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Fostering 15–16-Year-Old Students' Social Responsibility through a Physics E-worksheet: An ENACT Learning Model Intervention

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ABSTRACT

Education in the 21st Century significantly emphasizes developing key competencies, including social responsibility. However, a substantial gap persists between students' theoretical understanding of social responsibility and its practical application, particularly in physics education. This study aims to develop a physics student worksheet based on the ENACT (Engage, Navigate, Anticipate, Conduct, and Take Action) learning model to foster social responsibility among students aged 15 to 16. This study employed the Research and Development (R&D) methodology and adopted the Borg and Gall development model (stages 1–7), involving validation by media and content experts and a practicality assessment. The sample comprised two teachers and 127 students from two public schools in Bandar Lampung, with data collection techniques including structured interviews, observations, and Likert-scale questionnaires. Validation results indicated high quality, with 92% from media experts and 94% from content experts, while practicality assessments yielded scores of 93% from teachers and 89% from students, categorizing the worksheet as highly practical. The teachers and students provided positive feedback, highlighting the worksheet's ease of use, relevance, engaging content, and potential to cultivate social responsibility among students. This study contributes to integrating digital technology into physics education by underscoring the role of interactive learning tools in fostering social responsibility. However, further research is recommended to examine the effectiveness of ENACT-based e-worksheets in diverse educational contexts and across different subject areas.

INTRODUCTION

Education in the 21st Century emphasizes the development of competencies that extend beyond the mastery of theoretical concepts (Lestari et al., 2023; Lubis et al., 2023) to encompass broader social dimensions, including social responsibility. Social responsibility is a fundamental competency in individual and community development (Macalalag et al., 2020), encompassing awareness of social issues (Laura & Olivia, 2020), the ability to contribute positively to society (Lee et al., 2020), and an understanding of how individual actions impact the environment (Fernandez, 2013; Xu et al., 2022). This principle highlights the obligation of individuals, including students, to consider the social implications of their actions (Børsen et al., 2013; Idowu & Sitnikov, 2020). Although social responsibility has gained increasing attention in education, a significant disparity persists between conceptual understanding and practical

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application. While students may grasp the theoretical aspects of social responsibility, they often encounter challenges applying these principles in daily life (Alsaeed, 2022; Buğdayci, 2019). Schools play a crucial role in fostering social responsibility (Zandvoort et al., 2013). However, the current education system focuses predominantly on cognitive development and lacks sufficient opportunities for students to engage in experiential, action-based social learning (Hope, 2016; Zeidler, 2011). Educational approaches continue to emphasize knowledge transmission rather than providing authentic experiences that empower students to analyze, evaluate, and take action on social issues relevant to their lives (Temporin, 2014).

Preliminary research conducted at SMAN 5 and SMAN 9 Bandar Lampung revealed a substantial disparity between students' theoretical comprehension and the practical application of social responsibility in daily life. Findings indicate that 56% of students acknowledged a lack of active participation in social responsibility initiatives, while 68% reported an incomplete awareness of environmental and social issues in their surroundings. The instructional methods in both schools remain predominantly lecture-based, supplemented by classroom discussions. Additionally, teachers' teaching materials are largely conventional, consisting of textbooks, printed modules, and paper-based student worksheets, with digital media usage limited to learning videos and presentation slides. These findings underscore the restricted extent of students' engagement with social responsibility. A key contributing factor to this deficiency is the limited availability of effective digital teaching materials designed to foster social responsibility values among students.

The absence of interactive digital teaching materials designed to cultivate social responsibility in physics education represents a critical gap that requires attention. E-worksheets, however, offer an innovative solution for facilitating experiential learning (Sudirman et al., 2024). These digital resources provide enhanced accessibility and flexibility (Khotami et al., 2023), allowing students to engage with learning content anytime and from any location using mobile devices (Rahma & Novita, 2024; Soenarko et al., 2022). Moreover, e-worksheets contribute to a more engaging and contextually relevant learning experience (Zahroh & Yuliani, 2021) while also fostering a deeper understanding of social problems and issues (Lee et al., 2013; Purnamayanti et al., 2023).

Previous research has focused on developing e-worksheets as instructional materials in physics education, employing various learning models to enhance specific cognitive skills. These include e-worksheets utilizing the SSIBL model to improve scientific literacy (Putra et al., 2023), the SSCS model to foster critical thinking skills (Nurmala & Fatisa, 2022), and the guided inquiry model to enhance conceptual understanding in physics (Putri et al., 2022). Additionally, e-worksheets have been developed for optics in physics using a guided-inquiry approach (Febriani et al., 2022), for electric current circuits in high school students through the PBL model (Hasanah, 2021), and for electric field concepts to improve scientific literacy (Fadhila, 2022). Further applications include e-worksheets on global warming (Atmaja & Samsudin, 2024), problem-solving through the PBL model (Nenggala et al., 2024), and the ExPRession learning model to cultivate critical thinking skills (Fadilah et al., 2023). However, while these studies have successfully integrated various pedagogical approaches, the explicit incorporation of social responsibility within e-worksheet-based learning remains largely unexplored.

The selected learning model that effectively integrates social responsibility into the interactive learning process is the ENACT Learning Model. The ENACT learning model (Engage, Navigate, Anticipate, Conduct, and Take Action)

connects physics concepts with relevant social issues while equipping students with critical and reflective thinking skills to address real-world problems (Erna et al., 2023). This model offers numerous pedagogical benefits, including a deeper understanding of content knowledge, enhanced teamwork abilities, improved problem-solving skills, and increased awareness of social issues (Ok et al., 2021). The ENACT model is further enriched through integration with the socioscientific issues (SSI) approach (Lee et al., 2020). The SSI approach enables students to grasp their decisions' social, scientific, and ethical implications (Hwang et al., 2023). By understanding these implications, students are encouraged to think critically about the consequences of their actions on both the environment and society (Sadler & Zeidler, 2005), which, in turn, fosters a more responsible attitude and a deeper awareness of their role within an interconnected global society.

Previous research on the ENACT model has successfully increased social responsibility in various educational contexts. For example, Erna et al., (2023) implemented the ENACT model in chemical engineering education at a university in Indonesia, which resulted in increased student social responsibility. Choi & Lee, (2022) increased social responsibility among junior high school students in South Korea through a STEM science curriculum, while Hwang et al., (2023) promoted social responsibility in safety engineering students at a university in South Korea, and Ok et al., (2021) encouraged social responsibility among engineering students through online courses at a university in South Korea. This ENACT learning model explains a lot about its implementation in learning. However, no research has examined developing teaching materials integrating the ENACT learning model. Therefore, this study aims to develop physics electronic worksheets using the ENACT learning model to foster social responsibility among 15–16-year-old students. This research focused on developing the electronic worksheets and analyzing students' responses to the developed product without evaluating their social responsibility improvement or effectiveness.

METHODS

This study employed a Research and Development (R&D) methodology, a systematic approach designed to produce specific educational products (Sugiyono, 2019). The development process follows the Borg and Gall model, specifically stages 1 to 7 (Sugiyono, 2018). These stages provide a structured framework to ensure the developed products undergo rigorous validation before broader implementation. The selection of the Borg and Gall model allowed researchers to adapt research procedures in alignment with the specific needs of the development process. Multiple techniques were used to collect comprehensive data, including structured interviews, observations, and questionnaires. Structured interviews were conducted with two teachers using predefined interview guidelines to explore instructional needs and gather preliminary insights regarding students' and teachers' requirements in the learning process. Observational techniques were implemented using observation sheets to analyze the needs of students, teachers, and schools while monitoring classroom instruction and evaluating the application of the developed product in an authentic educational setting.

Additionally, questionnaires were distributed to 127 students and six experts to collect quantitative data on their perceptions of the developed e-worksheet. The validation process involved assessments from three media experts and three content experts, who evaluated the feasibility and quality of the instructional media using a structured validation questionnaire. Furthermore, a student response questionnaire was administered to assess students’ perceptions of the quality,

usability, and interactivity of the e-worksheet. The following section details the stages of the Borg and Gall research procedure.

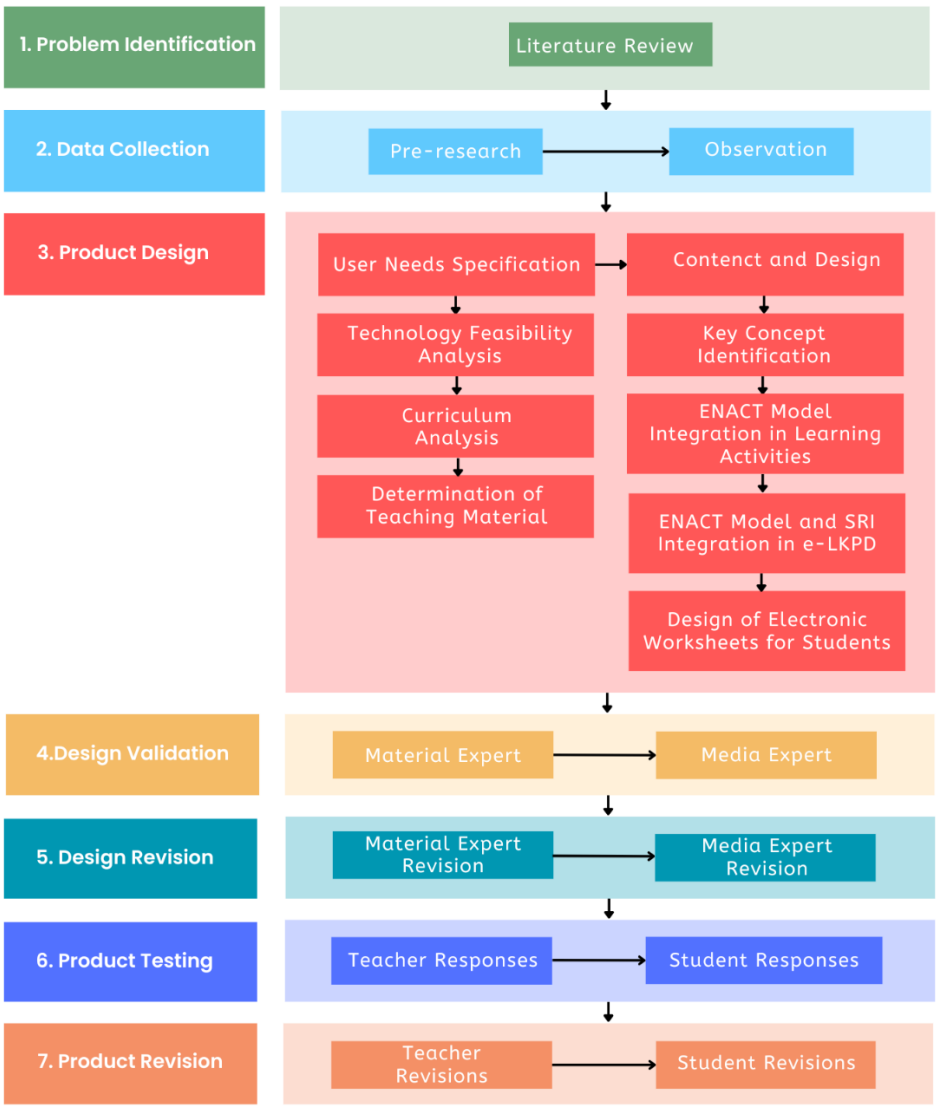


Figure 1. Research Procedure

Content and design development encompasses structuring learning materials, incorporating relevant scientific issues, and implementing them within instructional activities. This process follows a systematic approach to ensure coherence between pedagogical objectives and content delivery. At this stage, the ENACT learning model is deliberately integrated to enhance students' social responsibility by fostering engagement with real-world issues. The following section provides a detailed overview of the content and design development process and an illustration of the ENACT model's application in learning.

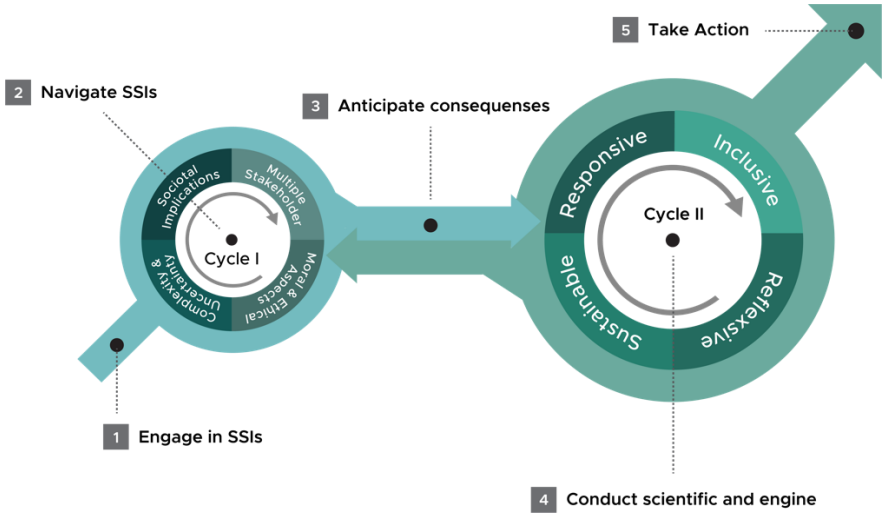


Figure 2. ENACT Model (Lee et al., 2020)

Each stage of the ENACT model is systematically aligned with social responsibility indicators to ensure that the e-worksheet content effectively cultivates students' social awareness and accountability. By integrating global warming material, the e-worksheet allows students to engage with real-world environmental challenges, critically analyze their implications, and take informed actions. The following section illustrates the e-worksheet content development process, demonstrating the integration of the ENACT model with social responsibility principles.

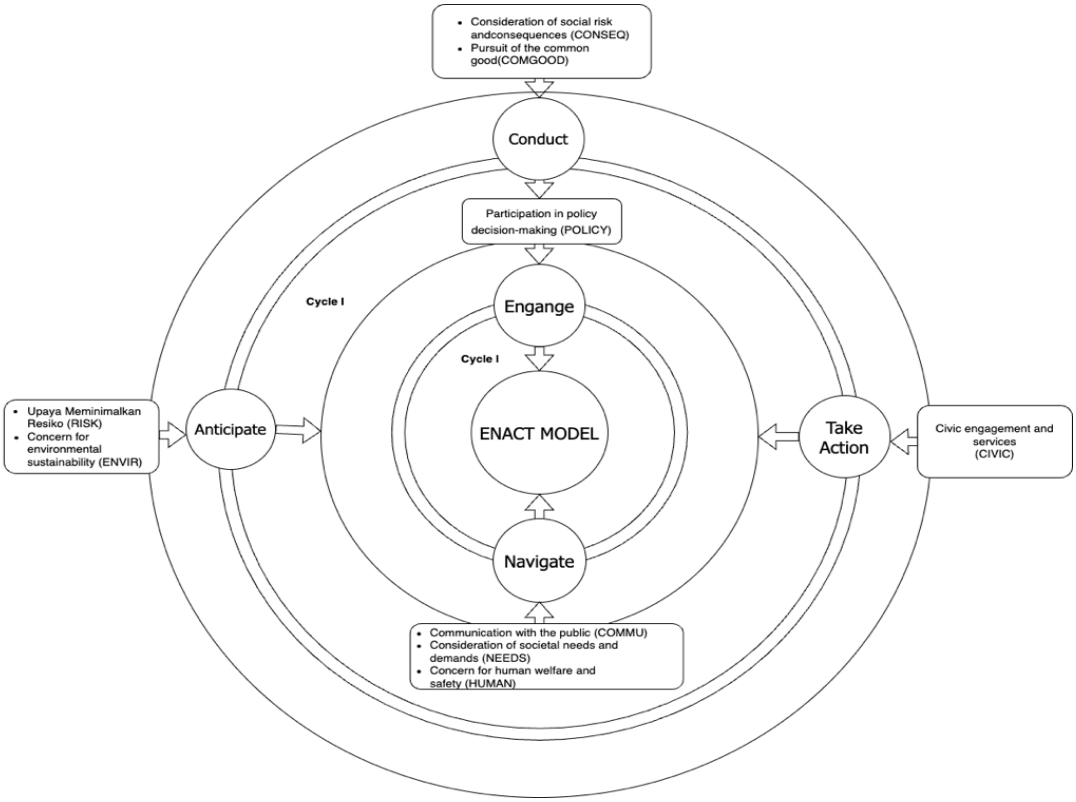


Figure 3. Development of E-worksheet Content Integrated with the ENACT Model and Social Responsibility

The product trial involved 127 students from SMA Negeri 5 and SMA Negeri 9 Bandar Lampung and two teachers from each school. Data collection was carried out in several stages. The first stage involved distributing pre-research questionnaires to students to assess their initial understanding of social responsibility. Next, instrument validation was conducted by involving two experts: material experts who evaluated the content's alignment with the curriculum and media experts who assessed the technical aspects and presentation of the e-worksheet. Following the validation process, a pilot test of the e-worksheet was conducted, after which student response questionnaires were distributed to measure their perceptions of the product's quality and interactivity. Data analysis in this study was conducted descriptively using both qualitative and quantitative approaches. The data collected were analyzed using a Likert scale, modified to a 4-point scale to eliminate ambiguous response categories, such as 'somewhat agree' or 'somewhat good' (Hartanto, 2017). This modification was intended to yield more accurate data. The Likert scale was employed to analyze students' needs, the validity of the material and media experts, and the responses from teachers and students. Data from the expert validators were analyzed using the following formula (Wiliyanti et al., 2022).

$$P = \frac{s}{N} \, x \, 100 \, \%$$

Explanation:
P = Percentage obtained from the validator
s = Total score for each selected criterion
N = Ideal total score

The obtained percentage is then used to evaluate the feasibility of the product, following the interpretation guidelines provided by (Irwanto et al., 2021)**:**

Table 1. Likert Scale Percentage Assessment

Percentage	Criteria	Description
80% - 100%	Excellent	Can be used without revisions
60% - 80%	High	Can be used with minor revisions
40% - 60%	Low	Not recommended for use as major revisions are needed
0% - 40%	Poor	Cannot be used

Qualitative data from the interviews were analyzed using thematic analysis, where the results of the interviews were coded to identify patterns and themes related to the needs of students, teachers and schools. Meanwhile, observation data was analyzed using descriptive narrative, focusing on learning activities, student engagement, and the application of learning media in the classroom. The results of this analysis were used to complement the quantitative data, providing a comprehensive picture of the relevance of ENACT-based e-worksheets.

RESULTS AND DISCUSSION

Potential and Problems

The research began with an analysis of the potential and problems related to the needs of both teachers and students. The results of this analysis served as the foundation for designing the study. The researcher employed questionnaires and observation techniques. The study was conducted at two schools, SMAN 5 and SMAN 9 Bandar Lampung, both are equipped with adequate technological facilities, such as Wi-Fi and student access to smartphones, and have implemented an independent curriculum. The researcher selected physics material on global warming to foster students' social responsibility. The following are the results of the pre-research conducted by the researcher:

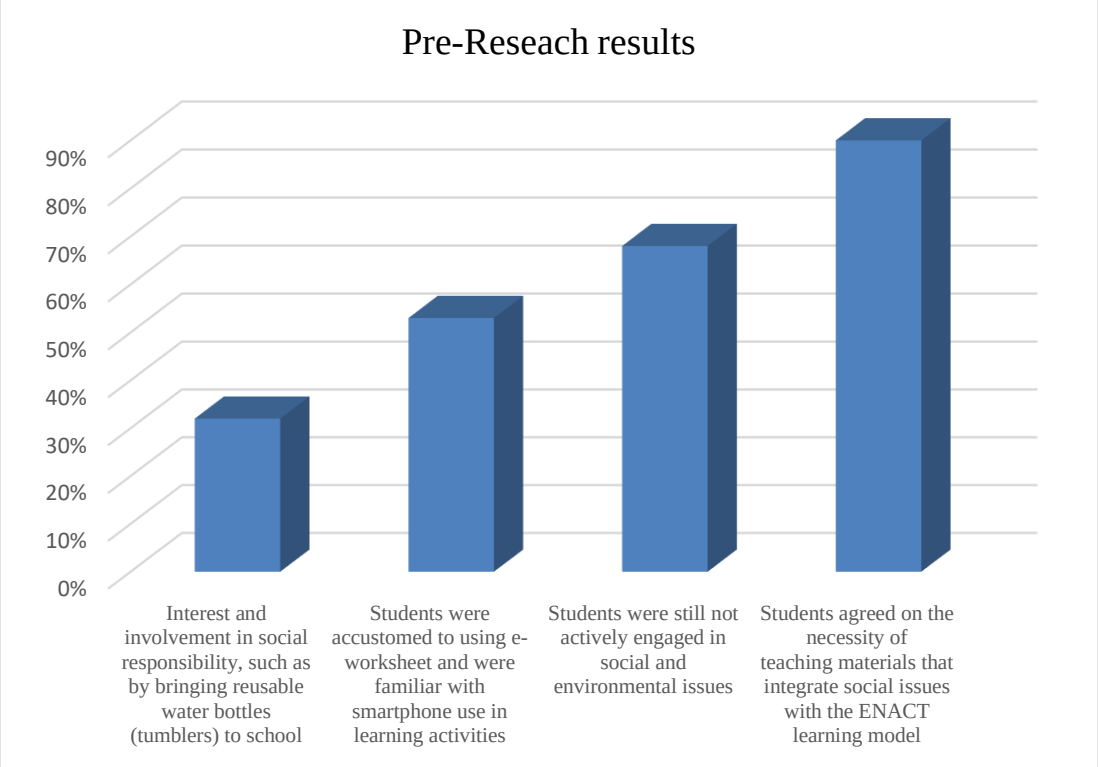


Figure 4. Pre-research Results

Figure 4 shows the pre-research results on student engagement in social and environmental issues. Only 32% of students showed interest in social responsibility through simple actions, such as bringing a reusable water bottle. In comparison, 80% of students were not actively contributing to social and environmental issues. This finding confirms a significant gap between theoretical understanding and practical application. On the other hand, 53% of students were familiar with digital technology, such as smartphones, indicating their readiness to receive digital-based teaching materials. Furthermore, 90% of students supported the development of teaching materials that integrate social issues with the ENACT learning model, reflecting the need for innovative learning media relevant to real-life challenges. This research focused on developing e-worksheet teaching materials utilizing the ENACT model to foster students' social responsibility.

Product Design

This e-worksheet design integrated the ENACT learning model, which consisted of five main steps: Engage, Navigate, Anticipate, Conduct, and Take Action. Each step was adapted to interactive learning activities to foster students' social responsibility. The main characteristic of this e-worksheet lies in integrating social responsibility indicators in each stage of the ENACT model, which ensures students not only learn physics concepts but also develop social sensitivity and the ability to take responsible action.

The development of this e-worksheet went through a systematic process, starting with creating a visual design using Canva cloud-based design software. The design was made with an attractive and user-friendly appearance and tailored to students aged 15 to 16. After completing the graphic design, the e-worksheet was developed into a website-based digital learning tool using WordPress. The final product of this e-worksheet is a website, which can be accessed through various devices, such as

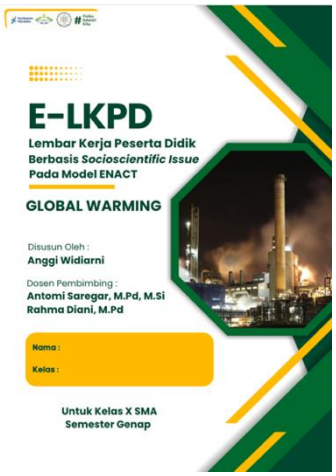
smartphones, tablets, or computers. The website-based platform was chosen for its accessibility and the ability to integrate multimedia elements, such as videos, which are aligned with the ENACT learning model.

These main characteristics include the integration of the ENACT model into the e-worksheet. The following is a table on the integration of the ENACT learning model into learning activities:

Table 3. Integration of the ENACT Learning Model into Learning Activities

No	ENACT Model Steps	Social Responsibility Indicator	Instructional Approach	Student Activities in the E-worksheet
1	Engage in SSI	• Participation in decision-making (POLICY)	Identify issues by searching the internet and engaging in group discussions	• Explore various SSI issues related to global warming, such as reading articles and news and watching YouTube videos. • Discuss the readings with group members.
2	Navigate in SSI	• Communication with the Community (COMMU) • Consideration of Community Needs (NEED) • Protection of Human Welfare and Safety (HUMAN)	Map the stakeholders involved in the SSI	• Select SSI issues provided by the teacher. • Identify the stakeholders involved (e.g., companies, government, etc.). • Explore potential conflicts and various perspectives among the stakeholders on the selected issues.
3	Anticipate	• Risk Minimization Efforts (RISK) • Promotion of Environmental Sustainability (ENVIR)	Write future scenarios	• Write the desired future scenario. • Discuss how to reduce and resolve the related issues/problems.
4	Conduct	• Consideration of Social Consequences (CONSEQ) • Pursuit of the Common Good (COMGOOD)	Experiment	• Conduct scientific experiments related to the issues to propose solutions (e.g., practical examples).
5	Take Action	• Service and Community Involvement (CIVIC)	Campaign, Policy proposals	• Take action (e.g., creating posters, making videos, etc.) on solutions to the issues.

Table 4. The Design of Physics E-worksheet

Product Design	Description
	**Cover :** The e-worksheet cover design combines green and yellow to represent the balance between nature and energy, which aligns with the environmental theme. The title uses modern and clear typography to enhance readability and visual appeal. The main visual feature illustrates industrial heat generation, designed to promote student's social responsibility towards global environmental issues.
	**Learning outcomes :** The learning outcomes are designed to develop students' competencies in understanding and analyzing global warming issues through a socioscientific issues (SSI) approach.
	**Engage:** In the engage stage, students are asked to read materials or watch videos provided by the teacher related to SSI issues on global warming. After reading, students answer, "How does this issue impact the surrounding community?" This question also aims to assess social responsibility based on the indicator of participation in decision-making (Policy).

Product Design	Description

Navigate :

The second step in the ENACT learning model is the navigate stage, where students and their group members explore the issues identified concerning global warming. At this stage, students and their group discuss the issues they will choose, as provided by the teacher. The social responsibility indicators at this stage are communication with the community (COMMU), consideration of social consequences (CONSEQ), and the protection of human welfare and safety (HUMAN).

Anticipate:

The third stage in the ENACT learning model is anticipated. At this stage, students are asked to anticipate what will happen in the next 10 years if the selected issue is addressed and what will happen if it is not. The social responsibility indicators at this stage are efforts to minimize risks (RISK) and the promotion of environmental sustainability (ENVIR).

Conduct:

In this stage, students are asked to plan solutions and conduct experiments according to their plans. The social responsibility indicator at this stage is the consideration of social consequences (CONSEQ).

Product Design	Description
	**Take Action:** Take Action is the final stage in the ENACT learning model. After identifying, exploring, and anticipating the issue and planning solutions/conducting scientific practices, the final step is for students to take action for the community. At this stage, students are asked to share the solutions they have developed through platforms such as social media or campaigns held within the school environment. The social responsibility indicator at this stage is civic engagement (CIVIC).

Design and Revision Design

The feasibility evaluation of the e-worksheet teaching materials was conducted through formative evaluation, involving two main aspects: assessment by content experts and media experts. The content expert assessment covered aspects such as content feasibility, presentation, language, ENACT model evaluation, and social responsibility integration within the teaching materials. Meanwhile, the media expert assessment focused on the components of the e-worksheet, user interface, user experience, and the software used in its development.

Table 5. The results of material and media experts

Validation	Aspects	Percentage	Average	Category
Material Expert	Content Feasibility Aspects	96%	95%	Excellent
	Presentation Feasibility Aspects	93%		
	Language Assessment Aspect	94%		
	ENACT Model Assessment Aspects	99%		
	Social Responsibility Aspects	89%		
Media Expert	Component of E-worksheet Aspects	92%	92%	Excellent
	User Interface Aspect	94%		
	User Experience Aspects	88%		
	Software Aspect	92%		

The validation results above show that the aspects received an excellent expert assessment. The researcher made minor revisions, as suggested by the material expert, to sharpen the addition of the ENACT model components and social responsibility indicators into the e-worksheet activities, thus creating a learning experience that can foster students' social responsibility.

Product Testing and Product Revision

Product trials were conducted to assess the teacher's and student's responses to the physics e-worksheet. Teachers assessed that the e-worksheet facilitates learning, increases student involvement, and presents physics concepts interactively and in-depth. Students also stated that this e-worksheet is interesting, presents physics concepts more interactively, and is relevant to everyday life related to social issues. In addition, students revealed that these e-worksheet can increase their motivation to learn, facilitate effective self-learning and increase their social responsibility. The results of this trial confirm that the physics e-worksheet is very practical and follows the current technology-based learning needs. The following are the results of the Physics e-worksheet response according to teachers and students:

Table 6. The results of the response

Practicality	Aspects	Percentage	Average	Category
Teacher's Response	Content Component Aspect	94%	95%	**Excellent**
	User Interface Aspect	95%		
	Social Responsibility Aspect	91%		
Students' Response	Interest in the teaching materials aspect	88%	89%	**Excellent**
	Mastery of the content aspect	86%		
	Appearance Aspects	90%		
	Feasibility Aspects	92%		

Based on the trial results from both teachers and students, the physics e-worksheet product was rated as highly practical, effective, and aligned with modern learning needs. The average teacher response score was 93%, and the student response score was 89%, both in the feasible category. Therefore, no revisions were necessary, as this product has already met expectations in fostering students' social responsibility and facilitating interactive, technology-based learning.

Discussion

This study revealed that developing e-worksheet teaching materials involves structured steps that refer to the ENACT learning model. The development process began with identifying learning needs through questionnaires, observations, and interviews at SMAN 5 and SMAN 9 Bandar Lampung. Observations were conducted to analyze the needs of students, teachers and schools, while structured interviews with two teachers were used to explore the needs for teaching materials. The data showed that only 32% of students had interest and involvement in social responsibility, while 53% were familiar with using e-worksheets and smartphones in learning activities. However, 68% of students showed low social participation, especially in social and environmental issues. These findings emphasize the need for effective learning media to bridge the gap between students' theoretical understanding and practical application of social responsibility. The physics material

used in this e-worksheet product focuses on global warming.

The validation process of this e-worksheet involved three media experts and three material experts. The validators used Likert-based criteria to evaluate the feasibility of the e-worksheet design and content quality. The validation results showed an average score of 92% from the media experts and 94% from the subject matter experts, which placed the e-worksheet in the 'excellent' category and 'suitable for use without revision.' The validators gave high scores on visualization aspects, the material's systematic structure, and the relevance of the content to social responsibility indicators. From the user side, 93% of teachers and 89% of students responded positively to the e-worksheet, noting that it is easy to use, interesting, and relevant to modern learning needs. This is in line with constructivist learning theory, which states that active exploration-based teaching materials can improve students' understanding more meaningfully.

Constructivist learning theory supports using e-worksheets as a medium or teaching material that allows students to actively engage in learning (Chen & Lertamornsak, 2023). E-worksheet is designed to provide a learning experience that relies on the passive reception of information and encourages students to explore and discuss relevant social issues, such as global warming. The socioscientific inquiry (SSI) approach in e-worksheet prompts students to identify and discuss social issues related to the subject matter, thereby integrating social contexts into physics learning. Previous research indicates that e-worksheets incorporating social issues can increase student engagement. For instance, research by (Wahyuni et al., 2024) demonstrated that SSI-based e-worksheets can enhance students' scientific argumentation, while (Pratiwi & Lestari, 2024) found that e-worksheets utilizing the PBL learning model significantly improved students' science literacy skills. This suggests that e-worksheet development can effectively address students' lack of engagement with social issues and aims to foster their social responsibility. Furthermore, the chosen learning model promotes students' social responsibility.

The e-worksheet product design was developed using cloud-based design software (Canva) to produce an attractive and user-friendly appearance. The e-worksheet was then developed into a web-based platform using WordPress, which allows students to access learning materials and videos anytime and anywhere. Although the e-worksheet is not fully interactive, as students cannot write directly on the platform, the product is designed to provide flexible and structured access, thus supporting independent learning. The use of the ENACT model is the main advantage of this e-worksheet, as each stage is designed to integrate social and environmental issues into physics learning.

In the context of this e-worksheet development, the ENACT learning model plays a significant role in enhancing students' understanding of complex social problems. The ENACT model operates through cycles (Cycle I and Cycle II) aimed at shifting epistemological beliefs towards the development of science and technology by identifying socioscientific issues (SSI). In Cycle I, which includes the Engage, Navigate, and Anticipate steps, the focus is on examining aspects of the problem, such as social implications, customary stakeholders, moral and ethical dimensions, and complexity and uncertainty. Cycle II, comprising the Conduct and Take Action steps, emphasizes responsiveness, inclusivity, reflexivity, and sustainability (Erna et al., 2022).

The learning design activity in this product begins with integrating the

ENACT learning model into the e-worksheet. For instance, the first step of the ENACT model, 'Engage in SSI,' involves students in identifying relevant socioscientific issues (SSI) that interest them. The researcher provides reading materials and videos from various sources, such as news or journal articles. Students then discuss these issues with their group members and select SSI topics provided by the teacher in the e-worksheet. This approach aligns with the research of Choi & Lee, (2022), who applied the ENACT model in junior high schools by offering students various topics. However, unlike Choi, other researchers, such as Hwang et al., (2023), did not limit the issues engineering students could choose from when applying the ENACT model.

In the second step of the ENACT learning model, 'Navigate in SSI,' students explore the selected issues. The third step follows this, 'Anticipate,' where students create a narrative about the potential developments over the next 10 years and design solutions to the issue. This aligns with the research of Erna et al., (2023), who also explored SSI issues and involved students in mapping or interviewing indigenous stakeholders related to the issues under study. In the fourth step, 'Conduct Scientific and Engineer,' students implement their solutions by conducting experiments or constructing arguments based on their plans and the selected issues. This approach differs from that of Ok et al., (2021), who utilized programming tools such as MATLAB or Python to create solution prototypes. The final step of the ENACT model, 'Take Action,' involves students disseminating their solutions through school campaigns by creating posters or videos. The results of this step are published, which is consistent with the findings of Erna et al., (2023), Hwang et al., (2023), and Ok et al., (2021) who used social media or posters as a medium for publication.

The e-worksheet design in this study was designed using a graphic design platform that allows researchers to create teaching materials with a visually appealing appearance. This platform allows students to access e-worksheets electronically, both inside and outside the classroom. Although it is not interactive because students cannot write their answers directly on this e-worksheet, this e-worksheet makes it easy for students to view materials and watch videos that have been structured. The accessibility of e-worksheets through electronic devices makes it easy for students to follow learning wherever they are, thus supporting flexibility in the learning process. Media and material experts consider The e-worksheet very feasible/good. The response of teachers and students is also very good on this e-worksheet. This research is in line with Tri Wahyuni et al. (2024) findings, which showed that e-worksheets can improve students' learning ability.

Although the development of this ENACT model-based e-worksheet shows significant potential in fostering students' social responsibility, some advantages and limitations need to be considered. One of the main advantages of this product is its ability to effectively integrate social issues, such as global warming, into physics learning in the ENACT learning model. This provides a more relevant and meaningful learning context for students while increasing their engagement in the learning process. The interactive approach adopted through the ENACT model allows students to engage in activities that facilitate the development of critical thinking skills, problem solving and cooperation. In addition, this e-worksheet has been designed for technology-based learning, which is highly relevant to the needs of learning in today's digital era, facilitating independent and flexible access to learning materials.

However, several limitations must be acknowledged. This study was conducted in only two schools, which may limit the generalizability of the findings to a broader population. Additionally, while this e-worksheet effectively addresses global warming content, its application to other physics topics has not been thoroughly explored. Further development is required to expand the range of physics topics that can be integrated into the e-worksheet using the ENACT model. Moreover, this research has not directly assessed the effectiveness of the e-worksheet in fostering students' social responsibility. Therefore, further in-depth studies are needed to evaluate the impact of e-worksheet implementation in a broader and more diverse educational context.

Despite these limitations, the research's product development contributes significantly by providing teaching materials that bridge the gap between physics education and the development of students' social responsibility. Although this study does not aim to measure the worksheet's effectiveness, the development process demonstrates significant potential in fostering students' social awareness and responsibility concerning relevant environmental and social issues. By integrating socioscientific issues into physics learning, students learn physics concepts and develop critical thinking skills regarding the social impact of their scientific decisions.

This research also contributes to the growing body of literature on the use of digital technology in social issue-based learning. While many studies have examined the application of technology in education, particularly in the form of e-worksheets, this study introduces a novel approach by integrating the ENACT model, which actively engages students in fostering social responsibility among 15-—to 16-year-olds.

CONCLUSION AND SUGGESTION

This research demonstrates that the e-worksheet, integrated with the ENACT learning model, is feasible for use in physics education, particularly in teaching global warming to foster students' social responsibility. The development process involved several key stages, including needs identification, design development, expert validation, and trials with students and teachers. The results showed that the average scores from media experts were 92%, and from material experts, 94%. Positive responses from students and teachers indicate that the product is relevant and can be effectively implemented in modern learning environments, with response scores of 93% from teachers and 89% from students.

This research contributes significantly to the literature on the use of digital technology and relevant learning models. Although this study did not directly measure the product's effectiveness, the results indicate substantial potential for the ENACT learning model to foster students' social responsibility. Nonetheless, further research is required to assess its effectiveness across diverse school environments and with other physics topics to enhance the product's impact and relevance.

AUTHOR CONTRIBUTIONS

A.W. developed the background, research methodology, results, and discussion sections. A.S. provided corrections and revisions to the title and background, while R.D. reviewed and improved the research methodology. A.A developed results and discussion sections. MA proofreading and revising the background – discussion. A.W., A.S., R.D., A.A., and MA collaborated on the data analysis. All authors contributed to the discussion and finalization of the manuscript.

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