# Integration of Waste-to-Energy in Physics Learning: An Andragogical Approach for Sustainable Education

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***Abstract*** *- This study explores the integration of Waste-to-Energy (WTE) concept with andragogical approach to enhance physics learning in supporting sustainable education. This descriptive qualitative research involved 14 students and 1 lecturer from a private university in Sumbawa, NTB, through questionnaires and semi-structured interviews. The results showed that the introduction of WTE was relevant in deepening students' understanding of renewable energy and thermodynamics, while increasing their engagement through experiential learning. The andragogical approach proved effective, despite the limited resources and complexity of the material. This study offers practical implications for physics teaching, namely the importance of integrating sustainability and renewable energy themes in the curriculum to prepare students to face global challenges in the fields of energy and the environment.*

***Keywords****: Waste To Energy; Physics Learning; Andragogy Approach; Sustainable Education*

## INTRODUCTION

Physics education has a strategic role in preparing the younger generation to face global challenges, including the need for sustainable solutions in energy and waste management (Erlangga et al., 2023; Malavoloneque & Costa, 2022). One relevant innovative solution is Waste-to-Energy (WTE) technology, which utilizes waste as a renewable energy source. This technology integrates physics principles, such as thermal energy, conversion efficiency, and thermodynamics, so it has great potential to enrich physics learning in higher education (Debrah et al., 2021; Mukherjee et al., 2020). However, in the context of education in Indonesia, the teaching of WTE concepts in the physics curriculum is still very limited and has not been systematically integrated. This concept is often only briefly mentioned in thermodynamics or energy topics without in-depth discussion, so that students only get a minimal theoretical overview. In some cases, WTE is only presented through additional literature or supporting materials that are not the main focus of learning. As a result, students are less able to understand the relationship between the theories learned in class and their real-world applications, such as waste management and renewable energy solutions (Febrineng, 2024).

This limitation creates a significant gap between students' theoretical knowledge and the practical skills needed to face global sustainability challenges, especially in the context of the energy crisis and environmental management (Debrah et al., 2021). This situation underlines that the current physics learning system does not fully support the development of students' competencies to apply physics principles in creating real solutions that are relevant to the needs of the world of work and sustainability issues.

Furthermore, the lack of WTE teaching in the curriculum also reflects a lack of recognition of the importance of integrating sustainability concepts into physics education. In the context of the

global urgency for the transition to renewable energy and better waste management, the physics curriculum needs to develop a learning approach that not only focuses on knowledge transfer but also fosters critical and innovative thinking skills (Kwangmuang et al., 2021; Usmeldi et al., 2017). By integrating WTE into the physics curriculum, students can understand the complexities of renewable energy technologies, practice the application of theory, and develop science-based solutions that have a direct impact on society.

The andragogical approach offers an effective solution to increase the relevance and meaningfulness of physics learning, especially at the tertiary level. This approach emphasizes experiential learning, the relevance of the material to real-world contexts, and empowering students to learn independently (Hsu et al., 2015). With this approach, students can more actively connect physics theory to real-world challenges, such as waste management in their environment, and design solutions based on WTE technology (Gitterman, 2004; Rena et al., 2022). Methods such as project-based learning, case studies, and practical experiments have been shown to be effective in increasing student engagement and understanding of sustainability concepts (Santana & de Deus Lopes, 2024; Weng et al., 2022).

International studies have shown that integrating sustainability issues into science education can lead to the development of more applicable and relevant curricula (Fuertes-Camacho et al., 2019; Gamage et al., 2022). For example, a recent study by (Debrah et al., 2021) highlighted the importance of teaching WTE in higher education to prepare students to face global challenges in renewable energy and environmental management. This study aims to examine students' and lecturers' perceptions regarding the integration of WTE into physics learning, and to explore the role of andragogical approaches in supporting sustainability education. The results of the study are expected to provide practical recommendations for the development of a physics curriculum that is more relevant, applicable, and in line with the global need for sustainability-based education.

## RESEARCH METHODS

This study uses a descriptive qualitative approach that aims to explore students' and lecturers' perceptions of WTE integration in physics learning with an andragogy approach. This approach was chosen because it focuses more on an in-depth understanding of respondents' experiences, views, and thoughts in the context of physics learning that is relevant to issues of sustainability and energy technology (Austin & Sutton, 2014). This study involved 14 students from various classes and semester levels, as well as 1 lecturer teaching courses related to energy and sustainability at a private university in Sumbawa, NTB. The involvement of lecturers with more than five years of teaching experience is expected to provide in-depth insight into the challenges and opportunities for WTE integration in physics learning. Data collection was carried out through open-ended questionnaires and semi-structured interviews. The questionnaire was designed to obtain initial data related to students' level of knowledge and perceptions of the relevance of WTE in physics learning, as well as to assess the application of the andragogy approach, especially experiential learning and independent learning abilities. Semi-structured interviews with lecturers were conducted to explore more deeply the views on WTE teaching, the application of the

andragogy approach, and the challenges and opportunities in integrating this topic into physics learning. The questionnaire data were analyzed descriptively using percentage distribution to describe the pattern of student perceptions, while the interview data were analyzed using thematic analysis methods.

Thematic analysis was conducted through several systematic steps. First, the researcher familiarized herself with the interview data by rereading the transcripts to understand the overall context. Second, initial codes were established based on important elements that emerged from the data, such as "relevance of WTE," "learning challenges," and "experiential learning." These codes were then grouped into main themes, such as "perceptions of WTE," "andragogy in physics learning," and "resource challenges." After that, the identified themes were reviewed again to ensure their suitability with the research objectives. The next step was to define the themes in detail by providing concrete examples from the interviews, which were finally compiled in the form of descriptive narratives to provide an in-depth understanding of the respondents' perceptions and experiences.

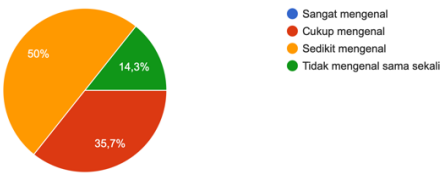
This study had a limited number of respondents, namely 14 students and 1 lecturer from a private university in Sumbawa, so the results were less generalizable. As a first step, these findings need to be interpreted with caution. Further research is recommended involving larger and more diverse samples from public and private universities in various regions, and using mixed methods to increase validity. Additional perspectives from students across study programs, lecturers from other fields, and renewable energy experts can enrich insights and produce more applicable recommendations for the development of relevant and sustainable physics curricula.

## RESULTS AND DISCUSSION

### Results

#### *Student Perceptions of WTE Integration in Physics Learning*

1. Student Understanding of WTE




How familiar are you with the concept of Waste-to-Energy (WTE)?


What do you know about how WTE-based power plants work?

**Figure 1**. Students' Understanding of WTE

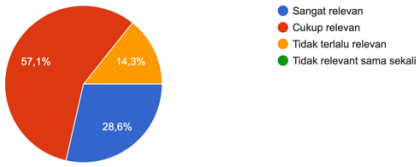
In Figure 1, it can be seen that most of the 50% of students admitted to having a little knowledge of the concept of WTE, while the other 35.7% were only quite familiar, and 14.3% admitted to not knowing the concept of WTE at all. Students' understanding of how WTE-based power plants work, 64.3% of them admitted to not knowing much about this and 35.7% only knew the basics. Although students have a basic understanding of WTE, their level of understanding of the concept and how WTE-based power plants work is still low.

2. Relevance of WTE in Physics Learning

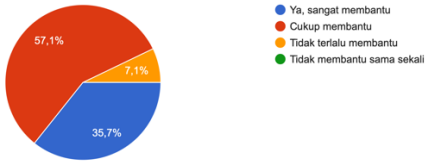
In Figure 2, 57.1% of students felt that the WTE concept was quite relevant and 28.6% felt that it was very relevant and 14.3% of them felt that it was not very

relevant to the physics course. As many as 57.1% of students stated that learning about WTE was quite helpful and 35.7% stated that it was very helpful and 7.1% stated that it did not really help them to deepen their understanding of the concepts of energy, thermodynamics, and energy conversion.

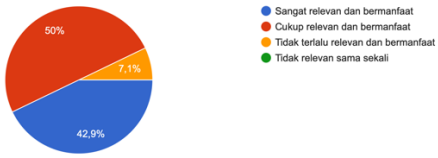
Regarding WTE being able to provide real solutions to energy and sustainability problems, 50% of students stated that the concept was quite relevant and useful, 42.9% of them stated that it was very relevant and useful, and 7.1% stated that it was not very relevant. In line with that, 78.6% of students felt quite involved and 14.3% felt less involved and 7.1% were not involved at all in learning physics when the topics taught were relevant to sustainability and real-world issues, such as WTE. Overall, most students felt that learning about WTE was very relevant to physics courses, deepened their understanding of physics concepts, and could provide real solutions to energy and sustainability issues. In addition, the relevance to sustainability issues could also increase their engagement in physics learning. Therefore, the integration of WTE concepts in physics learning has the potential to improve the quality of education and provide a more holistic understanding of the application of physics in renewable energy technologies and global sustainability issues.



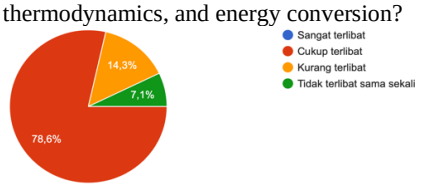

Do you feel the concept of WTE is relevant to Physics courses?




Do you feel that learning about WTE can deepen your understanding of physics concepts, such as energy, thermodynamics, and energy conversion?



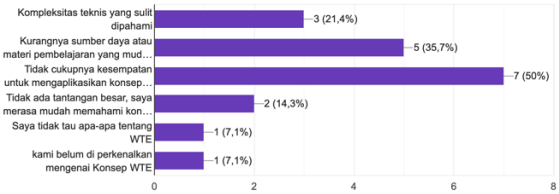

To what extent do you feel that learning about WTE can provide real solutions to real-world energy and sustainability problems?



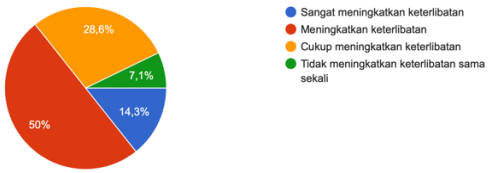

Do you feel more engaged in learning physics when the topics taught are relevant to sustainability and real-world issues, such as WTE?

**Figure 2**. Relevance of WTE in Physics Learning

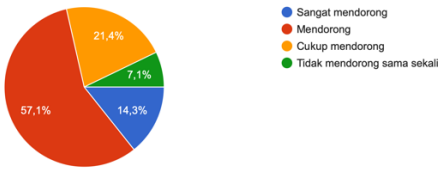
3. Challenges and Potential of Integrating WTE in Physics Learning




What is the biggest challenge you face in understanding the concept of WTE or connecting it to the physics theories you have studied?




How do you assess the potential of WTE-based learning in enhancing your engagement in physics learning?

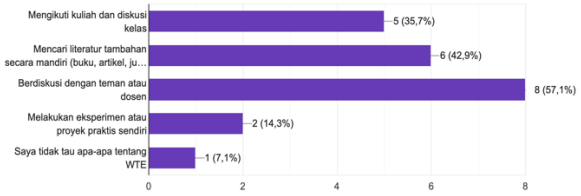



Do you feel that WTE learning will give you the opportunity to develop critical and creative thinking skills in solving problems?

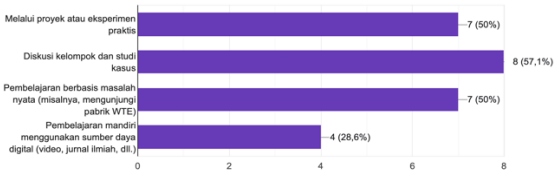
**Figure 3**. Challenges and Potential of Integrating WTE in Physics Learning

The main challenges faced by students in integrating WTE in physics learning are insufficient opportunities to apply concepts, lack of resources, and technical complexity that is difficult to understand. Despite the challenges, students stated that the integration of WTE in physics learning can increase their engagement in physics learning (50%), 28.6% stated that it somewhat increases engagement, and 14.3% of them stated that it greatly increases engagement. The integration of WTE will also provide opportunities for them to develop their critical and creative thinking skills. Where 57.1% of students stated that the integration of WTE will encourage them to develop both thinking skills, 21.4% stated that it will somewhat encourage, and another 14.3% stated that it will greatly encourage them to develop them.

4. Approaches to WTE Integration in Physics Learning




How do you typically learn about new concepts in physics that relate to technology or real-world applications, such as WTE?




In your opinion, what is the best way to study WTE technology in the context of physics education?


Do you think WTE learning needs a more experiential approach to understand it thoroughly?

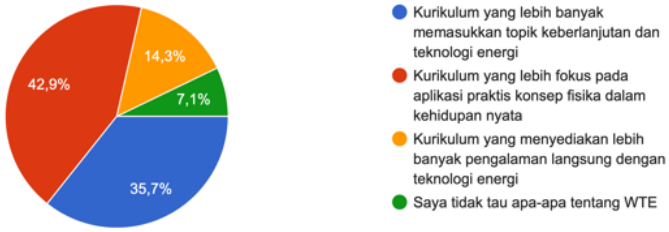
**Figure 4**. Approaches to WTE Integration in Physics Learning

Figure 4 shows that 57.1% of students usually learn about new concepts in physics related to technology or applied concepts such as WTE through discussions with friends or lecturers, 42.9% by independently searching for additional literature, 35.7% by attending lectures and class discussions, and 14.3% by independently conducting experiments or practical projects. The best way to learn WTE technology according to students is through group discussions, real-world problem-based learning, and practical projects, and independent learning. Students stated that the experiential approach is very necessary (42.9%), quite necessary (42.9%), and 14.3% of them stated that WTE can be integrated into physics learning depending on whether the material can provide meaningful experiences or not. Experiential learning, such as group discussions and case studies as well as practical projects and field trips, is seen as the best way to understand WTE. The experiential approach is considered very important to deepen the understanding of WTE technology, because it provides a real context that enriches physics learning in the real world.

5. Expectations for the Physics Education Curriculum

Students expect the physics education curriculum to focus more on the practical application of physics concepts in real life (42.9%), 35.7% stated to include topics of sustainability and energy technology, and 14.3% of them stated that the physics education curriculum provides hands-on

experience. They expect physics learning to not only talk about basic theories, but also real applications in the industrial world and sustainable energy technology.




What are your hopes for a physics education curriculum that includes WTE topics in the context of sustainability and energy?

**Figure 5**. Expectations for the Physics Education Curriculum

***Lecturers' Perceptions on Integrating WTE into Physics Learning***

1. Lecturers' Understanding of WTE

Based on interviews, respondents agreed that introducing WTE into physics learning can help students understand more complex physics concepts. This concept provides students with the opportunity to link physics theory with the application of environmentally friendly technologies, which are highly relevant to global issues such as energy sustainability and climate change.

2. Relevance of WTE in Physics Learning

The results of the interviews showed that lecturers considered WTE highly relevant to be taught in physics courses. WTE is considered relevant to basic physics concepts such as energy, energy conversion, and thermodynamics, as well as important in real-world contexts. This topic also provides insight into waste management and energy sustainability that are increasingly urgent for students to understand.

3. Challenges in Integrating WTE into Physics Learning

Despite strong support for teaching WTE, lecturers expressed challenges in integrating this concept into the existing curriculum. This is because the concept of WTE has never been taught directly. The main obstacles faced include time constraints, dense material, and lack of adequate resources to teach this topic in depth.

4. Approaches to Integrating WTE into Physics Learning

In terms of teaching approaches, lecturers propose various methods that can enrich students' learning experiences. Lecturers have used an andragogy approach, which emphasizes experiential learning and the relevance of the material to real life. Students are given the opportunity to learn independently, such as through reading scientific articles and practical experiments. Lecturers suggest that teaching on real-world problem-based topics/materials such as WTE involves a project-based approach, real case studies, and the use of digital media to deepen students' understanding.

5. Expectations for the Physics Education Curriculum

Lecturers hope that the physics education curriculum can integrate more topics related to renewable energy technology and sustainability. Students need more practical experience in applying physics concepts, especially in the industrial world, and hope that there will be more collaboration between physics and other disciplines, such as energy engineering, to provide a more holistic and applicable perspective.

**Discussion**

Sustainable education emphasizes the importance of learning that focuses not only on the transfer of theory, but also on practical application in real life. One relevant approach to achieve this is the andragogy approach, which places the needs, experiences, and motivations of adult learners at the heart of the learning process (Herod, 2002). In this study, the integration of the Waste-to-Energy (WTE) concept in physics learning through the andragogy approach aims to bridge the gap between physics theory and its application to global issues such as energy sustainability and climate change.

The andragogy approach allows learning to start from the needs and experiences of learners (Knowles, 1980). This study found that students, even though they only had basic knowledge of WTE, felt more motivated to learn technologies that were relevant to global sustainability issues. Students expressed that learning that linked physics theory to real-world problems, such as energy and waste management, provided a meaningful and relevant context to their needs. For example, the concept of thermodynamics, which is often considered abstract, can be more easily understood through the application of WTE that converts waste into energy.

From the lecturer's perspective, WTE teaching is considered an effective way to explain complex physics concepts by connecting them to real-world applications. This approach allows students to not only understand the theory but also see how concepts such as energy efficiency and heat transfer work in environmentally friendly technologies. In the context of andragogy, the lecturer acts as a facilitator who helps students relate their life experiences to the physics theories they are learning (Blackley & Sheffield, 2015). This encourages students to see the direct relevance between physics learning and practical solutions to global challenges.

One of the main strengths of the andragogy approach is its ability to connect learning materials to students' needs and interests (Roessger et al., 2022). The results of the study showed that WTE concepts are very relevant in physics courses, especially in exploring thermodynamics, energy, and energy conversion. By integrating WTE, students can learn how physics concepts are applied to solve real-world problems such as the energy crisis and waste management. This experiential approach allows students to understand that physics is not just a collection of theories but also a tool that can be used to create innovative solutions to global problems.

The andragogical approach also supports real-world problem-based learning, where students are faced with challenges such as designing a WTE system to manage local waste. In this way, they can develop critical, analytical, and creative thinking skills. This is in line with the goal of continuing education, which is to equip students with the skills to deal with issues relevant to the real world (Forrest & Peterson, 2006). Although the andragogical approach provides many benefits, the integration of WTE in physics learning faces a number of challenges. Students often have difficulty understanding complex concepts such as energy efficiency or thermal processes related to WTE. In addition, limited resources, such as access to experimental or simulation facilities, are obstacles to providing rich learning experiences. In this context, the andragogical approach emphasizes the importance of flexibility and adaptation of teaching methods (Rana et al., 2016). The proposed solution is project-based learning, where students can learn through

independent exploration and collaboration in solving relevant problems. Students need space to develop critical and creative thinking skills, and they need support from their lecturers to achieve this (Garrison, 1991; Motlhabane & Dichaba, 2013; Youde, 2018). Projects such as a simulation of a WTE system design or a case study of waste management in their area can provide hands-on experiences that help students connect physics theory to practical applications. This not only enhances understanding but also builds skills relevant to their future in renewable energy and sustainability (Motlhabane & Dichaba, 2013).

The main principle of the andragogical approach is experiential learning, where students are given the opportunity to learn through hands-on activities, such as experiments, collaborative projects, and field trips (Ekoto & Gaikwad, 2015; Tezcan, 2022). This study found that students tend to be more enthusiastic about this method compared to lecture-based learning. For example, case studies or simulations of WTE systems provide real-world contexts that make physics concepts more interesting and relevant. In this case, experiential learning not only enhances students' understanding of physics theory but also strengthens their ability to apply knowledge to create practical solutions. This approach also allows students to play an active role in learning, which is in accordance with the andragogical principle that adult learners learn most effectively when they have control over their learning process (Palis & Quiros, 2014; Roessger et al., 2022). Thus, the integration of WTE through an experiential approach not only adds value to physics education but also prepares students to contribute to global sustainability.

## CONCLUSION

Integration of WTE in physics learning with an andragogy approach can help students understand physics concepts in an applicable and relevant way to global issues such as energy sustainability. This approach, through experiential and project-based learning, not only strengthens theoretical understanding but also develops practical skills that are relevant for their future. For wider application, the curriculum needs to be adjusted with interactive methods, such as simulations, collaborative projects, and field trips, as well as cross-disciplinary collaboration. This study is limited to a small sample from one institution and does not test the direct effectiveness of the WTE approach. Further research is recommended to involve more institutions, test this approach on other renewable energy technologies such as solar and wind power, and evaluate its impact on student learning outcomes. This step will ensure the development of more relevant physics education and support global sustainability.

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