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Integrating Gudeg in AI-Based Physics Learning Media: Feasibility Study on Enhancing Students' Critical Thinking, Creativity, and Physics Identity

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Abstract: This study aims to develop AI-based learning media integrated with Yogyakarta's local wisdom, particularly *gudeg*, in physics education. The research aims to facilitate 21st-century skills and students' physics identity in the 5.0 era through socially and culturally relevant media. The research method used is Research and Development (R&D) with a 4D model, including define, design, and development stages. Observations and interviews were conducted at two high schools in Yogyakarta to identify learning needs. We developed three AI-based learning products: an e-book, an e-module, and an e-worksheet. Expert feasibility assessment showed very feasible results, with the e-book achieving the highest score (2.15), followed by the e-worksheet (2.05) and e-module (2.00). The use of these media increased students' interest, understanding, and skills in critical thinking, creativity, and physics identity. Integrating technology and local wisdom in physics learning media also positively contributes to education quality and supports Sustainable Development Goals (SDG 4: Quality Education, SDG 7: Affordable and Clean Energy, SDG 11: Sustainable Cities and Communities, and SDG 17: Partnerships for the Goals).

Keywords: AI-based learning media, critical thinking, creative thinking, physics identity, local wisdom integration.

Introduction

Along with the times, technology continues to develop and begins a new, more sophisticated era. This development has an impact on various aspects of life, one of which is learning, resulting in changes in both learning models and the curriculum used to meet the demands of current developments. After the Industrial Revolution 4.0 which introduced artificial intelligence or what could be called AI, then continued with the Industrial Revolution 5.0. In the 5.0 revolution, humans are required to be able to solve various challenges and problems by utilizing innovations born from the 4.0 revolution era and centered on technology (Sakiinah, A. F. P. Mahya, & G. Santoso, 2022). In short, it can be concluded that in this era, humans are required to be able to work side by side with technology. In education, AI has the potential to create and prepare learning that is tailored to the individual needs of students (Kennedy, 2023). By utilizing AI, physics learning will be more interesting and fun for students because it is packaged more sophisticatedly, making it easier to achieve physics learning goals (Suparno, 2019).

Understanding natural phenomena is one of the distinctive characteristics of physics learning. Physics learning aims to ensure students master physics concepts (Pratiwi, 2021). Physics learning does not only focus on understanding physics concepts but also aims

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to train students in scientific reasoning skills (Aslinda, Hufri, & Amir, 2017). Apart from that, physics learning also teaches the application of these concepts in the context of everyday life (Yuliati & Parno, 2018; Melawati, Evendi, Halim, Yusrizal, & Elisa, 2022). Thus, learning physics requires various competencies and certain attitudes. These competencies include the ability to think critically, creatively, proactively, solve problems, judge, make decisions, and manage emotions positively (Dębowska & Greczyło, 2017). The competencies that students need to be successful in the 21st century are 4C which consists of Critical Thinking, Communication, Collaboration, and Creativity (Yusliani, Burhan, & Nafsih, 2019). Another thing that students need to have is physics identity, a benchmark for assessing student learning outcomes that reflect understanding and skills in the physics material studied. Students will better understand learning and be able to achieve the goals and competencies needed if learning is linked to daily life, one of which is the local wisdom of an area.

Learning from the surrounding environment makes learning more contextual or concrete, such as local wisdom (Rahmatih, Maulyda, & Syazali, 2020). So, learning by integrating local wisdom can make students better understand the material presented by interacting directly with the concepts of the material (Syahidi, Hizbi, Hidayanti, & Fartina, 2020). Integrating local wisdom in learning can support the success of the learning process in the classroom (Suprapto, Prahani, & Cheng, 2021). In this integration, learning can be done using learning media. Local wisdom-based learning media is a contextual approach that presents material based on the concept of local wisdom knowledge (Perdana, Riwayani, Haroky, & Eveline, 2024). Learning by integrating local wisdom can make students better understand the material presented by interacting directly with the concepts of the material (Syahidi et al., 2020). The benefits of using local wisdom in physics education are shown by increasing students' interest and understanding of the subject matter (Usmeldi & Amini, 2020)(Susanto, Husen, & Lajis, 2023). This can happen because students are familiar with the culture in their environment so that abstract physics concepts are easier to understand.

One aspect of culture that reflects regional richness and diversity and is an important part of local wisdom that must be maintained is traditional food (Juniarti, 2021). One of the famous dishes from Yogyakarta is made from young jackfruit, which is cooked for quite a long time, namely gudeg (Nurjanah, 2023). Several physical concepts can be explained in how to cook gudeg, starting from the process of cutting jackfruit which can be explained using the concept of speed to the boiling process which contains the concepts of temperature and heat. As time goes by, gudeg packaging has also developed from previously using baskets and jugs, now canned gudeg is available. With this innovation, we expand the physics concepts that can be studied in the process of making gudeg, especially canned gudeg. By integrating gudeg into physics learning, it is very possible to improve students' critical thinking skills through analysis, synthesis, and evaluation (Abrami et al., 2015; Damayanti & Kuswanto, 2021; Jolley, Davis, Lavender, & Roberts, 2022; Sari Dewi & Kuswanto, 2023). Apart from that, students' creative thinking abilities can also be developed by solving problems related to the gudeg cooking process (Alyami & Alagab, 2013)(Indranuddin, Susetyarini, & Miharja, 2024)(Sari, Nikmah, Kuswanto, & Wardani, 2020).

The last is the suitability of research with sustainable development. Sustainable development is very important in pioneering a prosperous life while sustainably maintaining the surrounding environment. So, there is a need for research that supports SDGS goals.

From the description above, it is necessary to develop a learning tool that can facilitate students' 21st-century abilities and physics identity. Apart from that, the learning tools developed must contain technological advances that are integrated with the local wisdom of a region and support the SDGs. Therefore, this research will develop AI-based learning tools that are integrated with local wisdom to improve students' critical thinking and creative thinking skills, as well as physics identity. This research aims to test the feasibility of integrated gudeg AI-based learning media to improve students' creative, critical thinking, and physics identity abilities.

Method

This research is development research or Research and Development (R&D) which was developed using a 4D model. There are several stages in the 4D model, namely define, design, develop, and disseminate. However, this article will present only the results of the media feasibility testing, following the research objective, which is to assess the feasibility of the developed instructional media. The research stages can be seen in Figure 1.

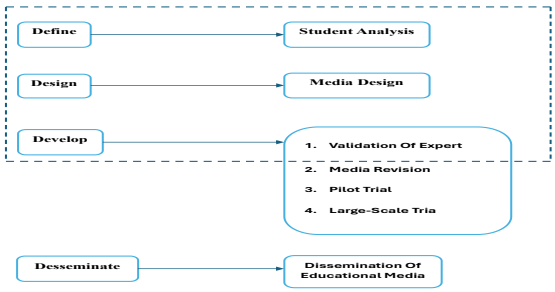

Figure 1. Development Flow

Define

The define stage is very important for determining and defining the things needed in the learning process and collecting information related to the product to be developed. At this stage, observations and interviews were conducted with teachers and students from SMA N 1 Ngaglik and SMA N 5 Yogyakarta.

Design

After finding problems in the previous stage, the product design stage is carried out. At this stage, the learning media that will be used and the local wisdom that will be integrated into physics learning are determined. The learning media to be developed include: Gudeg integrated AI-based e-book to improve students' creative thinking skills and physics identity; Gudeg integrated an AI-based e-module to improve students' critical thinking skills and physics identity; and AI-based E-Worksheet is integrated with gudeg to improve students' critical thinking skills and physics identity. The learning media developed is electronic media because it can add features such as videos and images so that it can support students' understanding. Meanwhile, the materials chosen in this research are temperature and heat, because they often occur in everyday life.

Develop

At this stage, product preparation is carried out by the previous planning stage. The resulting product is then submitted to an expert lecturer for feasibility testing. The feasibility test process by experts is very important to determine the feasibility of the product before it is tested and disseminated. The product will be assessed by two theoretical experts who are lecturers in Physics Education at UNY. Aspects assessed at this stage include content, language, design, and appearance, as well as ease of use of the product. The results of the feasibility test will be analyzed using the MSI method and used as a reference for revising the product so that the design, concept, and content available on the learning media can be following the objectives that have been formulated. The analysis results can be categorized Table 1.

Table 1. Feasibility Category

Score Range	Category
$\bar{X} > \bar{X}_i + 1{,}5\ SBi$	Very Feasible
$\bar{X}_i + 1{,}5\ SBi \geq \bar{X} \geq \bar{X}_i$	Feasible
$\bar{X}_i > \bar{X} \geq \bar{X}_i - 1{,}5\ SBi$	Less Feasible
$\bar{X}_i - 1{,}5\ SBi > \bar{X}$	Not Feasible

Result and Discussion

What must be present in learning is teaching resources. Learning is a programmatic teacher activity in instructional design, to make students learn actively, which emphasizes the provision of learning resources (Dimyati & Mudjiono, 2015). Learning resources can be packaged into interesting learning media so that students are motivated to learn and do not get bored easily. Learning media is a tool used to visualize the learning process and is often used in scientific disciplines, including physics (Syahrial, Wulan Deliana, Vina Dwi Cahyani, & Ahmad Fakhri Husaini, 2022). Apart from that, learning media is an intermediary tool for learning material to students which is expected to make it easier for teachers to convey the material, help students understand the material, and make students not bored. Creative use of media can increase the effectiveness of learning so that learning goals can be achieved (Kurniawati & Nita, 2018).

From the observation stage, it was found that in every high school, there was an adequate physics laboratory, but it was rarely used because educators felt that the material being taught could not be used for practical work. When learning in class, students do not pay much attention to the teacher's explanations and many students are sleepy. Then interviews were conducted with teachers and high school students. Based on interviews with teachers, teachers found it quite difficult to adapt to the new curriculum because the time provided for learning physics was less than before. Teachers also have difficulty adapting to the recommended learning model because they are used to using the lecture method, even though in the independent curriculum students are required to play an active role in learning. As well as a lack of new, more flexible learning resources.

Based on interviews with students, it was found that they felt bored during the learning process because they only listened so physics learning did not attract students' attention. Apart from that, students also feel that learning physics is not very important, because it has nothing to do with everyday life, even though physics concepts are closely related to everyday life. Based on the results of observations and interviews at SMA N 1 Ngaglik and SMA N 5 Yogyakarta, learning media needed that follow the demands of the independent curriculum, able to direct students to play an active role in learning and provide a concrete picture of physics concepts in everyday life.

From the results of interviews and observations, AI-based electronic learning media was created which was integrated with local wisdom to improve students' 21st-century abilities and physics identity. This research is aimed at testing the feasibility of electronic learning media in the form of AI-based E-Books, E-Modules, and E-LKPD which are integrated with the Yogyakarta gudeg concept to improve students' 21st-century abilities and physics identity.

Gudeg Integrated AI-Based E-Book to Improve Students' Creative Thinking Abilities and Physics Identity

E-books are learning media that have a design like a printed book but are presented in online form. The advantage of E-Books compared to printed books is that E-Books can include moving animations and audio to support learning. With a more sophisticated, attractive, and flexible design, it can increase students' interest and motivation to study physics. E-books can be used as a medium to improve students' creative thinking skills in physics lessons (Salamiyah & Kholiq, 2020). By providing interactive features that can support students' exploration and in-depth understanding, as well as multimedia attached to the e-book, it allows students to better understand the physics concepts being discussed and their concrete implementation.

Students' creative thinking abilities need to be developed because in physics subjects there are many concepts and formulas that students must understand and apply. Through creative thinking skills, students can solve existing problems with their abilities. Creative thinking ability is the ability of a person must see a problem or situation from various points of view and use their imagination to produce new and innovative ideas (Aldig & Arseven, 2017)(Trianggono, 2017). Creative thinking skills are very necessary to improve learning outcomes and students' abilities in solving problems in physics learning (Maghfiroh, Lesmono, & Supriadi, 2017).

In this research, we developed an AI-based e-book integrated with Gudeg. The e-book includes a stage where students are guided to use AI as a tool to enhance their knowledge.

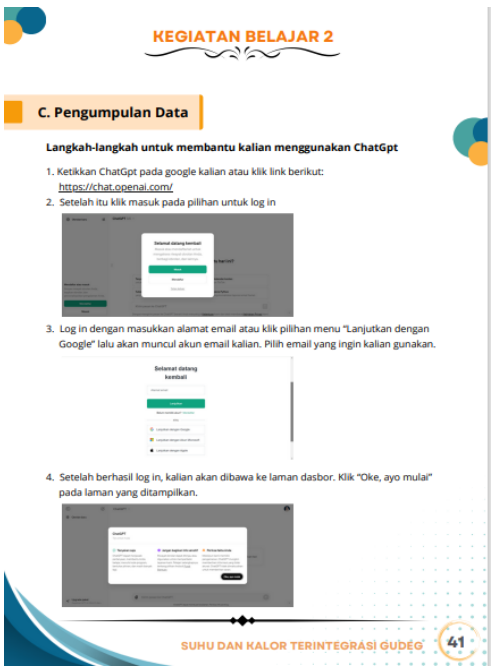

Figure 2. AI Application

Apart from that, the problems and material presented in the e-book are related to gudeg Yogyakarta. This integration is carried out so that students can more easily understand the concepts being taught and introduce existing local wisdom. The e-book is equipped with pictures and video illustrations that will make it easier for students to visualize abstract physics concepts.

Figure 3. Integration of Gudeg

Then the product will be tested for feasibility by experts, the data that has been obtained is in the form of ordinal data which will later be converted into intervals and using SBI as an assessment category. After processing, the data obtained Figure 4.

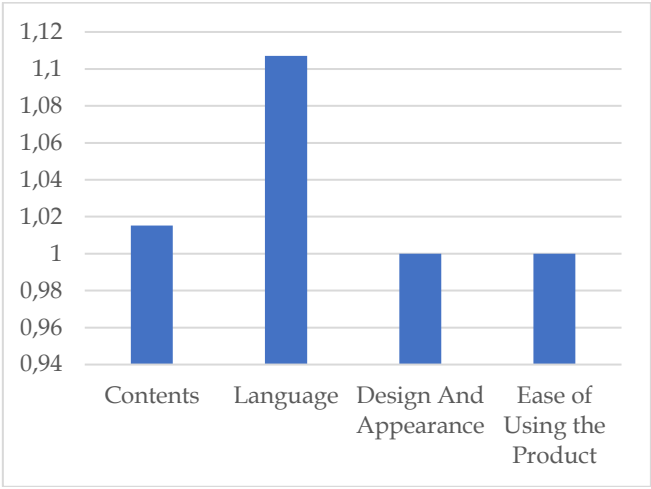

Figure 4. E-book Feasibility Result

There are four aspects assessed, namely, content, language, design and appearance, and ease of using the product. In the content aspect, the things assessed are the suitability of the e-book's objectives with the learning objectives and variable indicators to be developed, as well as the feasibility of the features displayed to support student understanding. The feasibility results on the content aspect are categorized as very feasible. The linguistic aspect assesses the appropriateness of the language used and the narration and instructions used which can be understood by students well, the results are categorized as adequate. The design and appearance assessed the placement of e-book features and the presentation of images as supporting student understanding, and the results were categorized as adequate. In terms of ease of use, the product is feasible. Overall, the e-book obtained a score of 2.15 and is categorized as very feasible and can be published. This is in line with research which states that e-books can improve students' creative thinking abilities (Salamiyah & Kholiq, 2020).

Gudeg Integrated AI-Based E-Module to Improve Students' Critical Thinking Abilities and Physics Identity

Another learning media is modules, namely teaching materials written so that students can learn independently (Bakri, 2021). Over time, modules have been innovated in electronic form to become e-modules. E-module is a module in digital form (Diantari, Damayanthi, Sugihartini, & Wirawan, 2018). Electronic modules or e-modules are a form of presenting independent teaching materials that are arranged systematically to achieve certain learning objectives that are presented electronically (Nikita, Lesmono, & Harijanto, 2018). In the 21st century, there is a goal to improve students' 21st-century abilities, one of which is critical thinking. Critical thinking skills are very important for students to have because they can support their problem-solving abilities (Cahyono, 2016). E-modules have been proven to improve student's critical thinking skills in physics subjects (Rasyid & Wiyatmo, 2024).

This research develops an AI-based e-module integrated with gudeg to improve students' critical thinking skills and physics identity. In the e-module, the learning objectives have been adjusted to indicators of critical thinking and physics identity. The learning material presented is integrated directly with the process of cooking and canning gudeg so that students have a concrete picture regarding the application of physics concepts in everyday life.

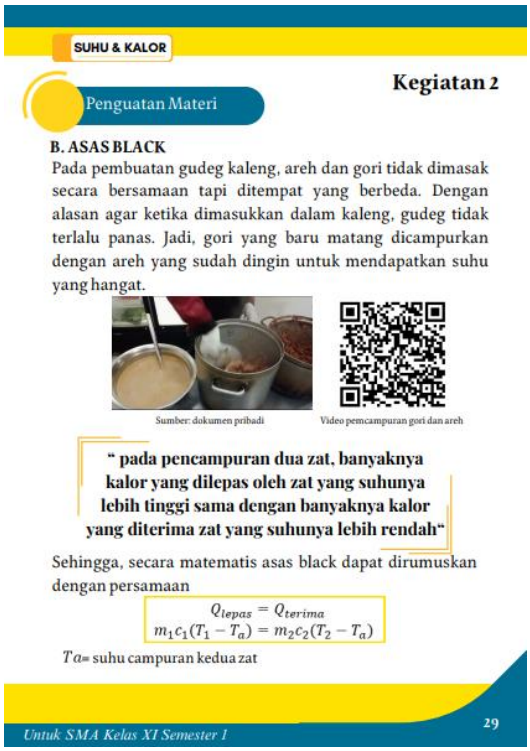

Figure 5. Integration of Gudeg

Apart from that, in the learning process, students are directed to create hypotheses and then search for the truth of the hypotheses they formulate through AI. In this case, it is hoped that students can determine the information they need to solve a problem so that students' critical thinking skills are better honed.

Figure 6. AI Application

Then the product will be tested for feasibility by experts, the data that has been obtained is in the form of ordinal data which will later be converted into intervals and using SBI as an assessment category. After processing, the data obtained Figure 7.

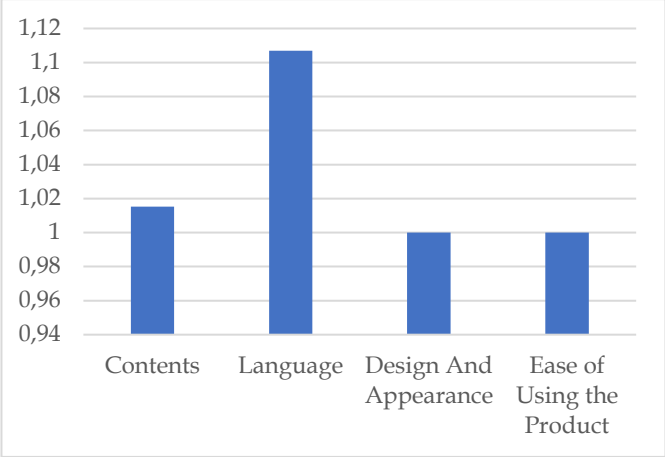

Figure 7. E-Module Feasibility Result

There are four aspects assessed, namely, content, language, design and appearance, and ease of using the product. In the content aspect, the things assessed are the feasibility of the e-module objectives with the learning objectives and variable indicators to be developed, as well as the feasibility of the features displayed to support student understanding. The feasibility results on the content aspect are categorized as adequate, meaning that the objectives formulated in the e-module are in accordance with the feasible indicators developed and the features in the e-module support improving students' abilities. The linguistic aspect assesses the appropriateness of the language used and the narration and instructions used which can be understood by students well, the results are categorized as very appropriate. This means that the language used in the e-module is in accordance with PUEBI and is communicative so that it is easy for students to understand. In the design and appearance, the placement of the e-module features and the presentation of images are assessed as supporting student understanding, and the results are categorized as adequate. From these results, it can be interpreted that the design and appearance of the e-module is appropriate and able to attract students' interest in learning. In terms of ease of use, the product gets very decent results. Overall, the e-module obtained a score of 2.00 and is categorized as very feasible for publication and supports improving students' critical thinking skills and physics identity. Other research also proves that e-modules can improve students' critical thinking skills (Rasyid & Wiyatmo, 2024).

Gudeg integrated AI-Based E-Worksheet to Improve Students' Critical Thinking Skills and Physics Identity

Worksheets are one of the learning support components that are used to achieve learning indicators or goals in accordance with the applicable curriculum (Apertha, Zulkardi, & Yusup, 2018). The use of printed worksheets can be replaced with electronic worksheets which can make teaching and learning activities more lively, deeper, and increase student innovation (Lathifah, Hidayati, & Zulandri, 2021). Worksheets are a digital learning tool that students can access online. Using worksheets can make it easier for educators to manage the learning process, can be used to develop students' abilities, can guide students in discovering material concepts in groups, and help educators see students' learning success (Noprinda & Soleh, 2019). Thus, worksheets have many benefits that can be optimized for learning.

The media product developed here is an AI-based worksheet integrated with gudeg to improve students' critical thinking skills and physics identity. In the E-Worksheet, there is a stage when students are directed to use AI as an aid to build student knowledge.

Figure 8. AI Application

Apart from that, the problems and material presented in the Worksheet are related to gudeg Yogyakarta. This integration is carried out so that students can more easily understand the concepts being taught and introduce existing local wisdom. The

worksheets are equipped with pictures and video illustrations that will make it easier for students to visualize abstract physics concepts.

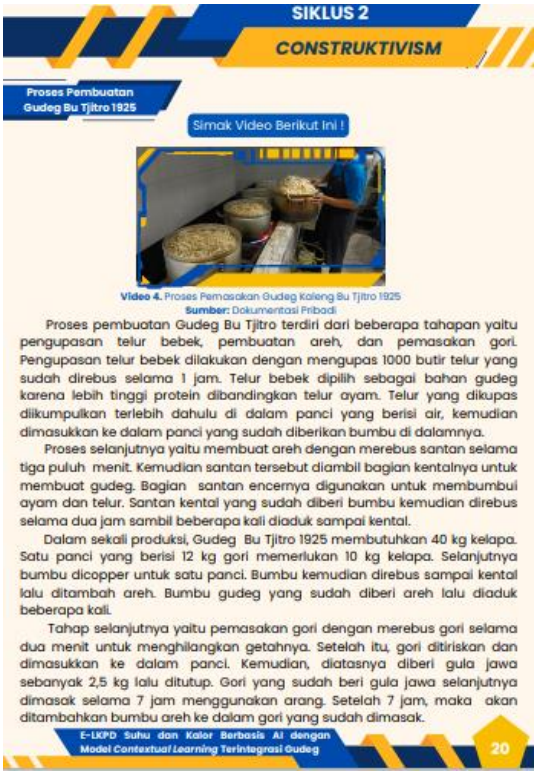

Figure 9. Integration of Gudeg

Then the product will be tested for feasibility by experts, the data that has been obtained is in the form of ordinal data which will later be converted into intervals and using SBI as an assessment category. After processing, the data obtained in Figure 10:

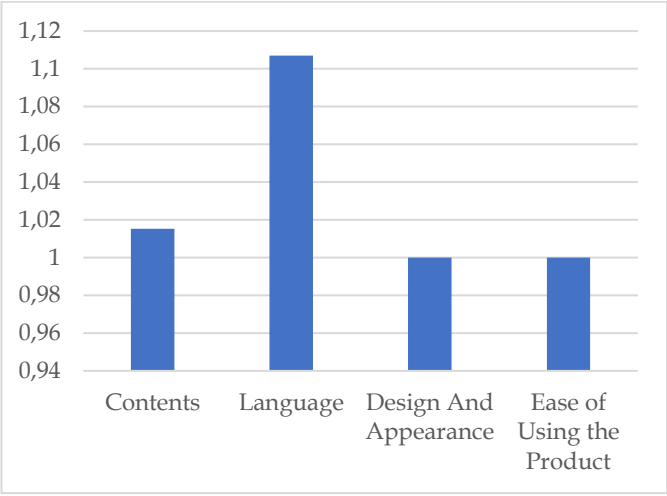

Figure 10. E-Worksheet feasibility result

There are four aspects assessed, namely, content, language, design and appearance, and ease of using the product. In the content aspect, the things assessed are the feasibility of the worksheet's objectives with the learning objectives and variable indicators to be developed, as well as the feasibility of the features displayed to support student understanding. The validation results on the content aspect are categorized as very feasible. The linguistic aspect assesses the appropriateness of the language used and the narration and instructions used which can be understood by students well, the results are categorized as very appropriate. The design and appearance assessed the placement of worksheet features and the presentation of images as supporting students' understanding, and the results were categorized as very feasible. In terms of ease of use, the product gets very decent results. Overall, the e-worksheet obtained a score of 2.05 and is categorized as very feasible and can be published.

Physics can be used as a tool to overcome global challenges in line with the SDGs (Humas Unesa, 2023). This research supports SDG 4 Quality Education, by using the gudeg cooking process as a context for teaching physics concepts such as temperature and heat, learning will be more interesting and easier to understand so that it can motivate students to learn. SDG 7 is clean and affordable energy, this is related to heat transfer and thermal efficiency. The process of cooking gudeg can explain the concepts of conduction, convection, and radiation in heat transfer. Gudeg is cooked for quite a long time, around 8 hours. so that by integrating gudeg into physics learning, students will learn to increase thermal efficiency in cooking gudeg to reduce energy consumption. Then SDG 11 Sustainable Cities and Communities, integrating local wisdom can increase students' awareness and appreciation of the culture around them, besides that it can also support conservation culture and contribute to the development of sustainable communities that are aware of local values. Integrating local wisdom in physics learning also supports SDG 17 Partnerships for the Goals, because it can strengthen cooperation between the community, government, and educational institutions and increase community participation in the education process. So, the learning media in this research not only makes it easier for teachers and students in the learning process but also supports the SDG's program.

Conclusion

In the current 5.0 era, when technological advances are taking place very quickly, education is needed that can provide students with supporting abilities, so they are ready to compete in the 21st century. To support successful learning, learning media is very important as a means of delivering material from teachers to students. Through learning media, teachers can design the desired

learning and integrate various things to support student understanding. From this research, it can be concluded that: (1) Gudeg integrated AI-based e-book to improve students' creative thinking abilities and physics identity, very feasible for use and able to improve students' creative thinking abilities and physics identity. (2) Gudeg integrated AI-based e-module to improve students' critical thinking skills and physics identity, very feasible for use as a support for improving students' critical thinking skills and physics identity, (3) Gudeg integrated AI-based e-worksheet to improve students' critical thinking skills and physics identity, is very feasible for use and can improve students' critical thinking abilities and physics identity, (4) Integrating local wisdom in learning can also help the sustainability of the SDG's program.

In the future, it is hoped that there will be a lot of research that integrates local wisdom and technological advances in one learning media and teaching resource. Apart from making it easier for students to understand learning concepts, it also supports students' 21st-century abilities and introduces students to preserving the culture around them.

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Author Contributions

Conceptualization, P.P. and B.S.; methodology, P.P.; software, T.B.N.R.; validation, P.P., B.S. and R.P.; formal analysis, T.B.N.R.; investigation, R.N.H.; resources, R.P.; data curation, D.P.M.; writing—original draft preparation, R.N.H.; writing—review and editing, P.P.; visualization, S.A.N.; supervision, B.S.; project administration, P.P.; funding acquisition, B.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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