGs in the module is also found in the practical learning activity 3 as shown in Figure 6. This practicum is a practicum based on the principle of green chemistry so as to minimize waste in accordance with the principles of SDG-12. After the editing process is complete, it is published and converted into a version html5 so that it can be accessed through website.

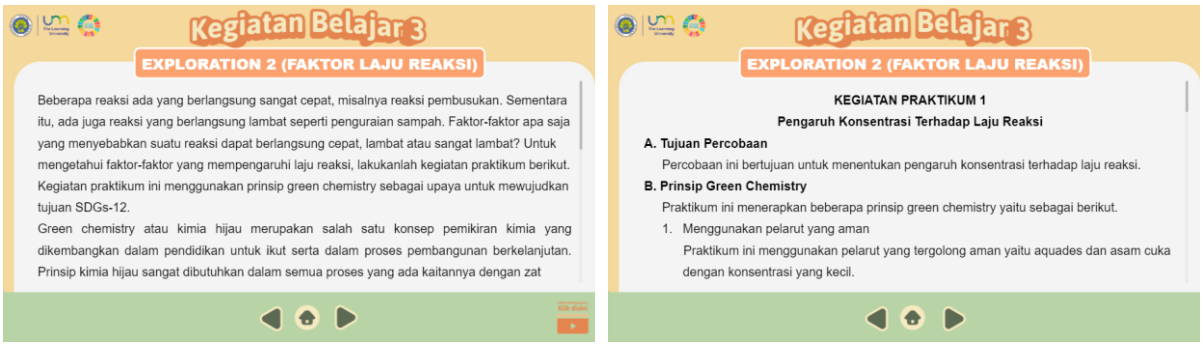

Figure 6. Green chemistry practicum

The ESD-oriented reaction rate learning module developed has been validated by validators, subject matter experts, and media experts. The results of the material validation assessment by the validator can be seen in table 3.

Table 3. Subject matter expert validation score

Assessed aspects	Validation V_1	Validation V_2	TM	TE	(%)	Category
Content Eligibility	29	27	70	56	80,0	Good
Eligibility of Serving	33	29	50	40	80,0	Good
Language	17	15	70	62	88,6	Very Good
Percentage of Material Feasibility in Learning Modules					82,9	Very Good

Description: TE: Total Empirical (V_1+V_2); TM: Maximum Total; V: Validator

Based on table 3, the results of material validation from all aspects resulted in a percentage of 82.9% which is included in the "very good" category. These results indicate that the material displayed in the ESD-oriented reaction rate learning module developed is very feasible and ready to proceed to the trial stage, provided that the revision has been carried out according to the advice of material experts.

The feasibility obtained from the material expert validator is due to the suitability between the material presented with the learning objectives, the collapse of the material, the correctness of the concept and the use of appropriate language. The coorelation between learning objectives, learning flow, material presentation, and language use can make it easier for teachers and students to learn, so that learning objectives can be achieved optimally (Rati et al., 2022). Media validation assessment consists of two aspects, namely media display and media performance. The results obtained from the validation of media experts are indicated in table 4.

Table 4. Media expert validation score

Assessed aspects	Validation V1	Validation V2	TM	TE	(%)	Category
Media Display	45	40	100	85	85,0	Very Good
Performa Media	17	15	40	32	80,0	Good
Percentage of Material Feasibility in Learning Modules					82,5	Very Good

Description: TE: Total Empirical (V_1 + V_2); TM: Maximum Total; V: Validator

Based on table 4, it is known that the results of the validation of media experts from these two aspects are included in the "very good" category with a percentage of 82.5%. These results show that the ESD-based reaction rate learning module developed is very feasible to use and ready to proceed to the trial stage, by revising according to the suggestions of the validator.

The feasibility of this media aspect is due to the fact that the module has met the characteristics of the learning module because it has an attractive media appearance, the suitability of color combinations, the shape of the font chosen clearly with an easy-to-read size, the suitability of the selection of learning videos, images and narratives presented. The combination of colors and neatness of the modules adds an aesthetic element (Munir, 2012). In addition, the developed module is very smooth and easy to operate. Ease of access to modules and easy-to-use navigation buttons. The criteria for good media quality are if the media is smooth in operation, easy in the installation of navigation connectivity (Firdaus, 2017)

The last stage of development was to conduct a readability test on 36 students in grade XI at Malang High Schools who had studied the reaction rate material. The readability test was carried out to determine the practicality of the e-module developed for users. The test was carried out by filling out a questionnaire and the results were obtained as contained in table 5.

Table 5. Readability test results

Assessment Aspects	Validity Percentage	Category
Content eligibility	86,8%	Very High
Language eligibility	86,5%	Very High
Design feasibility	88,9%	Very High
Benefit	85,2%	Very High
Average	86,46%	Very High

Based on the results of the readability test, a validity percentage of 86.46% was obtained with the "Very High" category, so it can be concluded that the e-module developed is easy to understand and use by students. Positive responses to the e-module were also obtained from students based on the comments given. Students stated that the appearance of the module was quite good and attractive and easy to operate. In addition, the addition of images and videos in the module helps clarify the material and add information related to the material. However, some students gave suggestions for more animation to be added.

Implementation

The modules that have been developed are implemented in learning activities to determine the effectiveness of the use of modules on students' sustainable consciousness. Implementation is carried out by providing pretest questions before learning and posttest after learning. The questionnaire instrument for the pretest and posttest questions consisted of 20 statements related to the sustainable consciousness of the SDGs-Responsible Production and Consumption which covered 3 domains, namely cognitive, socio-emotional, and attitude domains. The instrument used is adapted from (Gericke & Pauw, 2019; Michalos & Creech, 2012) Based on the results of the implementation stage, data on learning outcomes in the form of grades *pretest* and *posttest* as can be observed in Figure 7.

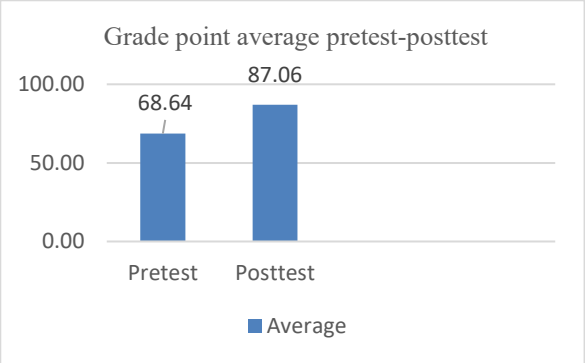

Figure 7. Grade point average pretest and posttest ongoing consciousness

The score data was statistically analyzed to determine the influence of the use of learning modules on students' understanding of the SDGs-Responsible Production and Consumption. Based on the Shapiro-Wilk normality test, pretest data (sig. 0.070 > 0.05) and posttest (sig. 0.118 > 0.05). The Paired-Samples T Test was conducted to find out if there was a significant difference between the pretest and posttest scores. The output of the t-test was obtained with a value of Sig. (2-tailed) 0.000 < 0.05. So it can be concluded that there is a significant difference between the pretest score and the posttest score. The magnitude of the influence or effectiveness of the use of the module was analyzed using the N-gain test on the pretest and posttest values. Based on the tests carried out, an N-gain value of 0.5752 was obtained, which if translated into the criteria, is included in the "moderate" category, because the N-gain value obtained is in the range of $0.30 \leq g \leq 0.70$. The interpretation of the effectiveness of the N-gain

value is in the category of "quite effective". This means that the use of this module is still quite effective in increasing students' consciousness of sustainability.

Integrating the SDGs into learning has proven to be quite effective in increasing students' understanding of sustainable development goals. When the concepts of the SDGs are linked to the subject matter, students not only learn about global issues such as environmental damage, poverty, hunger, inequality, and climate change, but also understand their relevance and practical applications in daily life(Laurie & Nonoyama, 2016). By studying the SDGs, students can better understand how actions can contribute to a more sustainable future. This will help create consciousness and involve students in the implementation of the SDGs (Radha & Arumugam, 2023).

Although this quantitative data indicates a moderate level of effectiveness, drawing valid and comprehensive conclusions requires support through data triangulation. In this context, methodological triangulation can be carried out by combining quantitative data from the pretest and posttest with qualitative data such as classroom observations and student interviews. This approach not only reveals the extent of score improvement, but also how students internalize sustainability values within the context of their daily lives. This statement is further supported by the results of interviews conducted with several students, as presented below.

Q: "Before learning with the ESD-based reaction rate module, are you familiar and aware of the SDGs or sustainable development?"
R1: "Never Heard of It"
R2: "Don't know"
R3: "Don't know and haven't heard of it at all"
Q: "Is this ESD-based reaction rate module able to improve your understanding of the SDGs, especially SDGs-12 "Responsible Production and Consumption"?"
R1: "Yes, I now know what the SDGs are"
R2: "This module opens my insight into the SDGs"
R3: "Yes. I came to know what the SDGs are, which adds to my horizons"
Q: "What information do you get from this module?"
R1: "I came to know what the SDGs are, what are the SDGs targets so that I become aware to care more about the environment"
R2: "I came to know that chemistry has benefits for the surrounding environment, and we must protect the environment to help realize the SDGs"
R3: "SDGs are sustainable development targets, the goal of which is to protect the earth so that in the future the earth is still maintained"
Q: "After learning to use this module, has your concern for the environment increased? What attitudes and behaviors will you do to help realize the SDGs, especially SDGs-12?"
R1: "Reducing waste and food waste"
R2: "Don't litter"
R3: "Reducing food waste and recycling waste"

Based on the results of data analysis and interviews, overall, the use of this *e-module* is able to introduce and instill the values of sustainable consciousness to students related to the SDGs.

CONCLUSION AND RECOMMENDATION

The ESD-oriented reaction rate e-module has been rated "very good" by expert validators and media experts, with a validity score of 82.7% and a readability test score of 86.46%. This module contains reaction rate chemistry material connected to SDGs-Sustainable Production and Consumption, presented digitally in the form of a website. The implementation of this module shows a significant influence on the understanding of SDGs-Responsible Production and Consumption, with a significant difference between pretest and posttest scores (Sig. 0.000 < 0.05). The N-gain value of 0.5752 shows that this learning module is "quite effective" in increasing students' consciousness of sustainability. This result is also supported by the results

of interviews which stated that this module can provide students with an understanding of the SDGs and instill attitudes and behaviors of sustainable consciousness to achieve sustainable development goals. Future studies are recommended to explore the implementation of the 5E Learning Cycle-based e-module oriented toward Education for Sustainable Development (ESD) across different chemistry topics beyond reaction rates, such as chemical equilibrium, thermochemistry, or environmental chemistry. This will help to generalize the effectiveness of the module in enhancing students' sustainable consciousness across broader scientific contexts.

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