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Effectiveness of global warming disaster mitigation e-module in increasing students' creative thinking

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ABSTRACT

Background: Global warming is an environmental problem that has a broad impact on human life and ecosystems. Disaster mitigation due to global warming is a crucial step that needs to be implemented in various aspects, including education. The Merdeka Curriculum emphasizes project-based learning and innovation, so that the development of e-modules based on disaster mitigation with a guided inquiry approach is a relevant solution for improving students' creative thinking skills. **Methods:** This research uses the Research and Development (R&D) method with the Van den Akker model in developing e-modules, as well as a quasi-experimental approach with a pretest-posttest control group design to test its effectiveness. The research subjects were class X students at MAN 3 Mandailing Natal who were selected using a purposive sampling technique. The research instrument is a creative thinking test which is validated by experts and tested for reliability. Data analysis was carried out using the N-Gain test and the Mann-Whitney test. **Findings:** The research results showed that the experimental class that used guided inquiry-based e-modules experienced a higher increase in creative thinking skills than the control class. The average N-Gain score for the experimental class was 0.66 (high category) while the control class was only 0.33 (low category). The Mann-Whitney test showed a significant difference between the two groups (Asymp. Sig. < 0.05), indicating the effectiveness of the e-module in improving creative thinking skills. **Conclusion:** This research confirms that e-modules based on disaster mitigation with a guided inquiry approach are effective in improving students' creative thinking skills. **Novelty/Originality of this article:** The novelty of this research lies in the integration of e-modules in disaster mitigation learning in the Merdeka Curriculum, which has not been studied much before. The authenticity of this research is supported by an experimental approach and measurement based on structured creative thinking indicators.

KEYWORDS: e-module; guided inquiry; global warming; disaster mitigation; creative thinking.

1. Introduction

Global warming has become an important environmental issue that continues to receive international attention because of its profound and long-lasting effects on environments and the survival of people. Because of human activities like utilizing fossil fuels, deforestation, and industrial emissions, which raise the concentration of greenhouse gases in the atmosphere, the average temperature of the Earth has increased considerably. Among the environmental changes caused by global warming are rising sea levels due to the collapse of polar ice caps and an increase in the frequency of natural disasters such as heat waves, floods, droughts, and extreme weather shifts (IPCC, 2021). In addition to

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interfering with everyday human activities, these events seriously jeopardize biodiversity, agricultural output, water supplies, and ecological equilibrium. Furthermore, socioeconomic vulnerabilities are made worse by catastrophic weather events that cause harm to human settlements and infrastructure, particularly in developing nations (Humaida & Murniningsih, 2024).

Comprehensive and long-term disaster mitigation measures are necessary to reduce the risks of disasters and the adverse effects of global warming. Sustainable natural resource management is one of the many methods included in these mitigation techniques. This strategy emphasizes encouraging proper land use, safeguarding water supplies, and maintaining forests. Additionally, lowering greenhouse gas emissions is greatly aided by the usage of ecologically friendly technology. According to Ulum (2014), examples of such technologies include the use of energy-efficient systems, carbon capture techniques, and renewable energy sources. Additionally, as stressed by Nugroho (2022), raising public awareness through education is an essential step in cultivating a sense of responsibility toward environmental conservation. To promote sustainable lifestyles and active engagement in climate change, these educational activities can be incorporated into government policies, community programs, and school curricula (Rahman & Astria, 2024). It is anticipated that by working together, we can lessen the harmful effects of global warming and ensure a more resilient and sustainable future for current and future generations.

In the field of education, developing creative and successful teaching resources is a vital way to increase students' knowledge and abilities to deal with calamities brought on by climate change (Fitriyah et al., 2023). Using e-modules based on disaster mitigation is one particularly promising tactic (Fitri et al., 2021). With the help of these e-modules, students can study a variety of topics both independently and interactively, giving them a more contextualized and pertinent education about the effects of global warming and the crucial mitigation strategies that can be implemented (Habibah & Fauzi, 2023). E-modules accommodate a variety of learning preferences and encourage active engagement by providing self-paced, interesting information. A more thorough and long-lasting comprehension of intricate environmental concerns may result from this autonomous learning strategy. E-modules centered on disaster avoidance have a great deal of promise to improve students' capacity for original thought in addition to imparting knowledge. Students are pushed to create unique and creative responses to a range of global warming-related catastrophic hazards through meticulously crafted problem-based scenarios (Rahim et al., 2023). Students are encouraged to think critically, assess circumstances, and come up with creative and useful solutions by using this problem-solving method. As a result, the incorporation of these e-modules actively fosters students' creativity in tackling urgent environmental issues in addition to facilitating a deeper understanding of scientific principles.

Numerous earlier studies have thoroughly examined the use of technology in education, especially through e-modules. E-modules can improve students' conceptual understanding and involvement in the learning process, according to a study by Permata & Safitri (2021). Research by Sugiyanto et al. (2024), on the other hand, shows that e-modules focused on disaster mitigation offer a more engaging and relevant learning experience, particularly when it comes to comprehending adaption and prevention tactics for global warming-related disasters. According to these results, e-modules have a great deal of potential to enhance learning quality by taking a more experience-based and contextual approach. But there are also gaps in the research on how well e-modules foster students' capacity for creative thought, especially when it comes to mitigating the effects of global warming on disasters. In order to support structured investigation and the methodical development of students' creative thinking abilities, a number of recent studies emphasize the significance of integrating guided inquiry learning into e-modules (Haspen et al., 2021). Thus, creating e-modules that incorporate guided inquiry as a way to promote creative thinking in addition to emphasizing conceptual comprehension is still a crucial component that needs more research.

An adaptable and creative approach to education is encouraged by Indonesia's implementation of the Merdeka Curriculum (Kemendikbud, 2022). In light of this, creating an e-module on disaster mitigation brought on by global warming becomes extremely pertinent and in line with curriculum goals. Through inquiry-based problem-solving techniques, this e-module fosters students' creative thinking abilities while also assisting them in understanding scientific ideas linked to catastrophe mitigation and global warming. Students are encouraged to recognize issues, create hypotheses, evaluate information, and create suitable mitigation plans depending on their local circumstances through guided inquiry (Rasidi, 2024). This method is in line with constructivist philosophy, which highlights the value of hands-on learning opportunities and student participation in solving real-world issues (Vygotsky, 1978).

E-modules' contribution to students' development of creative thinking abilities is intimately tied to the tenets of problem-based learning (PBL). Although PBL encourages students to investigate issues, evaluate information, and come up with answers, this process necessitates directed inquiry to guarantee that students can successfully negotiate difficult scientific ideas and problem-solving techniques (Hmelo-Silver, 2004). When it comes to disaster mitigation education, guided inquiry is essential for assisting students in actively tackling real-world problems like creating early warning systems for extreme weather events or constructing housing structures that can withstand flooding. This method improves students' creativity and problem-solving skills while also helping them grasp scientific ideas more thoroughly by offering structured coaching.

Additionally, research has demonstrated that adding multimedia components to e-modules—like interactive simulations and virtual experiments—can greatly improve learning outcomes and student engagement (Mayer, 2021). According to Paivio's dual coding hypothesis (1990), kids are better able to process information when they are exposed to both visual and auditory stimuli. Interactive models illustrating the effects of climate change and mitigation techniques can give students a more concrete learning experience in the context of catastrophe mitigation, helping them to understand abstract ideas. The capacity of disaster mitigation e-modules to be tailored to various learning requirements and styles is another crucial component. While some students might benefit more from hands-on exercises or written explanations, others might gain more from visual representations. A wider range of students can successfully interact with the material and hone their creative thinking abilities when varied instructional tactics are incorporated into e-modules (Tomlinson, 2001).

Furthermore, creative problem-solving heavily relies on cooperation and teamwork. Incorporating group-based activities into e-modules, where students collaborate to develop and test mitigation measures, can promote leadership and communication abilities in addition to creativity (Johnson & Christensen, 2020). These cooperative experiences are similar to actual crisis management situations, when several parties need to work together to provide workable solutions. The use of e-modules has many advantages, but there are drawbacks as well, such as issues with teachers' and students' access to technology and digital literacy. According to a study by Priantini & Widiastuti (2021), e-modules provide creative learning opportunities, but their efficacy is mostly dependent on the availability of supporting infrastructure and sufficient teacher training. To maximize the impact of e-modules in disaster mitigation education, these issues must be addressed through teacher training programs and fair access to digital resources. To sum up, including e-modules on disaster prevention into science classes offers a novel way to improve students' comprehension and original problem-solving abilities. These e-modules can produce a more effective and engaging learning experience by utilizing collaborative activities, problem-based learning techniques, and multimedia components. Future studies should look into how to best develop e-modules to accommodate a variety of learners and examine long-term effects on students' readiness for emergencies.

The outcome of this research is to assess how well e-modules for catastrophe mitigation brought on by global warming foster students' capacity for original thought. It specifically aims to investigate the degree to which e-modules can enhance students'

comprehension and capacity for original thought within the framework of secondary-level physics instruction. This study intends to fill current research gaps and aid in the creation of more pertinent and successful educational resources by combining theoretical viewpoints from earlier research with creative teaching strategies. Additionally, it is anticipated that this study will offer fresh perspectives on how to improve students' higher-order thinking abilities using technology-based instructional design (Anderson & Krathwohl, 2001). It is therefore hoped that this study would shed new light on the efficacy of e-modules in science education and serve as a guide for educators and curriculum designers as they create more creative and adaptable teaching methods. In addition, the findings of this study can help develop educational programs that better address the problems posed by climate change and make the younger generation more equipped to deal with a variety of global warming-related disasters.

2. Methods

In order to develop an e-module based on guided inquiry for minimizing the effects of global warming, this project employed research and development (R&D) utilizing the Van Den Akker paradigm. The Van den Akker model was chosen due to its systematic approach to the development of instructional materials, which includes needs analysis, design, development, implementation, and assessment (Van den Akker, 1999). Additionally, this study's quasi-experimental methodology assesses how well e-modules nurture students' creative thinking using a pretest-posttest control group design. This study, which was carried out at MAN 3 Mandailing Natal, involved Class X students who were enrolled in physics lectures about reducing the effects of global warming. Purposive sampling was utilized to choose the research sample, and two classes served as the experimental group (using an e-module) and the control group (using traditional methods). In order to make sure that the created global warming disaster mitigation e-module satisfies validity, practicality, and effectiveness standards in fostering students' creative thinking abilities, this study was carried out in four major stages. From needs analysis to reflection and product enhancement, every step is essential to the entire research process.

A requirements analysis for a guided inquiry-based e-module aimed at enhancing students' capacity for creative thought was the initial step in this study's creation. This requirements analysis was carried out by determining the different difficulties that instructors and students encounter when learning physics, especially when it comes to mitigating the effects of global warming. Classroom observations, teacher and student interviews, and a review of the literature on guided inquiry-based learning methods and their application in the Merdeka Curriculum setting were all part of the data collecting process for the needs analysis. The analysis's findings formed the basis for creating an e-module that complies with the requirements of the relevant curriculum, learning objectives, and the characteristics of the students.

The e-module was created in the second stage in accordance with standards for practicality and validity. To inspire students to think creatively, the e-module design featured the creation of interactive, problem-based learning resources. In order to improve student involvement in the learning process, this step also involves integrating a variety of multimedia elements, including animations, photos, videos, and interactive simulations. Following the completion of the e-module design, it was validated by media, pedagogy, and content specialists. The purpose of this validation was to confirm that the created e-module complied with the necessary requirements and was appropriate for use in instruction. Regarding scientific topics, content specialists assessed the e-module's content for accuracy. In the meantime, educational specialists evaluated how well the e-module's teaching strategies aligned with the tenets of guided inquiry-based learning. Lastly, the quality of the e-module's appearance and interaction, as well as its visual design and readability, were confirmed by media specialists. Following validation, the e-module was updated based on expert input before moving on to the next phase of development (Sugiyanto et al., 2024).

The e-module's implementation and efficacy testing in the learning process constituted the third phase of this study. At this point, the experimental class began using the verified e-module, while the control group continued to use traditional teaching techniques. This phase's goal was to gauge how much the e-module had improved the pupils' capacity for original thought. The e-module was implemented in the experimental class using a guided inquiry-based learning strategy, which enabled students to actively participate in problem-solving processes linked to catastrophe mitigation and global warming while also exploring concepts on their own. Without the use of the e-module, the control group continued to study through lectures and discussions, which are more conventional approaches. Students' creative thinking abilities were assessed both before and after learning using pretest and posttest evaluations in order to gauge the efficacy of the e-module. The creative thinking skill indicators—fluency, adaptability, originality, and elaboration by Torrance — that Kim (2006) presented served as the foundation for these assessments. These metrics were used to evaluate how well students were able to come up with original, varied ideas and then develop and expand on them within the classroom.

The fourth phase of this research involved reflection and enhancement of the product based on the findings from the implementation of the e-module. Following the effectiveness testing, the gathered data were analyzed to assess the strengths and weaknesses of the e-module that was implemented. The analysis utilized a descriptive statistical method to ascertain the degree of improvement in students' creative thinking abilities after engaging with the e-module. Additionally, an inferential statistical test (Mann-Whitney) was used to ascertain whether there were significant changes between the experimental and control groups, and an N-Gain analysis was conducted to quantitatively assess the improvement in creative thinking abilities. This investigation shed more light on how well the e-module enhanced students' capacity for original thought. Alongside the quantitative analysis, a reflection process was carried out using the input from the study's teachers and students. This feedback was instrumental in guiding further enhancements to the e-module to maximize its effectiveness in supporting learning. Consequently, this stage of reflection and product improvement not only aimed to refine the e-module but also offered recommendations for the development of similar e-modules in the future.

In summary, the four phases of this research are interrelated and play a significant role in creating an e-module that is not only valid and practical but also effective in enhancing students' creative thinking abilities. The research methodology guarantees that the e-module is designed according to actual learning requirements, validated by specialists, empirically assessed for its effectiveness, and continuously refined based on reflections and feedback received. Through this guided inquiry-based e-module, it is anticipated that students will actively investigate physics concepts, cultivate their creative thinking skills, and be better equipped to comprehend and tackle issues associated with global warming disaster mitigation. The research instrument used consisted of a creative thinking test. Before implementation, this instrument was validated by experts and tested for validity and reliability. Descriptive statistics were used to examine the data and assess how much the e-module had improved the students' capacity for creative thought. An inferential statistical test (Mann-Whitney) was used to determine whether there were significant differences between the experimental and control groups, and an N-Gain analysis was used to gauge the growth in creative thinking abilities in order to evaluate the efficacy of the e-module. Using this approach, the study offers a summary of how well the e-module on global warming disaster mitigation fosters students' capacity for original thought.

3. Results and Discussion

3.1 Learning objective achievement criteria (LOAC)

The Learning Objective Achievement Criteria (LOAC) centers on the evaluation of whether the established learning objectives have been met. This pertains to assessments that are grounded in the students' attainment of the specified learning objectives. There is a

strong emphasis on guaranteeing that the learning objectives established are capable of being measured and assessed in an objective manner. The findings from the comparison of the achievement criteria regarding the creative thinking learning objectives of students in both the experimental and control classes are presented in Table 1.

Tabel 1. Learning objective achievement criteria (LOAC)

Learning outcomes	Experimental class				Control class			
	Pretest		Posttest		Pretest		Posttest	
	Number	Percentage (%)	Number	Percentage (%)	Number	Percentage (%)	Number	Percentage (%)
Completed ≥ 80	3	9.37	24	75	5	17	11	38
Not completed ≤ 80	29	90.63	8	25	24	83	18	62
Total	32	100	32	100	29	100	29	100

It is clear from the above table that both the experimental and control groups' learning outcomes significantly improved from the pretest to the posttest. The experimental group's pretest completion rate was 9.37%, and their posttest completion rate increased to 75%. The control group, on the other hand, completed the pretest with a completion rate of 17% and the posttest with a completion rate of 38%. It is evident from these data that the experimental group outperformed the control group in terms of learning completion. The posttest data, which show that 75% of students in the experimental group finished their studies while just 38% of students in the control group did so, further support this. This outcome aligns with the LOAC value established at MAN 3 Mandailing Natal, which is set at 80. Table 2 presents the results pertaining to the comparison of the mean creative thinking abilities of students in the experimental and control groups, together with the scores for each creative thinking metric and the total average score.

Tabel 2. Creative thinking skills in each indicator for experimental and control classes

Indicators of creative thinking	Experiment class				Control class			
	Pre test	Criteria	Post test	Criteria	Pre test	Criteria	Post test	Criteria
Fluency	51.17	S	89.06	VH	63.36	H	76.29	H
Flexibility	41.66	S	89.97	VH	60.20	S	86.20	VH
Originality	53.77	S	93.75	VH	47.70	S	78.73	H
Elaboratif	42.70	S	80.20	T	36.15	L	75.86	H
Mean	47.32	S	88.24	VH	51.85	S	79.27	H

Description
VH = Very high, H= High, S = Sufficient, L= Low, VL= Very low

The aforementioned table illustrates the differences between the experimental class, which uses guided inquiry-based physics e-modules, and the control class, which does not, based on the examination of creative thinking skill scores for each indication. The experimental class's average pretest score is 47.32, which is considered sufficient, and its posttest score significantly increased to 88.24, which is classified as extremely high. The control group, on the other hand, starts with a slightly higher average pretest score of 51.85, which is also considered sufficient, but only achieves a posttest score of 79.27, which is considered high. This implies that although both classes demonstrate an improvement in their capacity for creative thought, the experimental class shows a more notable rise than the class control.

The use of guided inquiry-based physics e-modules, which actively engage students in the investigation of topics, is responsible for the experimental class's higher posttest scores. This fosters a deeper comprehension and develops students' capacity for creative thought. However, there was less of a score rise in the control group, which did not use the e-modules. This suggests that the guided inquiry model in the e-module's organized learning method

has a key role in raising student achievement. Thus, it can be said that guided inquiry-based physics e-modules are useful for improving students' capacity for original thought and for more efficiently accomplishing learning goals.

3.2 N-gain score test

The N-Gain Score test, which derives learning outcomes from essay questions, was also used to assess the data on student learning outcomes pertaining to creative thinking skills. Pretest and posttest scores were obtained for both the experimental and control classes. These scores were used to analyze and compare the N-Gain Score values between the experimental class, which used the guided inquiry-based e-module, and the control class, which did not use it, in order to ascertain the improvement in pretest and posttest evaluations (Table 3).

Tabel 3. N-gain score test of creative thinking skills

Class	N-Gain	N-Gain (%)	Criteria	Interpretation
Experiment	0.66	66	High	Fairly effective
Control	0.33	33	Low	Ineffective

The experimental class achieved an average score of 66%, which is categorized as high and interpreted as being quite effective, according to the N-Gain Score statistics shown in the above table. The control group, on the other hand, received an average N-Gain Score of 33%, which is considered low and is considered ineffective. These findings suggest that the two groups' learning outcomes differed significantly. Thus, it can be said that using guided inquiry-based e-modules, as opposed to traditional teaching approaches, greatly improves students' capacity for creative thought. These e-modules' structured inquiry method improves learning outcomes by allowing students to interact with the material more deeply, research ideas on their own, and develop problem-solving abilities.

3.3 Hypothesis test results

3.3.1 Normality test

To determine whether the data gathered from the findings of this study are regularly distributed, the normality test is crucial. The SPSS 23 software is used to evaluate the data's normalcy. Additionally, a significance level of 0.05 is used in the data test. How will be accepted if the data is normally distributed and the value is > 0.05; if the data is normally distributed and the value is ≤ 0.05, Ho will be rejected. Table 4 displays the results of the normalcy test with regard to the data on creative thinking abilities.

Table 4. Results of the normality test of creative thinking skills data

Class		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Result	Pretest A (Experiment)	.144	32	.089	.950	32	.149
	Posttest A (Experiment)	.236	32	.000	.847	32	.000
	Pretest B (Control)	.108	29	.200*	.945	29	.135
	Posttest B (Control)	.168	29	.036	.849	29	.001

According to the findings presented in the table above, the significance value derived from the normality test is below the established threshold of 0.05. This suggests that the assumption of normality is not satisfied within this dataset. In other terms, the distribution of the data diverges from a normal distribution pattern. Given that normality is a fundamental assumption in numerous statistical analyses, this outcome implies that non-parametric tests might be more suitable for subsequent data analysis. The absence of normality could be affected by several factors, including sample size, variability in the data,

or the existence of outliers. Consequently, further diagnostic tests or methods for data transformation may be warranted to resolve this concern.

3.3.2 Homogeneity test

Finding out if the sample variances are equivalent is the goal of the homogeneity test. As per the findings of the homogeneity test performed with SPSS 23, data is considered homogenous if the significance level is > 0.05; on the other hand, data is classified as non-homogeneous if the significance level is < 0.05 (see Table 5).

Table 5. Results of homogenity test of creative thinking skills data

		Levene Statistic	df1	df2	Sig.
Outcome learning	Based on the average	3.438	1	59	.069
	Based on the middle value	2.281	1	59	.136
	Based on the middle value with adjusted df	2.281	1	49.853	.137
	Based on the trimmed average	3.002	1	59	.088

It is evident from the preceding table that the value of Based On Mean is 3.43, so it can be said that the data from this study is homogeneous, because it has a significance level of ≥ 0.05.

3.3.3 Mann Whitney test

Hypothesis testing is done using independent t-test for normally distributed and homogeneous result data. Meanwhile, for pretest and posttest result data that are not normally distributed, non-parametric statistics will be used, namely the Mann Whitney test. This hypothesis testing uses SPSS 23 for windows (Table 6).

Table 6. Mann Whitney test results creative thinking skills data

	Creative thinking learning outcomes
Mann-Whitney U	239.000
Wilcoxon W	674.000
Z	-3.279
Asymp. Sig. (2-tailed)	.001

It is evident from the preceding table that the Mann Whitney Test findings indicate an Asymp. Sig. (2-tailed) value < 0.05. These findings indicate that Ha is accepted and Ho is rejected. Based on the average difference between the experimental and control classes, it can be said that the e-module is effective.

3.4 Discussion

The aim of evaluating effectiveness, as articulated by Huang et al. (2020), is to ascertain the influence of e-modules on the enhancement of students' creative thinking abilities, particularly their capacity to generate original ideas or uncover innovative solutions. This research assessed the effectiveness of a guided inquiry-based physics e-module centered on global warming mitigation within the framework of the Merdeka Curriculum. The evaluation process included a comparison of the Learning Objective Achievement Criteria (LOAC) between an experimental group (utilizing the e-module) and a control group, alongside an analysis of the average scores from both classes.

It is essential to grasp the significant context in which this e-module was created. Global warming has triggered a series of environmental catastrophes, such as increasing extreme temperatures, the rapid melting of polar ice, rising sea levels, and changes in weather

patterns, resulting in more severe natural disasters like floods, droughts, and intense storms. These substantial effects go beyond ecological systems, profoundly impacting human existence, including food security, public health, and the global economy.

In this context, it is vital to enhance students' comprehension of global warming and its mitigation strategies. The guided inquiry-based physics e-module developed for this research was crafted not only to increase students' awareness of urgent environmental challenges but also to foster their creative thinking skills in formulating solutions to global issues. By employing a problem-based learning methodology, the e-module encourages students to analyze climate change data, understand the principles of the greenhouse effect, and devise both mitigation and adaptation strategies to address the consequences of global warming. The results of the study clearly indicate that utilizing this e-module not only enhances students' creative thinking abilities but also fosters their environmental awareness and concern. This finding is in perfect alignment with the goals of 21st-century education, which emphasize the significance of critical thinking, problem-solving, and global awareness in addressing future challenges.

A comparison of the Learning Objective Achievement Criteria (LOAC) between the experimental and control groups revealed that the experimental group achieved notably higher completion rates. Specifically, 75% of students in the experimental group reached learning completion, in contrast to only 38% in the control group, relative to the school's LOAC target of 80%. This considerable difference suggests that the incorporation of the e-module into the educational process was exceptionally effective in enhancing LOAC. This conclusion is consistent with the findings of Laili et al. (2019) regarding the efficacy of project-based learning e-modules, which similarly demonstrated an increase in students' classical completion rates.

Moreover, the indicators of creative thinking skills exhibited a more significant improvement in the experimental group compared to the control group. The most notable advancements were seen in the originality and flexibility indicators. This implies that the guided inquiry-based physics e-module effectively motivated students to produce unique ideas and investigate various approaches to problem-solving. This is in accordance with the tenets of constructivist learning theory (Ibda, 2015), which asserts that active student participation and exploration are essential for the construction of knowledge. The guided inquiry approach, integrated within the e-module, enables students to explore concepts through organized problem-solving tasks, thus facilitating deeper cognitive processing and creativity. The average percentage of each creative thinking skill indicator further highlighted a considerable disparity between the two classes, with the experimental class consistently demonstrating higher average values. A more in-depth analysis of how each component of creative thinking was influenced by the e-module revealed the following: Fluency: The experimental class showed a substantial increase in fluency, moving from a "Sufficient" category (51.17) to a "Very High" category (89.06). This improvement underscores the e-module's effectiveness in helping students generate a greater quantity of ideas when confronted with physics-related problems. The inclusion of open-ended questions and scenario-based exercises provided ample opportunities for students to practice expressing their thoughts freely. Flexibility: The ability to approach problems from diverse perspectives significantly improved in the experimental group, rising from "Sufficient" (41.66) to "Very High" (89.97). This result suggests that the e-module effectively prompted students to consider alternative solutions rather than relying on memorization or rigid problem-solving strategies. This aligns with Vygotsky's (1978) socio-cultural theory, which emphasizes that learning occurs through interaction with more knowledgeable individuals or instructional tools. Originality: A marked improvement in originality was observed, with scores climbing from "Sufficient" (53.77) to "Very High" (93.75). This indicates that students in the experimental class developed their capacity for innovative thinking and presenting unique solutions. The inquiry-driven tasks, which required students to formulate hypotheses and propose unconventional solutions, played a key role in stimulating their originality. Elaboration: Elaboration skills also demonstrated significant growth, increasing from "Sufficient" (42.70) to "High" (80.20). This suggests that

students became more adept at expanding on their ideas, adding relevant details, and refining their responses. The structured prompts and reflection exercises within the e-module facilitated this enhancement by encouraging students to articulate their reasoning in greater depth.

These findings collectively confirm that the guided inquiry-based physics e-module not only improved overall creative thinking abilities but also specifically enhanced different facets of creativity, thus demonstrating its effectiveness as an instructional tool. N-gain values were used to further evaluate the rise in pretest and posttest scores for each indicator in the experimental and control groups. The experimental class obtained an average N-gain value in the "high" category, indicating a "fairly effective" interpretation, according to the N-gain calculation results (shown in Table 3 of the original study). On the other hand, the N-gain computation results for the control class fell into the "low" range, suggesting a "ineffective" interpretation. Constructivist learning theory (Ibda, 2015; Vygotsky, 1978), which holds that learning is best successful when pupils actively create knowledge rather than passively absorbing it, significantly supports this finding.

The comparison of the average creative thinking skill scores between the experimental and control classes, as well as the completion rates of classical learning, provide strong evidence that the guided inquiry-based physics e-module can successfully enhance students' creative thinking abilities. The effectiveness of e-modules as a physics learning medium especially on practicum, during distance learning, is demonstrated by research by Mauliana et al. (2022), which found that students using e-modules in physics learning achieved a significant increase in learning outcomes compared to a control group. Compared to other studies utilizing e-modules, such as Sukmafani et al. (2021), this research notably highlights a significantly higher increase in the originality and flexibility aspects of creative thinking. One plausible explanation for this could be the structured problem-solving approach embedded in this specific e-module, which may facilitate better engagement with creative tasks. Conversely, Miskiyyah (2021) found that students sometimes struggle with the autonomy required in inquiry-based learning, which can limit their creative thinking. This suggests that proper scaffolding and teacher guidance are critical in ensuring the effectiveness of e-modules in fostering creativity.

As recommended by Johnson & Christensen (2020), a hypothesis was developed to enable researchers to verify and test their hypotheses regarding the correlation between variables. Using the Mann-Whitney test for hypothesis testing, the efficacy of the e-module was further confirmed. A significant difference between the experimental and control groups was confirmed by the statistical analysis, confirming the e-module's critical function in developing students' capacity for creative thought. From a pedagogical standpoint, the findings of this study underscore the importance of interactive and inquiry-driven learning materials in physics education. Traditional methods that heavily rely on rote learning and passive knowledge reception may not adequately cultivate higher-order thinking skills like creativity. The structured nature of the guided inquiry approach ensures that students actively engage with the learning material, apply their understanding to new contexts, and refine their cognitive abilities through iterative questioning and problem-solving.

Additionally, the digital format of the e-module offers greater flexibility and accessibility in learning. Unlike conventional textbooks, digital modules can seamlessly incorporate multimedia elements such as simulations, animations, and interactive exercises, catering to diverse learning preferences. This aligns with Paivio's (1990) Dual Coding Theory, which suggests that information presented both visually and verbally enhances cognitive processing and retention. The integration of these multimodal features within the e-module likely contributed significantly to the observed improvements in learning outcomes and creative thinking skills. Finally, the guided inquiry-based physics e-module on global warming mitigation content, created for the autonomous curriculum, was proven to be quite helpful in improving students' creative thinking abilities across numerous assessment criteria. Research by Asrizal et al. (2023) supports this, as their meta-analysis also showed that e-modules can improve students' capacity for critical and creative thought when studying science.

Teachers, curriculum designers, and legislators working to improve physics education should take note of the study's important conclusions. Considering the demonstrated efficacy of e-modules based on guided inquiry, educational institutions and schools have to give careful thought to integrating such digital learning resources into their teaching programs. Future research could delve into the long-term impact of such interventions on students' problem-solving skills and their ability to transfer creative thinking skills to other academic domains. Furthermore, expanding the study to encompass different educational levels, such as primary or tertiary education, could offer additional insights into the adaptability of guided inquiry-based e-modules across diverse age groups. Exploring the integration of artificial intelligence-driven adaptive learning technologies within these e-modules could also be a promising avenue for future research, enabling personalized learning experiences tailored to individual student needs. Additionally, recommendations include exploring the long-term retention of these skills and their applicability in real-world problem-solving scenarios, as well as the potential integration of the e-module into a broader curriculum framework. All things considered, these results clearly indicate that the guided inquiry-based physics e-module is a useful teaching resource for developing students' capacity for original thought and raising learning standards. Inquiry-based pedagogical frameworks and digital technology can be used by educators to develop more meaningful and engaging learning experiences that effectively equip students for the complex problems of the twenty-first century.

4. Conclusions

This study demonstrates how well the guided inquiry-based physics e-module fosters students' capacity for original thought when it comes to mitigating the effects of global warming-related disasters. According to the N-Gain test findings, the experimental group using the e-module had a large improvement in their capacity for creative thought (66%), while the control group using conventional methods only saw a slight improvement (33%). Additionally, the Mann-Whitney test revealed a significant difference between the two groups, highlighting how well the e-module fosters students' capacity for creative thought.

Moreover, this e-module aligns with the Merdeka Curriculum approach, which prioritizes project-based learning and adaptability in skill development for students. Consequently, the integration of e-modules in physics education not only enhances conceptual comprehension but also aids students in formulating innovative responses to global issues such as global warming. Therefore, the ongoing development and application of disaster mitigation-focused e-modules in science education are essential to enhance learning effectiveness and prepare the younger generation to confront the challenges posed by global warming.

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Author Contribution

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