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GUDEG MEETS AI: A CULTURALLY INTEGRATED DISCOVERY LEARNING E-BOOK TO EVOLUTE CREATIVE THINKING AND PHYSICS IDENTITY

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Abstract

This study aims to develop an AI-assisted Discovery Learning-based E-Book about Temperature and Heat, integrating the local context of Gudeg to enhance high school students' creative thinking skills and physics identity. Utilizing Research and Development (R&D) methods, this study adopts the three stages of the 4D model (define-design-develop) by Thiagarajan. The feasibility and practicality of the E-Book were assessed through expert validation consisting of two physics education lecturers and one practitioner teacher. The sample included twelfth-grade science students at Senior High School 1 Pundong, Indonesia, who participated in a limited trial of the AI-assisted Discovery Learning-based E-Book integrating the local Gudeg context. Student readability testing involved 58 grade 12 students. Data were collected using feasibility sheets, student assessments of the learning media, and test questions measuring creative thinking abilities encompassing fluency, flexibility, originality, elaboration, along with a physics identity questionnaire covering interest, competence, performance, and recognition. Data analysis used descriptive statistics (SBI) and inferential tests, including normality, homogeneity, one-sample t-test, and Wilcoxon test. The findings indicated that the developed E-Book was feasible for use (expert validation score = 2.148) and practical (student assessment score = 4.085) for physics learning. Moreover, statistical tests showed a significant increase (p = 0.001) in students' creative thinking skills and physics identity exceeding the benchmark standards. This study contributes to physics education by integrating AI-assisted Discovery Learning with local cultural elements, providing an innovative approach to fostering creative thinking and strengthening students' physics identity.

Keywords – E-book, AI, Discovery learning, Gudeg, Creative thinking, Physics identity.

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1. Introduction

Artificial intelligence (AI) refers to a system designed to perform commands or general tasks that require human intelligence. The utilization of AI in education helps teachers handle various matters such as how to create more active learning and facilitates students in carrying out learning activities (Gligorea, Cioca, Oancea, Gorski, Gorski & Tudorache, 2023; Halkiopoulos & Gkintoni, 2024). With the use of AI, educational institutions can offer data-based learning, allowing students to learn according to their individual needs. In other words, AI-based applications like Chat GPT have proven capable of enhancing higher-order skills, fostering creativity, and strengthening problem-solving abilities—competencies that are essential for students to thrive in the 21st century. However, without proper use, AI in learning may lead to misdirection or misuse, as evidenced by many students who do not analyze AI-generated answers and simply accept all responses (Ramadhan, Faris, Wahyudi & Kamayani, n.d.).Therefore, the teacher's role is crucial in guiding students to use AI responsibly.

The integration of Artificial Intelligence technology can be embedded into learning E-Books so that teachers can create more engaging, effective, and interactive learning processes while still considering technological usage limits. An E-Book is a digital learning medium combining text, images, audio, video, and animation that can enhance students' creative thinking skills (Venter, Coetzee & Schmulian, 2024). AI integration increasingly transforms E-Books from being mere static information repositories into intelligent and dynamic learning environments, for example, through Chat GPT features providing real-time automated feedback (Halkiopoulos & Gkintoni, 2024). AI technology is not intended to replace teachers but to serve as an aid in addressing learning challenges in the digital era (Mambu, Pitra, Ilmi, Nugroho, Leuwol & Saputra, 2023). Thus, AI use can be more directed and controlled. Nevertheless, research integrating AI technology in learning is still limited and requires further development.

Integrating AI into E-Books requires clear guidance for teachers in the learning process. Teachers are not only material deliverers but also facilitators who direct students to learn actively and meaningfully. Therefore, a structured learning model is needed to ensure the effective use of AI-based E-Books. One learning model that can be used is discovery learning. Discovery learning encourages students not to receive material in a final form but to identify problems, seek information, and then conclude their understanding (Putri, Lesmono & Aristya, 2017). According to (Winarti, Yuliani, Rohmadi & Septiana, 2021), discovery learning is suitable for physics education. Supporting research by Hotang (2019) shows that discovery learning can improve motivation and learning outcomes in physics. Through discovery learning, students are confronted with facts, not just theories, allowing them to actively discover new knowledge.

One challenge in physics education is making it relevant to students' lives. Many efforts have been made to overcome this by developing various innovative learning media, such as integrating local wisdom. Previous studies developed physics learning media based on traditional musical instruments (Damarsha, Niza, Fitriyah, Deta, Suliyanah & Saputra, 2023; Erlangga, Susanti & Amalia, 2022; Uran, Panis & Mukin, 2024) and traditional games (Astuti & Bhakti, 2022; Sari, Nikmah, Kuswanto & Wardani, 2020; Shofiyah, Wulandari & Setiyawati, 2020). Another local wisdom element rarely used but potential for integration into physics is traditional food. Traditional food is part of the culture close to students, thus can be an effective medium to relate physics concepts to their daily experiences. Silla, Dopong, Teuf and Lipikuni (2023) state traditional food has potential for integration into learning media. By using traditional food as an example, teachers can explain physics phenomena such as temperature changes during cooking, material expansion, or heat transfer processes.

One traditional food that can be integrated is Gudeg, a typical Yogyakarta dish with a long history and development (Yudhistira, 2022). Integrating Gudeg as local wisdom presents real-life concepts relevant to daily life, for example, in the physics topic of cooking and canning processes. This context can make physics learning, especially temperature and heat, contextual and meaningful. However, studies using Gudeg in physics learning are still very limited, both in media development and classroom implementation. Therefore,

this research is important to fill the gap by developing an AI-assisted discovery learning E-Book integrated with Gudeg local wisdom, providing students space to develop 21st-century skills.

21st-century skills to develop include the 4Cs: critical thinking and problem solving, communication, collaboration, creativity, and innovation (Arnyana, 2019). Among these, creative thinking enables students to solve problems effectively. Students with strong creative thinking have a high capacity to solve problems, resulting in optimal learning outcomes (Adiilah & Haryanti, 2023). Research by (Goran, Kaleka & Daud, 2021; Hasanah, Parno & Hidayat, 2021) found that students' average creative thinking ability indicators were below 50%, indicating low levels. Similarly Nazhifah & Wiyono (2023), reported most students struggle to generate flexible ideas in solving physics problems. This shows a gap between 21st-century curriculum demands emphasizing creative thinking skills and current learning, which is still dominated by conventional, memorization-centered approaches.

Besides challenges in improving creative thinking skills, another challenge in physics learning is low physics identity, which includes interest, competence, and performance (Hazari, 2010). Performance refers to students' confidence in their ability to perform physics-related tasks well. These three indicators are measured using questionnaires assessing students' interest in physics, their confidence in understanding and applying physics concepts (competence), and their confidence in demonstrating skills through assignments and activities. However, various studies show students' physics identity remains low. In terms of interest, students in grade eleven show low attention and activity, indicating low physics learning interest (Charli, Ariani & Asmara, 2019).

Research shows that combining the approaches above can positively improve students' creative thinking skills and physics identity. Anggraeni & Yohandri (2022), found an AI-assisted Discovery Learning-based E-Book to be valid, practical, and effective in improving students' creative thinking. Studies by Saputra (2024) and Wati, Apriani, Misbah, Miriam and Mahtari (2021), reported traditional food-based local wisdom integrated temperature and heat learning media were feasible and improved conceptual understanding. Afiliyani (2024), showed AI-based learning media increased student learning independence on temperature and heat topics. Based on these findings, E-Books innovated with AI and local wisdom integration can be an effective contextual approach to increase engagement, understanding, and physics identity.

Nevertheless, previous research mostly stands independently concerning discovery learning, local wisdom integration, or AI use. Few studies comprehensively combine these three aspects in one learning medium, especially on temperature and heat topics. Also, most research emphasizes conceptual understanding improvement, while effects on creative thinking and physics identity are rarely studied (Saputra, 2020). So far, studies combining AI technology like ChatGPT with local wisdom, particularly Gudeg making processes for temperature and heat lessons, are rare. Therefore, this research is important to fill this gap by developing an AI-assisted discovery learning E-Book integrated with Gudeg local wisdom to support not only conceptual understanding but also foster creative thinking skills and strengthen students' physics identity.

Based on these issues, this research develops an AI-assisted discovery learning E-Book on temperature and heat integrated with Gudeg (E-Book Gulearn) to improve high school students' creative thinking skills and physics identity. The researchers formulated three research questions:

1. How feasible is the AI-assisted Discovery Learning-based E-Book on Temperature and Heat (E-Book Gulearn) for improving high school students' creative thinking skills and physics identity?
2. How practical is the AI-assisted Discovery Learning-based E-Book on Temperature and Heat (E-Book Gulearn) for improving high school students' creative thinking skills and physics identity?
3. What is the profile of high school students' creative thinking skills and physics identity?

2. Methodology

This research is a type of development research aimed at developing a learning media in the form of an E-Book Model-Based Temperature and Heat Discovery Learning assisted by Gudeg Integrated AI. The research method used is the Research and Development (R&D) method adapting the three stages of the 4D model by Thiagarajan, Semmel and Semmel (1974). The research model stages implemented in this study are: define, design, and develop. The develop stage in this research was only carried out in a limited trial. This research only reaches the develop stage because the primary objective is to test the feasibility and practicality of the developed media, as well as to understand the profile of high school students' critical thinking skills and physics identity.

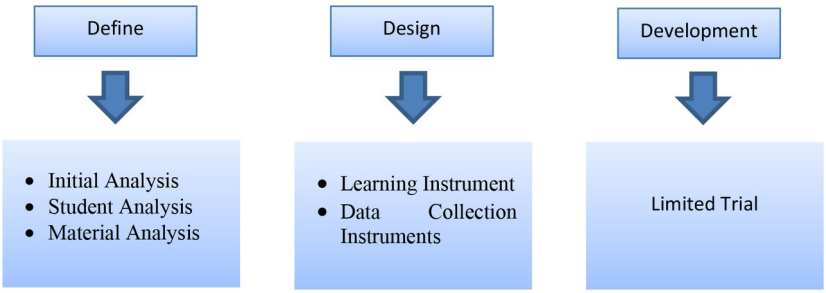

Figure 1. E-Book Development Stages through the 3D Model (Define, Design, Development)

2.1. Research Subjects

The subjects of this development research involved two twelfth-grade science classes at SMA Negeri 1 Pundong, Indonesia, with a total of 58 students consisting of 13 male and 39 female students aged 17–18 years. The sample was selected using purposive sampling, a technique in which participants are chosen based on specific considerations relevant to the research objectives. Out of the three available classes at the school, two classes were selected for the trial. Both classes use the Merdeka Curriculum, so the learning process aligns with the E-Book Gulearn devices developed based on this curriculum. In addition, both classes were taught by the same physics teacher and the academic abilities of students in both classes were relatively balanced based on report card scores and previous evaluations. This minimizes significant differences in academic backgrounds.

Students from both classes completed tests to measure creative thinking abilities and physics identity on the competence indicator. They also filled out questionnaires on interest in physics to assess the physics identity interest indicator. Additionally, students completed a questionnaire assessing their responses to the E-Book Gulearn to determine their evaluation of the developed E-Book.

2.2. Research Instruments

The research instruments used in this study consist of learning instruments and data collection instruments. The research instruments can be accessed at https://unyku.id/research-instruments. All instruments used are in Indonesian because the research subjects are in Indonesia. These instruments were validated by expert validators, consisting of one lecturer from the Physics Education Study Program who is an expert in physics learning media and one practitioner, namely a physics teacher. The validation was carried out to produce instruments that are appropriate, valid, and reliable for use. The learning instruments are the Gulearn E-Book and teaching modules. The data collection instruments include:

(1) a feasibility sheet for learning instruments covering content, language, design and appearance, and ease of use of the E-Book, (2) a validation sheet for data collection instruments covering construction, content, completeness, and language aspects, and (3) a student response questionnaire covering content, language, design and appearance, and ease of use of the E-Book.

Additionally, a test instrument consisting of eight questions was used to measure creative thinking ability and physics identity on the competence indicator. Creative thinking ability is measured based on four indicators: fluency (the ability to generate relevant ideas or answers in solving problems), flexibility (the ability to produce varied answers, ideas, or questions), originality (the ability to produce new and unique ideas), and elaboration (the ability to elaborate ideas in detail). The interest questionnaire, consisting of 10 items, measures physics identity on the interest indicator, which includes feelings of enjoyment, interest, attention, and participation of students. To measure physics identity on the performance indicator, a performance assessment sheet is used.

Before implementation, the test instruments for measuring creative thinking and physics identity on the competence indicator were validated and tested for reliability by expert lecturers and practitioners. The instruments were declared valid based on Aiken's V analysis with validity criteria shown in Table 1.

Validity Coefficient	Validity Category
$0,8 < V \leq 1$	Very Valid
$0,6 < V \leq 0,8$	Valid
$0,4 < V \leq 0,6$	Quite Valid
$0,2 < V \leq 0,4$	Less Valid

Table 1. Instrument Validity Categories (Azwar, 2016)

The reliability criteria are presented in Table 2.

Reliability Coefficient (r)	Reliability Level
$0,00 \leq r < 0,20$	Very Low
$0,20 \leq r < 0,40$	Low
$0,40 \leq r < 0,60$	Moderate
$0,60 \leq r < 0,80$	High
$0,80 \leq r < 1,00$	Very High

Table 2. Research Instrument Reliability Coefficient Criteria

The test instrument used to measure creative thinking ability and physics identity on the competence indicator was validated and reliability-tested by expert lecturers and practitioners before being implemented with students. The validity test using Aiken's V analysis resulted in a value of 0.900, categorized as very valid. A limited trial on students showed validity results as presented in Table 3. The reliability result was 0.54, categorized as moderate.

Question No.	INFT MNSQ	Validity Criterion
1.	1,00	Valid
2.	0,87	Valid
3.	1,19	Valid
4.	0,81	Valid
5.	0,82	Valid
6.	1,14	Valid
7.	1,19	Valid
8.	0,94	Valid

Table 3. Empirical Validity Test Results for Creative Thinking and Competence Physics Identity Instruments

The student response questionnaire used to measure the second research objective and the interest questionnaire to measure physics identity on the interest indicator were validated by experts and

practitioners. Aiken's V analysis showed that the student response questionnaire had a validity value of 0.907, and the interest questionnaire had a validity of 0.956, both categorized as very valid.

The interest questionnaire also went through a limited trial with students, producing validity and reliability results. Empirical validity test results for the interest questionnaire are presented in Table 4. The reliability of the interest questionnaire was 0.59, categorized as moderate.

Question No.	INFT MNSQ	Validity Criterion
1.	0,90	Valid
2.	1,16	Valid
3.	1,35	Valid
4.	1,02	Valid
5.	0,78	Valid
6.	1,09	Valid
7.	0,77	Valid
8.	1,05	Valid
9.	1,26	Valid
10.	0,93	Valid

Table 4. Empirical Validity Test Results of Interest Questionnaire

2.3. Research Design

The first stage is define. The define stage is the initial stage aimed at determining the needs and requirements for developing the e-book. The define stage consists of three steps: initial analysis, student analysis, and material analysis. In the initial analysis, several problems were identified that necessitate the development of learning media. The analysis was conducted using literature studies and field studies.

The initial analysis began with observations and interviews at the Gudeg Miss Tjitro 1925 Production House to identify the physical concepts involved in making Gudeg. The observations and interviews at Gudeg Bu Tjitro 1925 Production House were conducted over two months, from March to April. The cooking process of Gudeg is shown in Figure 2., where traditional cooking methods are still used. Based on field studies at Bu Tjitro 1925 Gudeg Canning Production House, the cooking and canning process of Gudeg contains physics concepts. One of the physics concepts frequently found is temperature and heat. Thus, the cooking and canning process of Gudeg can be integrated into physics learning on temperature and heat.

Figure 2. The process of cooking gudeg using traditional methods at the Gudeg Bu Tjitro production house

In addition, observations and interviews were also conducted at Senior High School 1 Pundong to identify problems that necessitate the development of learning media. Based on the field study results at the school, students' creative thinking skills and physics identity are still low. Furthermore, interviews revealed

that students have difficulty understanding temperature and heat concepts. The low creative thinking skills and physics identity among students are caused by uninteresting learning media.

Student analysis was conducted by identifying student characteristics, focusing on eleventh-grade students. This analysis involved observations and interviews with students. Material analysis was performed to identify general content that aligns with the applicable independent curriculum. Learning achievements on temperature and heat were selected based on the school's independent curriculum. These learning achievements became the basis for developing learning objectives indicators. Additionally, sub-material on temperature and heat to be taught were analyzed. This series of observations and analysis at the school lasted approximately one month.

The second stage is design. This stage consists of developing learning instruments and data collection instruments. The learning instruments developed are the AI-assisted Gudeg Integrated Discovery Learning Model-Based Temperature and Heat E-Book and teaching modules. The data collection instruments include questionnaires and tests. The developed E-Book follows the Discovery Learning syntax stages implemented with the help of AI ChatGPT. The E-Book integrates temperature and heat with the Gudeg cooking and canning process to help students understand the application of the material in daily life for deeper understanding. The E-Book also features images, videos, and practice questions to increase appeal and facilitate student understanding. At this stage, the initial E-Book draft consists of three main parts: introduction, core, and conclusion. The introduction includes components such as cover, E-Book identity, foreword, table of contents, E-Book description, discovery learning syntax, usage instructions, learning outcomes, learning objectives, indicators, and concept maps. The design stage took approximately five months, from April to August.

The final stage is the development stage. At this stage, the feasibility assessment was carried out through a focus group discussion (FGD) with expert evaluators. The validators provided suggestions and feedback, which then served as the basis for revising the Gulearn E-Book. After the Gulearn E-Book was revised and declared feasible, it was distributed to 58 twelfth-grade students at SMA Pundong for learning use. Subsequently, the students were asked to assess the practicality of the E-Book by completing a questionnaire. The feasibility and practicality assessments of the E-Book were conducted using questionnaires with the same evaluation aspects. The questionnaire aspects measured included content, language, design and appearance, as well as ease of use. The aspects of the questionnaire used to evaluate the feasibility and practicality of the developed E-Book are presented in Table 5.

Aspects Assessed
Content
Language
Design and Appearance
Ease of Use

Table 5. Aspects of Feasibility and Practicality Testing for the AI-Assisted Discovery Learning-Based Temperature and Heat E-Book Integrated with Gudeg

Data on creative thinking ability and physics identity for the competence indicator were obtained using a test instrument, while physics identity for the interest indicator was obtained using an interest questionnaire. The test was conducted after the students received the Gulearn E-Book and assessed its practicality. The entire process in the development stage lasted for one month. The research process can be seen in Figure 3, which shows students observing the Gulearn E-Book.

Figure 3. The seventh author conducting research by showing the Gulearn E-Book to students

2.4. Data Analysis

The data obtained from the feasibility and practicality questionnaire responses for the AI-assisted Gudeg Integrated Discovery Learning Model-Based Temperature and Heat E-Book are ordinal data. This ordinal data must first be converted into interval data. The conversion of ordinal data to interval data is done using the Method of Successive Intervals (MSI). After the data has been converted to interval data, an analysis is conducted to determine four classification scales for feasibility and practicality.

The first research objective is to determine the feasibility level of the Gulearn E-Book media as assessed by expert validators and practitioners using the Standardized Ideal Score (SBI). The criteria for feasibility assessment of the Gulearn E-Book are presented in Table 6.

Score Range	Category
$\bar{X} > 1{,}977$	Very worthy
$1{,}977 \geq \bar{X} \geq 1{,}318$	Worth it
$1{,}318 > \bar{X} \geq 0{,}659$	Not worthy
$0{,}659 > \bar{X}$	Not feasible

Table 6. Classification Scale for Feasibility

The second research objective analyzes practicality using SBI to assess the practicality level as rated by students through a student response questionnaire. The practicality assessment criteria for the Gulearn E-Book are presented in Table 7.

Score Range	Category
$\bar{X} > 4{,}049$	Very practical
$4{,}049 \geq \bar{X} \geq 3{,}033$	Practical
$3{,}033 > \bar{X} \geq 2{,}016$	Not practical
$2{,}016 > \bar{X}$	Not practical

Table 7. Classification Scale for Practicality

The third objective is to analyze students' creative thinking and physics identity abilities after completing the given instruments. The analysis compares students' scores to the benchmark standard or Minimum Passing Criteria (KKM) set by the school, which is 76. Data collected for creative thinking ability does not have a normal distribution and is not homogeneous. Thus, a non-parametric Wilcoxon test is used to compare scores with the KKM. Physics identity data shows normal distribution and homogeneity, so parametric analysis using a one-sample T-test is applied.

The hypotheses for analyzing creative thinking ability are:

i. H_0: The average student score is less than or equal to 76.
ii. H_a: The average student score is greater than 76.

The decision criteria for the Wilcoxon test are:

i. The null hypothesis is rejected and the alternative accepted if the significance value $p \leq 0{,}05$.
ii. The null hypothesis is accepted and the alternative rejected if the significance value $p > 0{,}05$.

The hypotheses for analyzing physics identity are:

i. H_0: The average student score is less than or equal to 76.
ii. H_a: The average student score is greater than 76.

The decision criteria for the Wilcoxon test are as follows:

i. The null hypothesis is rejected and the alternative hypothesis accepted if the significance value $p \leq 0{,}05$
ii. The null hypothesis is accepted and the alternative hypothesis rejected if the significance value $p > 0{,}05$.

3. Result And Discussion

3.1. Result

3.1.1. The Feasibility of the Developed "Discovery Learning Model-Based Temperature and Heat E-Book Assisted by AI Integrated with Gudeg"

The developed E-Book named Gulearn can be accessed at https://unyku.id/EbookGulearn. The introductory section consists of several components such as the cover, E-Book identity, foreword, table of contents, E-Book description, discovery learning syntax, user guide, learning outcomes, learning objectives, indicators, and concept maps. This E-Book includes user instructions to help readers understand how to access, read, and utilize the available features. As an introduction before starting the learning process, students are provided a concept map that offers an overview of the concepts to be studied through the developed E-Book.

The developed Gulearn E-Book was first tested for feasibility before being used in learning. The feasibility test was conducted by expert lecturers and practitioners. The Gulearn E-Book's feasibility was assessed based on 20 feasibility criteria grouped into 4 assessment aspects. The results of the feasibility test, particularly the content aspect of the Gulearn E-Book, can be seen in Figure 4 below.

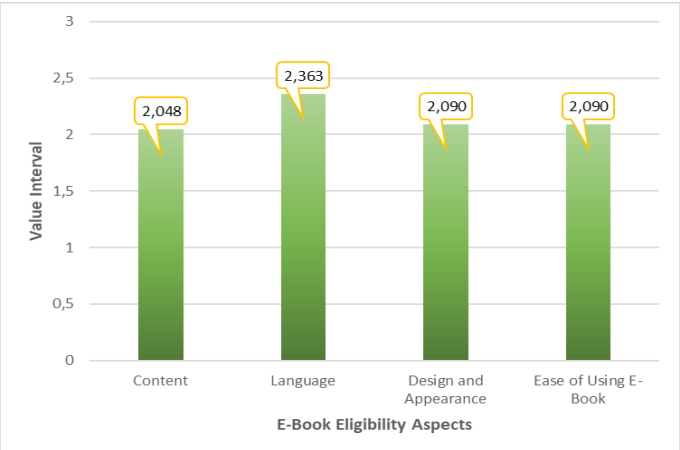

Figure 4. Graph of the Feasibility Test Analysis of the E-Book based on content, language, design and appearance, and ease of use aspects

Based on the Gulearn E-Book feasibility assessment results presented, it can be seen that all four aspects scored above 1.977. Thus, all aspects fall into the very feasible category according to Table 6. The language aspect scored the highest, categorized as very feasible. In the figure above, the content aspect scored the lowest, but it is still categorized as very feasible. The overall feasibility score of the Gulearn E-Book was 2.148, placing it in the very feasible category. Therefore, the Gulearn E-Book is feasible for use in physics learning on temperature and heat materials.

3.1.2. Practicality of the "Discovery Learning-Based Temperature and Heat E-Book Assisted by AI Integrated with Gudeg" Developed

Before being used in physics learning, the Gulearn E-Book's practicality was tested. The practicality test was conducted by distributing readability questionnaires to twelfth-grade students. The completed questionnaires were analyzed using the Ideal Readability Standard (SBI) analysis. The Gulearn E-Book's practicality was assessed based on four aspects: content, language, design and appearance, and ease of use. The results of the practicality test for the Gulearn E-Book are shown in Figure 5 as follows.

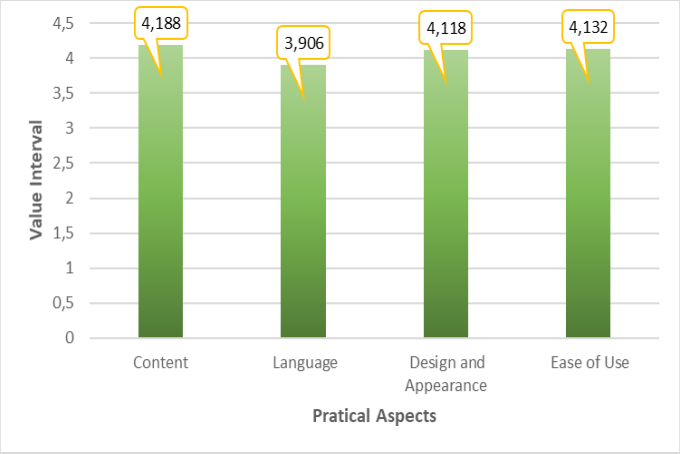

Figure 5. Practicality Test Graph of Gulearn E-Book on the Content Aspect

Based on the student response scores from the limited trial, the practicality values for the Gulearn E-Book were obtained. From the analysis shown in Figure 5, the content, design and appearance, and ease of use aspects scored above 4.049, indicating these aspects fall into the very practical category based on Table 7. The language aspect scored below 4.049, indicating it is categorized as practical. The average score across all aspects showed a practicality score of 4.085 for the Gulearn E-Book, placing it in the very practical category. Thus, the Gulearn E-Book is practical for use in physics learning on temperature and heat topics.

3.1.3. Mapping the Profile of High School Students' Creative Thinking Ability and Physics Identity

An analysis of students' profiles regarding creative thinking ability and physics identity was conducted to summarize the characteristics of the sample. Based on prerequisite tests, it was found that students' creative thinking data did not have a normal distribution and was not homogeneous, so a Wilcoxon test was used for further analysis. Meanwhile, the physics identity data was normally distributed and homogeneous. The results of the creative thinking ability and physics identity analysis are shown in the following graphs in Figures 6 and 7.

Based on Figure 6 and 7, the average student scores on creative thinking aspects varied greatly. Fluency and Elaboration both had scores of 84.83, indicating that students are capable of generating many ideas and detailed elaborations. Flexibility had an average score of 81.21, followed by Originality with 80.34. This indicates that students relatively easily elaborate and articulate ideas and various alternative problem-solving materials.

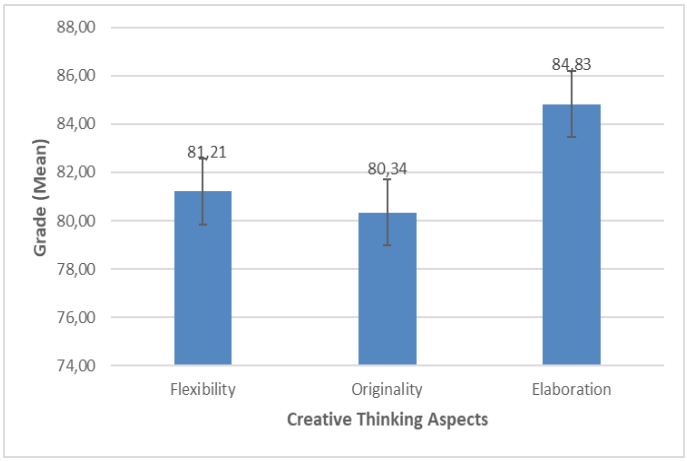

Figure 6. Distribution of scores for creative thinking aspects (fluency, flexibility, originality, elaboration)

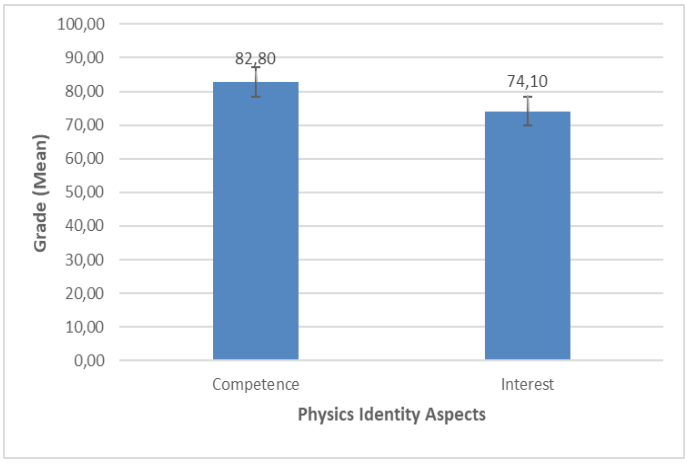

Figure 7. Distribution of scores for physics identity aspects (competence dan interest)

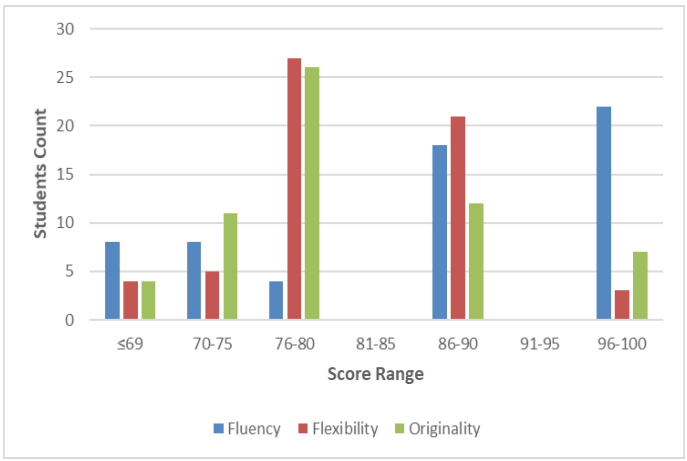

Figure 8. Distribution of scores for the creative thinking aspect (fluency, flexibility, originality, elaboration) based on student score ranges

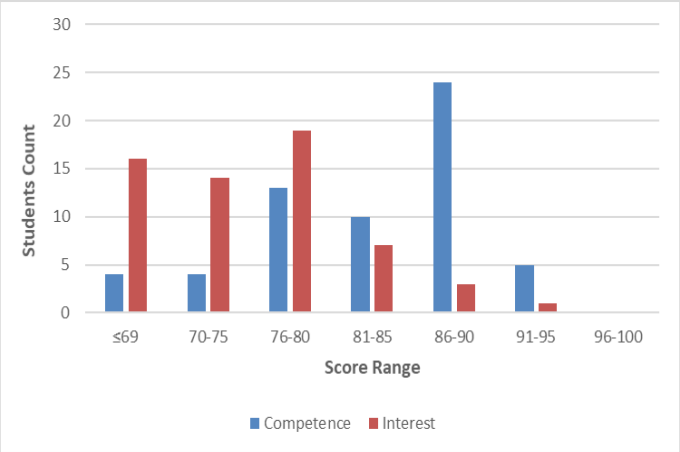

Figure 9. Distribution of scores for the physics identity aspect (competence and interest) based on student score ranges

Regarding physics identity, students showed varying results. The highest score was in the performance aspect with an average of 81.92, followed by competence with an average score of 82.80, while the lowest was interest with an average score of 74.10. This means the learning process was effective in improving ability and confidence, but strategies need to be developed to further increase students' interest in physics to enhance their overall physics identity.

The data is supported by diagrams in Figure 8 and 9, where most students achieved scores above the minimum completeness criteria (≥ 76) as established by the school in all creative thinking aspects (fluency, flexibility, originality, elaboration) and physics identity aspects (competence, interest, performance). In terms of creative thinking, particularly fluency and elaboration, students showed excellent achievement with most scoring high (91 – 100). Flexibility and originality also showed satisfactory results, though scores were more concentrated in the 76 – 80 range. This means most students can think flexibly and originally, though not all have reached very high levels.

In physics identity, competence was relatively stable with most students scoring between 86 – 90, indicating good material understanding. Interest showed a wider variation, with many students below the minimum criteria, suggesting the need to improve students' interest in physics learning. On the other hand, performance showed the highest achievement; almost all students scored between 96 – 100, indicating excellent physics learning performance.

The analysis of students' profiles regarding their creative thinking ability and physics identity was conducted to determine the characteristics of the research sample. The analysis of creative thinking ability profiles was carried out based on the Wilcoxon test values. The results of the Wilcoxon test for creative thinking ability are presented in Table 8.

Indicator	V	p-value
Fluency	1711.000	0,001
Flexibility	1711.000	0,001
Originality	1711.000	0,001
Elaboration	1711.000	0,001

Table 8. Results of the Wilcoxon Analysis for Creative Thinking Ability Indicators

Based on the Wilcoxon test analysis, the p-value for creative thinking ability was less than 0.05. According to the decision criteria, this means that the null hypothesis is rejected and the alternative hypothesis is accepted. Therefore, it can be concluded that the students' median score is higher than 76, indicating that their creative thinking ability is good or above the reference average standard.

Based on the results of the Wilcoxon test analysis, the V value for each indicator of creative thinking ability shows a consistent ranking difference between students' scores and the minimum mastery criterion (KKM) of 76. This indicates that the differences between students' scores and the KKM across all four indicators are relatively similar. A high V value suggests that the median score of students is above the KKM (76). This finding is supported by the p-value, which is less than 0.05, indicating a significant difference between students' scores and the KKM. Therefore, the alternative hypothesis H_a is accepted, meaning that students' creative thinking abilities in each indicator are above the reference standard average.

The analysis of the physics identity profile was carried out using a one-sample t-test. The results of the one-sample t-test analysis on the physics identity data are presented in Table 9.

Variable	t	p-value
Physics identity	99.255	0,001

Table 9. Results of the One-Sample T-Test Analysis

Based on the results of the One-Sample T-Test analysis, the calculated t-value was greater than the t-table value (± 2.003; df = 57). Therefore, the null hypothesis (H_0) was rejected, and the alternative hypothesis (H_a) was accepted, indicating that the students' mean score was significantly higher than the reference value of 76. This is also supported by the p-value, which was less than 0.05, showing a significant difference between the students' mean score and the reference standard value (76). Thus, it can be concluded that the students' physics identity is categorized as good or above the average reference standard.

3.2. Discussion

3.2.1. Feasibility of the Developed "AI-Assisted Discovery Learning Model-Based Temperature and Heat E-Book Integrated with Gudeg"

The feasibility test results on the content aspect fall into the very feasible category. The content aspect of the Gulearn E-Book feasibility relates to learning objectives, materials, discovery learning model, use of AI ChatGPT, and videos that support learning. The very feasible rating indicates that the materials and activities presented in the Gulearn E-Book are considered relevant and appropriate for students' needs. Furthermore, the AI ChatGPT and videos presented can support the learning process. This aligns with the study by Afiliyani (2024), which states that AI-based learning is feasible and can be used to support physics learning. Moreover, research by Rofiah & Mundilarto (2021), asserts that video use can support physics learning. Thus, the content in the Gulearn E-Book can help students understand the concepts of temperature and heat.

The language aspect's very feasible result shows that the Gulearn E-Book complies with language standards. It uses good and proper language according to PUEBI guidelines, making the material clearly understandable by students. Additionally, it is written in a communicative style, facilitating students' ability to follow and grasp every step in the learning process. This is supported by Harahap, Aswirna and Hurriyah (2023), who state that strengthening language in conveying physics concepts is crucial to increasing learning effectiveness. The language aspect scored an average of 2.363, indicating a very feasible category. Therefore, the Gulearn E-Book is effective in delivering information clearly, structured, and easy to understand.

The careful selection of design and appearance in creating learning media is highly considered to improve learning effectiveness. A good design and appearance can attract attention and increase student interest. This is supported by research by (Ruddamayanti, 2019), which states that attractive learning media positively impact student learning interest. The feasibility test on design and appearance aspects yielded an average score of 2.090, which falls into the very feasible category. Thus, the Gulearn E-Book presents interesting, well-structured design elements aligned with learning needs.

The feasibility test results on the ease of use aspect indicate that this aspect falls into the very feasible category, which means the E-Book is easy to access and use by students. The Gulearn E-Book is available in PDF format, allowing students to read anytime and anywhere. Additionally, the format provided is easy to download and open on various devices. The Gulearn E-Book can accommodate both online and offline learning. With the ease of access provided, students can access learning materials more flexibly, whether studying at school or at home. The selected AI ChatGPT used in the E-Book is easy to access. ChatGPT as an assistant tool in the Gulearn E-Book can be accessed quickly and easily and provides clear responses to questions asked. The ease of using the E-Book is also supported by Ruddamayanti (2019), who states that E-Books are practical and easy to use.

Learning with the Gulearn E-Book is expected to enhance creative thinking skills, as supported by implementing creative thinking indicators at each stage of discovery learning syntax. This aligns with research by Anggraeni and Yohandri (2022) and Salamiyah and Kholiq (2020), which found that E-Books using discovery learning models effectively improve students' creative thinking abilities in physics. Additionally, Gulearn increases physics identity on the interest indicator by integrating the local wisdom of gudeg and other appealing features. It also improves physics identity on competence and performance indicators because students actively understand and apply temperature and heat concepts in the gudeg-making and canning processes.

The Gulearn E-Book comprises two core learning activities. Activity 1 covers materials on temperature, expansion, and heat. Activity 2 includes materials on the basic blackbody principle, phase changes, and heat transfer. At the beginning of each activity, students are presented with facts about gudeg, such as its history and recipe. Each learning activity includes six stages performed by educators and students, aligned with discovery learning syntax.

In Figure 10, the stimulation stages are presented, beginning with interesting information about gudeg, a traditional Yogyakarta dish. The stimulation phase is supported by various interactive features. The information is accompanied by images and videos illustrating the gudeg canning process. These videos can be easily accessed through QR codes or links that can be scanned or clicked within the Gulearn E-Book, allowing students to study independently anytime and anywhere. By integrating gudeg and videos, physics learning can become more relevant, engaging, and meaningful, thereby stimulating student interest before advancing to the next learning stages. This aligns with Ramli, Sakti, Basri, Idamyanti and Yusdarina (2024), who state that local wisdom-based learning helps students relate the material to their surroundings, enhancing understanding and interest in physics. Additionally, Rofiah and Mundilarto (2021), assert that video learning media can boost student interest. Thus, the stimulation level can increase physics identity in terms of interest.

In the problem identification syntax, students are guided to identify problems from the prior stimulation. The Gulearn E-Book presents questions that provoke student curiosity, encouraging them to identify and analyze issues based on the stimulation. Through this stage, students are given opportunities to identify as many physics concepts as possible within the presented phenomena. Consequently, this stage can enhance creative thinking skills, especially fluency. This is supported by Trianggono (2017), who states that fluency is the ability to rapidly generate many relevant ideas or answers.

During problem identification, students apply their physics knowledge to relate concepts to the gudeg cooking process. This promotes deeper understanding of relevant physics concepts, improving their ability to answer questions. This aligns with Hazari (2017), who relate competence to students' confidence in completing tasks and understanding concepts. Thus, the problem identification stage enhances both fluency and physics identity in competence.

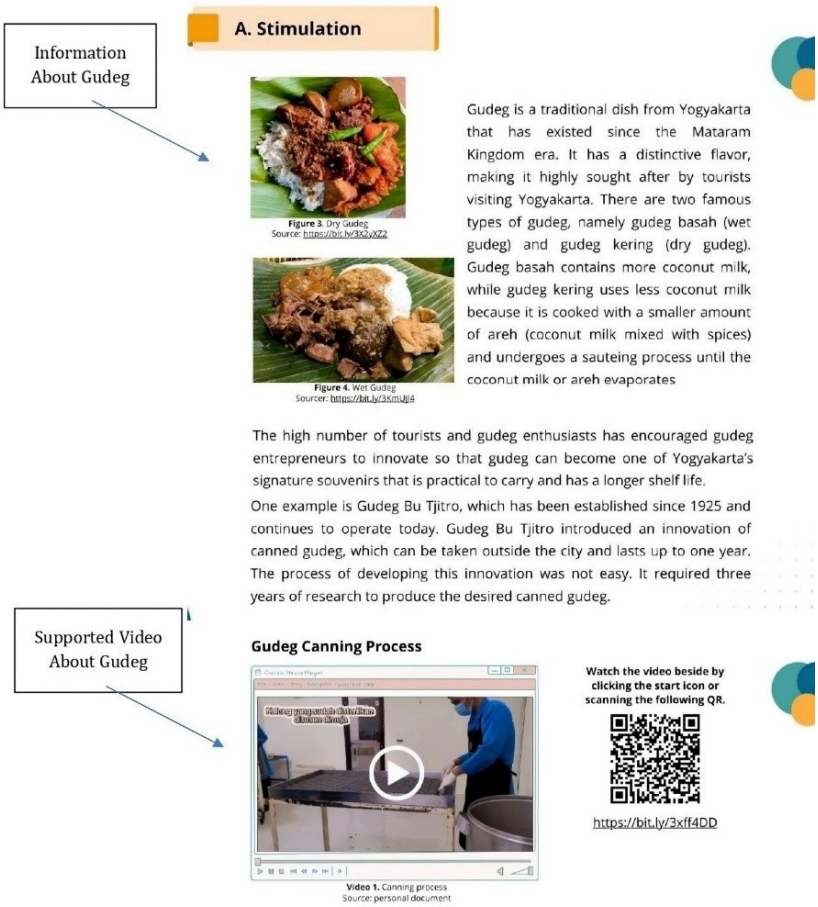

Figure 10. Stimulation stage containing explanatory text about *gudeg* as a traditional food of Yogyakarta, an image of wet *gudeg* and dry *gudeg*, as well as a video of the *gudeg* canning process

The data collection syntax in the Gulearn E-Book aims to encourage students to actively search for and gather information relevant to the topic. At this stage, students explore through activities such as experiments. Videos showing the gudeg cooking process, accompanied by narration, are presented for observation and discussion. These activities involve students in exploration consistent with Piaget's theory emphasizing active learning through exploration (Hendrowati, 2015). Here, physics experiments and observing gudeg cooking provide real-world context linking physics concepts with direct experience.

In the data collection syntax, students face problems requiring the application of physics concepts to explain observed phenomena. By seeking diverse information and connecting it with their experiments, students practice flexible thinking to find solutions. Using ChatGPT for additional information enriches their perspectives. Gulearn provides guidance on using ChatGPT critically and responsibly. This activity encourages flexible thinking, as students generate various ideas and solutions linking experiments and ChatGPT findings. This trains students not to fixate on a single answer. Therefore, the data collection syntax enhances flexible thinking skills.

Data collection through experiments also improves learner performance. Samsudin, Efendi and Suhandi (2012), found that physics experiments develop performance skills. At this stage, students present their experiment results by uploading them on Instagram. Besides performance improvement, this syntax includes AI ChatGPT and videos that boost learning interest. Consistent with Nada, Kamelia, Rifky and Sulaiman (2024), ChatGPT positively affects learning interest and videos enhance student motivation. Thus, data collection syntax enhances physics identity in interest and performance indicators.

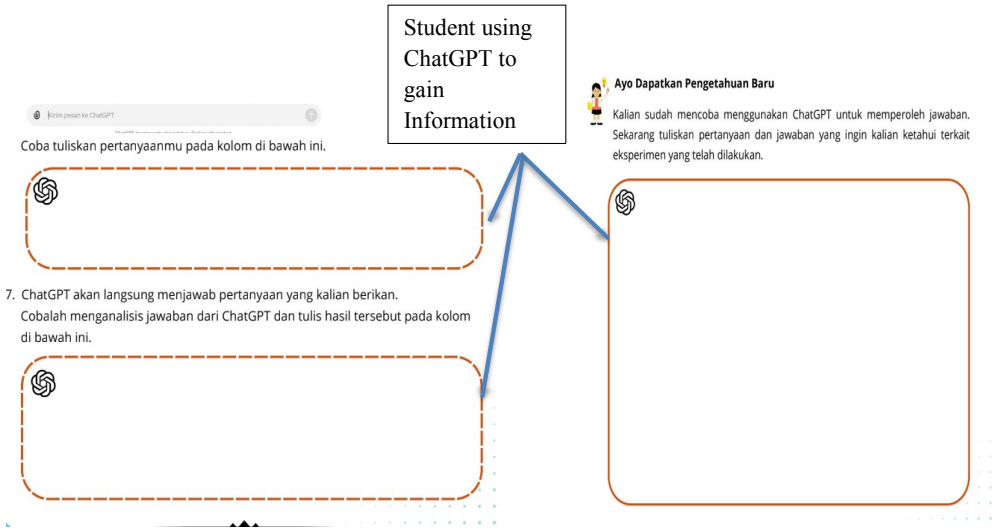

Figure 11. The use of ChatGPT displaying a column for students to write their questions, the automatic responses from ChatGPT, and a space for students to analyze and rewrite the obtained information

At the data processing syntax stage, students are guided to organize the results of experiments and information obtained from ChatGPT, as shown in Figure 11. Students write their analysis by detailing and explaining the results based on their initial understanding. Through this syntax, students can improve their elaboration skills. Elaboration is the ability to generate new ideas and explain them in detail (Yusro, 2017). The data processing involves activities such as integrating new information with existing knowledge, developing new ideas, and creating solutions so that students can produce broader and deeper understanding.

The Gulearn E-Book also presents questions related to activities students have conducted to ensure their understanding. Thus, the data processing phase can enhance student competence. Additionally, in this phase, students are asked to present the results of their analysis. This activity indirectly increases student performance. According to Hazari (2017), competence and performance refer to the belief that students can understand physics concepts and complete their tasks. Therefore, it can be said that the data processing syntax can improve both competence and performance as students enhance their understanding and confidence in presenting their results.

Verification in the Gulearn E-Book aims to ensure students can evaluate their findings or answers against the correct concepts. At this stage, the E-Book presents temperature and heat materials so students can verify their understanding. The temperature and heat materials are integrated with the local wisdom of Gudeg, accompanied by supporting images and videos. This aims to provide a more contextual learning experience for students. To facilitate access to videos, the E-Book provides QR codes and links that can be scanned or clicked to play videos supporting material comprehension.

Integration of Gudeg into the temperature and heat materials aligns with Vygotsky's learning theory emphasizing social and cultural interaction as tools for cognitive development (Suardipa, 2020). In Gulearn, Gudeg serves as a social and cultural tool to construct the material. By relating temperature and heat concepts to the Gudeg cooking process, students associate the concepts with real life. The verification syntax process also supports elaboration and competence, as students are encouraged to analyze the relationship between physical phenomena and the Gudeg cooking process. Furthermore, students compare concepts they previously constructed with existing concepts. This activity encourages expansion of insight, information integration, and construction of more complex knowledge.

Verification also enhances student interest through Gudeg and supporting images and videos. This aligns with Ramli et al.(2024), stating that local wisdom and videos Rofiah and Mundilarto, (2021), can improve student understanding and interest. Thus, verification syntax can improve elaboration skills and physics

identity on competence and interest indicators. Verification helps reinforce understanding and correct conceptual errors during learning.

At the generalization syntax stage, students are given the opportunity to independently develop new knowledge concepts based on results obtained from previous stages. This process supports students in increasing their original thinking skills. Trianggono (2017), defines original thinking as the ability to produce new ideas using easily understandable language. At this stage, students are encouraged to generate new understanding that is easier to grasp. This way, students not only repeat existing knowledge but also create more original thoughts.

Generalization syntax not only enhances original thinking skills but also improves student competence. By independently formulating conclusions, students better understand physics concepts by constructing their knowledge through analysis and reflection. Moreover, students are asked to present their conclusions, indirectly improving performance. This process aligns with constructivism theory, according to Siti-Lathifah, Hardaningtyas, Pratama and Moewardi (2024), which can enhance student activity and learning outcomes. Thus, inferential syntax (generalization) improves original thinking skills and physics identity on competence and performance indicators.

Example questions presented in the Gulearn E-Book aim to give students a general overview of question types related to temperature and heat materials they have studied. The example questions include videos that students can play by pressing the play button or using the available barcode. The relationship between the discovery learning model and the E-Book in enhancing creative thinking skills and physics identity can be seen in Table 10.

No	Discovery Learning Stage	Fitur e-book	Critical Thinking	Physics Identity
1	Stimulation	Problems are presented through videos and illustrations of the canned gudeg production process.	–	Interest
2	Problem Statement	Guiding students to identify relevant physics concepts.	Fluency	Competence
3	Data Collection	Directing students to conduct experiments or observations and utilize ChatGPT to obtain information.	Flexibility	Interest and Performance
4	Data Processing	Guiding students to analyze the collected data, elaborate on their findings, and present them.	Elaboration Skills	Competence and Performance
5	Verification	Encouraging students to validate their discussion results with the theories provided.	Elaboration Skills	Interest and Competence
6	Generalization	Leading students to formulate conclusions based on their learning activities and present them.	Originality	Competence and Performance

Table 10. The Relationship Between Discovery Learning and E-Book Features in Enhancing Physics Identity and Critical Thinking

3.2.2. Practicality of the Developed "AI-Assisted Discovery Learning Model-Based Temperature and Heat E-Book Integrated with Gudeg"

The practicality test results on the content aspect fall into the very practical category. The content aspect of the Gulearn E-Book practicality relates to the user guide, learning outcomes, learning objectives, temperature and heat materials, activities within the E-Book, and AI ChatGPT that supports creative thinking abilities and physics identity. The very practical result indicates that the Gulearn E-Book has been developed according to the learning needs of students.

Based on the scores obtained, Gulearn already includes activities that support creative thinking and physics identity, such as providing opportunities for students to explore and relate physics materials to the

gudeg making process. Nevertheless, these activities can be further developed or enhanced, for example, by adding more interactive activities like experiments.

From the readability questionnaire results during the limited trial, the lowest practicality score was on the language aspect, but it still belongs to the practical category. This shows that Gulearn meets good language standards in its composition. However, the language aspect needs improvement to be easier for students to understand. This aligns with Harahap, Sinaga, Stio and Munthe (2024), who emphasizes the importance of strengthening language in conveying physics concepts to improve learning effectiveness. With clear, structured, and easy-to-understand language, Gulearn is practical for temperature and heat learning.

The practicality test on the design and appearance aspect shows that the design and illustrations used in the E-Book are attractive and appropriate to the content. Student responses indicate interest in the developed E-Book. Their interest may be due to the E-Book's appearance, illustrations, layout, and choice of colors. This is evident from positive ratings related to reading comfort and design relevance. The choice of design and appearance can attract attention and increase student interest. This is supported by research from Ruddamayanti (2019), which states that attractive learning media can increase students' learning interest. Therefore, the design and appearance of the Gulearn E-Book have the potential to boost student interest.

The practicality test results on the ease of use aspect show that the Gulearn E-Book is easily accessible to students. It is available in PDF format, allowing students to access it anytime and anywhere. The E-Book is practical for use both online and offline. The selected AI ChatGPT is easily accessible; however, some students still experience difficulties accessing it. Nonetheless, these difficulties can be overcome by carefully reading the usage guide provided in the Gulearn E-Book.

Based on student responses, the Gulearn E-Book received an average score classified in the very practical category. This aligns with Ruddamayanti (2019), who claims that one of the advantages of E-Books is their practicality. Furthermore, Afiliyani (2024), found that AI-based learning media are practical for physics learning, specifically temperature and heat. This indicates that the Gulearn E-Book effectively meets the learning needs and is practical for students.

Based on student comments about the Gulearn E-Book, students stated that the Gulearn E-Book is very helpful in understanding the concepts of temperature and heat. The Gulearn E-Book is equipped with images and videos that help visualize the actual process of making gudeg. In addition, the Gulearn E-Book includes practice questions and discussions that assist students in practicing the analysis of temperature and heat concepts. Students also expressed that they are interested in studying the material on temperature and heat in the Gulearn E-Book because it is equipped with images and colorful elements that make learning engaging and not boring. The Gulearn E-Book helps students develop creative thinking skills by encouraging them to express ideas and find solutions from various perspectives.

3.2.3. Mapping the Profile of High School Students' Creative Thinking Ability and Physics Identity

The validity analysis of the research instruments indicates that these instruments fall into the very valid category. This validity result reinforces that the instruments used in the research not only have good content quality but also can be relied upon to generate valid data. Content validity is a crucial aspect in instrument development because a valid instrument ensures that the collected data accurately reflect the construct being examined (Azwar, 2016).

The creative thinking ability analysis shows that students have met the four indicators of creative thinking: fluency, flexibility, originality, and elaboration skills. Fluency is evident in students' ability to generate various answers to a physics problem. Flexibility is reflected in their ability to view problems from different perspectives and utilize various problem-solving strategies. Originality appears in students'

answers that differ from most of their peers. Elaboration is seen in students' skill to detail their answers more completely.

This good achievement in creative thinking may be influenced by factors such as interactive learning media, learning activities that encourage idea exploration, and students' engagement in connecting concepts to real-life contexts. This aligns with Munandar (2012), who explains that creativity can develop when students are given opportunities to generate diverse ideas, think flexibly, and freely express thoughts in learning activities. Another contributing factor is students' involvement in relating physics concepts to real-world situations around them.

However, some students show relatively lower creative thinking results compared to their classmates. This could be caused by limited motivation, low confidence in expressing ideas, or a tendency to follow conventional thinking patterns. This finding aligns with the research of Hidayat (2019), which explains that Indonesian students' creative thinking skills vary and are often influenced by motivation and learning experiences.

Furthermore, the physics identity analysis shows that most students already understand and acknowledge their role as physics learners. They do not see physics merely as a subject but as part of their academic identity. Students feel they can learn, understand, and even apply physics concepts in daily life, indicating developing self-confidence.

Some factors influencing the development of physics identity include students' interest in physics, support from the learning environment (teachers, peers, family), and positive experiences in mastering or solving physics problems. Recognition or appreciation from others also strengthens physics identity. This aligns with Hazari (2010), who state that physics identity is influenced by individual interest in physics, social support or recognition, and self-belief in understanding physics concepts.

Nevertheless, based on the scores, some students still have relatively low physics identity. This indicates that some students may lack interest or confidence in their physics abilities. This finding is consistent with Abbas (2019), who reported low interest and achievement in physics learning. Therefore, efforts are necessary to improve students' creative thinking skills and physics identity. One approach is through engaging and relevant learning experiences connected to everyday life, providing students with learning experiences that make it easier to understand the material.

4. Conclusion

In general, the AI-assisted Gudeg Integrated Discovery Learning Model-Based Temperature and Heat E-Book is declared feasible and practical for use in physics learning. The profile of students' creative thinking ability and physics identity who assessed the Gulearn E-Book media can be considered good.

The feasibility of the Gulearn E-Book falls into the very feasible category based on assessments by expert lecturers and practitioners. This shows a very good category in terms of content, language, design and appearance, and ease of use of the E-Book. Limited trials show that students rate the E-Book as practical, interesting, and helpful in understanding temperature and heat concepts. The student profile based on the limited trial results shows that students' creative thinking and physics identity have met the benchmark standards.

The findings of this study have practical implications for teachers and educational media developers. The Gulearn E-Book can serve as an alternative contextual learning resource that encourages active student engagement in the learning process. Teachers can use this E-Book as a supporting medium in instruction to enhance students' creative thinking skills and physics identity. However, this study has a limitation, as the testing was conducted on a limited scale with a sample of only 58 students. Therefore, further testing on a larger scale is needed to measure the effectiveness of the Gulearn E-Book in improving students' creative thinking skills and physics identity.

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