VALIDITY OF AUGMENTED REALITY-BASED THERMODYNAMICS E-LKPD CONTAINING LOCAL WISDOM EVAPORATION MATERIAL GRADE XI STUDENTS OF TOAPAYA STATE SENIOR HIGH SCHOOL

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Abstract
The use of interactive digital media in physics learning remains limited, and the integration of local wisdom into science education is often overlooked, resulting in less contextual and engaging learning experiences for students. This study aims to develop and determine the validity of an Augmented Reality (AR)-based electronic student worksheet (E-LKPD) integrated with local wisdom on thermodynamics, specifically the evaporation topic for grade XI high school students. This research employed a Research and Development (R&D) approach using the ADDIE model, focusing on the development and evaluation stages. Product validation involved four validators consisting of two physics education lecturers and two experienced high school physics teachers. The validation instrument assessed interface design, interactivity, visual presentation, AR technology stability, media integration, and digital format consistency. Data were analyzed using descriptive quantitative techniques through percentage calculations to determine the validity level. The results indicate that the developed AR-based E-LKPD achieved a highly valid category, exceeding the established feasibility criteria. The integration of AR technology enables interactive visualization of thermodynamics concepts, while the incorporation of local wisdom provides contextual learning experiences for students. Therefore, the developed E-LKPD is feasible as an innovative digital learning medium to support more engaging and meaningful physics learning.

Keywords: E-LKPD, Augmented Reality; Thermodynamics; Evaporation; Local Wisdom

A. Introduction

Understanding thermodynamics concepts remains a challenge for many high school students because the processes involved are abstract and difficult to observe directly. One of the topics that frequently causes conceptual difficulties is evaporation, which involves microscopic molecular interactions and energy transfer that cannot be easily visualized through conventional teaching methods. Learning that relies mainly on textbooks, static images, or verbal explanations often results in superficial understanding and misconceptions among students. Therefore, innovative instructional media are required to help students visualize and comprehend abstract thermodynamic phenomena more effectively. Emphasising the microscopic description of physical systems can lead to a deeper understanding of thermodynamics, as it highlights the generality and application of its laws in various systems (Ercoli & Lubicz, 2023). A teaching sequence that links microscopic and macroscopic approaches has demonstrated an improvement in student understanding, suggesting that this method is suitable for secondary education (Malgieri et al., 2016).

Recent studies have highlighted the potential of Augmented Reality (AR) as an interactive technology capable of presenting complex scientific phenomena through three-dimensional visualization integrated with the real environment. AR-based learning environments allow students to observe invisible processes, interact with virtual objects, and develop deeper conceptual understanding of physics concepts (Beane, 1997). Several studies report that AR can enhance students' conceptual understanding, critical thinking, and engagement in physics learning by providing immersive visual representations of abstract phenomena. Furthermore, systematic reviews of AR applications in physics education indicate that AR technologies help learners visualize scientific processes and support inquiry-based learning experiences that are difficult to achieve through conventional media (Hasan et al., 2025).

In addition to technological innovation, integrating local wisdom (Ramanta & Samsuri, 2020; Yuliarti et al., 2023) into science education is increasingly recognized as an effective approach to contextualizing scientific knowledge. Local wisdom reflects community knowledge, cultural practices, and environmental experiences that can be linked with scientific concepts, thereby making learning more meaningful and culturally relevant (Cheong, 2012). Studies indicate that incorporating local wisdom into science learning can improve students' engagement, scientific literacy, and contextual understanding of scientific phenomena. In regions with strong maritime traditions such as the Riau Islands, evaporation phenomena are closely related to daily community activities, including salt production, coastal environmental processes, and traditional livelihoods (Hidayat et al., 2024).

Despite the growing interest in AR technology and culturally contextualized learning, most existing studies examine these approaches separately. Research on AR in physics education mainly focuses on visualization and technological innovation, while studies on local wisdom emphasize contextual learning and cultural relevance (Djamalu, 2016; Fogarty, 1991). However, research that integrates Augmented Reality technology with local wisdom content in physics learning materials particularly in thermodynamics topics such as evaporation remains limited. Moreover, the development and validation of AR-based electronic student worksheets (E-LKPD) that combine interactive visualization with culturally contextualized scientific explanations have not been widely explored. integrating Augmented Reality with local wisdom in physics, particularly in thermodynamics. It also notes the limited exploration of AR-based electronic student worksheets that combine interactive visualisation with culturally contextualised scientific explanations (Salsabila, T., Lumbantoruan, S. R., Siringoringo, I. M., & Lubis, 2025).

Therefore, this study aims to develop and validate an Augmented Reality (AR)-based E-LKPD integrated with local wisdom on thermodynamics, specifically evaporation material for grade XI high school students. The novelty of this research lies in the integration of AR-based interactive visualization with culturally contextualized local wisdom within a digital worksheet format, providing an innovative learning medium that connects abstract thermodynamics concepts with students' real-life cultural environment.

One form of learning media that is relevant to the demands of 21st-century learning is the Electronic Student Worksheet (E-LKPD). E-LKPD enables the presentation of material, activities, and evaluation in an integrated manner in an interactive digital format. However, before being used in learning, the developed E-LKPD needs to go through a validation process to ensure the suitability of its content, media, and pedagogy. Based on the above description, this study aims to determine the validity level of the Augmented Reality (AR)-based E-LKPD on thermodynamics with local wisdom content on the subject of evaporation for Year 11 high school students.

B. Method

This study employed a Research and Development (R&D) approach using the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation (Ford et al., 1996). However, this paper focuses primarily on the development and evaluation stages, particularly the product validation process. The earlier stages (analysis and design) were conducted to identify learning needs, determine the learning objectives, and design the structure of the Augmented Reality (AR)-based electronic student worksheet (E-LKPD). The development stage involved creating the E-LKPD prototype integrating AR technology and local wisdom content related to evaporation phenomena. The evaluation stage emphasized expert validation to assess the feasibility and validity of the developed learning media before classroom implementation.

The validation process involved four validators, consisting of two physics education lecturers with expertise in instructional media development and two experienced high school physics teachers who have practical experience in physics instruction. Their involvement aimed to ensure that the developed media met both academic standards and classroom applicability**.**

The instrument used in this study was a validation sheet employing a Likert rating scale, developed based on indicators covering several aspects: interface design, interactivity, visual presentation, AR technology stability, media integration, and digital format consistency(Lai, 2011). These indicators were designed to evaluate the quality of the learning media in terms of both technical and pedagogical aspects.

Data analysis was conducted using descriptive quantitative analysis by calculating the percentage of validation scores using the following formula:

$$\text{Validity Percentage } \frac{\text{Obtained Score}}{\text{Maximum Score}} \text{ x } 100\%$$

The resulting percentages were then interpreted using validity criteria to determine the feasibility of the product. The classification used in this study is presented as follows:

Table 1. Validity Criteria

Percentage Range	Validity Category
81–100%	Highly Valid
61–80%	Valid
41–60%	Moderately Valid
21–40%	Less Valid
0–20%	Invalid

A product is considered highly valid if the validation score reaches 81% or higher, indicating that the developed AR-based E-LKPD is appropriate for use as a learning medium with only minor revisions if necessary.

C. Findings and Discussion

Product Validation Test

At the product validation test stage, the researchers first conducted a validation process for each item of the instrument used by the validators, namely supervisor I Dr. Zaitun, S.Ag., M.Ag and supervisor II Dr. Dra. Nevrita,M.Pd., M.Si, who assessed the subject matter experts, media experts, and practitioners of teachers and students. After the product was completed, the next stage was validation by media and material experts. The media validation process was carried out by two media experts, namely media expert 1, a lecturer at the Indonesian College of Technology who is also an expert at the Riau Islands Provincial Communication and Information Agency, Danandjaya, S.S.T., M.Kom., and media expert 1, a physics teacher at SMA Negeri 1 Toapaya, Diah Elvira Suyuni, S.T. The material expert validation was carried out by two experts, namely material expert 1, Widyaswara KGTK Riau Islands, Yuri Yogaswara, S. Pd., M.Pd. Fis, and material expert 2, a physics teacher at SMA Negeri 1 Toapaya, Muhammad Habibullah, S.Pd.

The validators filled out the validation sheet at this stage, which aimed to obtain product validity and also to obtain suggestions, input, and comments for a better product. By going through the validation stage, the AR-based E-LKPD Thermodynamics with local wisdom content that was produced was ensured to meet the standards of content, appearance, and product suitability. The validation results provided by each expert are outlined as follows:

Media Expert Assessment of *the AR (Augmented Reality)* E-LKPD containing local wisdom

Media assessment has been carried out by teachers and lecturers who have the skills and experience in developing learning media. The assessment carried out by media experts consists of aspects of interface design, interactivity, visual display, AR technology stability, integration with other media, and digital format consistency. The results of the assessment by media experts, both lecturers and teachers, in the first validation are shown in Table 1 below.

Table 2. Results of Media Expert Assessment in Validation I

Aspect	Total Score			Maximum Score	Category
	Lecturer	Teacher	Average		
User Interface Design	14	15	14.5	15	96
Interactivity	6	9	7.5	10	75
Visual Display	15	14	14.5	15	96
AR Technology Stability	5	8	6.5	10	65
Integration with other media	9	9	9	10	90
Digital Format Consistency	18	20	19	20	95

Based on the findings from the initial validation phase conducted by media experts, the Augmented Reality (AR)-based educational material that was created in general has met the feasibility requirements. This is indicated by the scores obtained in each assessment aspect, which are in the feasible to highly feasible categories. However, the validation results also show that not all aspects have reached the optimal level in the early stages of development, so improvements are still needed before the media can be used more widely.

The aspects of interactivity and AR technology stability were the two aspects that received the lowest scores in the first stage of validation, each with a score of 75% in the feasible category. In terms of interactivity, media experts assessed that the media enabled interaction between users and learning content, but the variety of interactions and feedback provided to users could still be improved. Meanwhile, in terms of AR technology stability, although AR objects could be displayed well, there were still certain conditions where the stability of the display and system response were not yet fully consistent.

Based on these findings, the aspects of interactivity and AR technology stability were made the main focus of improvement in the revision stage before final validation (Willis, 1994). Improvements were made to enhance the quality of the students' learning experience, particularly in creating more responsive interactions and ensuring the stability of AR display in various conditions of use. With revisions made to these two aspects, it is hoped that the learning media developed can achieve a more optimal level of feasibility in the next validation stage.

Table 3 below shows the findings of the second validation evaluation by media experts, including instructors and lecturers.

Table 3. Media Expert Assessment Results

Aspect	Total Score			Maximum Score	Category
	Lecturer	Teacher	Average		
User Interface Design	14	15	14.5	15	96
Interactivity	8	9	8.5	10	85
Visual Display	15	14	14.5	15	96
AR Technology Stability	8	9	8.5	10	85
Integration with other media	9	92	9	10	90
Digital format consistency	18	20	19	20	95

Based on assessments by two media experts, the average results for the Interface Design aspect were 96%, Interactivity 85%, Visual Display 96%, AR Technology Stability 85%, Integration with Other Media 90%, and Digital Format Consistency 95%, with the criteria "highly valid/highly feasible". The media validation sheet calculations can be seen in the appendix on Page.

Material Expert Assessment of *AR (Augmented Reality)* E-LKPD containing local wisdom

The material assessment was carried out by teachers and Widyaswara KGTK Riau Islands who have the ability and experience in physics learning. The assessment carried out by material experts consisted of learning and material aspects. The results of the assessment by material experts, both Widyaswara KGTK Riau Islands and teachers in the first validation, are shown in Table 3 below:

Table 4. Results of Material Assessment

Aspect	Total Score			Maximum Score	Category
	KGTK Kepri Lecturer	Teacher	Average		
Curriculum Alignment	12	14	13	15	86
Scientific Concept Accuracy	7	8	7.5	10	75
Completeness of Materials	13	13	13	13	100
Integration of local wisdom	25	25	25	25	100
Language and readability	10	10	10	10	100

Based on the results of the first stage of validation conducted by subject matter experts, in general, the learning materials presented in the Augmented Reality (AR)-based E-LKPD have met the eligibility criteria. This can be seen from most of the assessment aspects that received a rating of acceptable to highly acceptable. The aspects of material completeness, integration of local wisdom, and language and readability each received a score of 100%, indicating that the material has been systematically organised, contextualised, and is easy for students to understand.

However, the validation results also show that there are aspects that still require further attention, namely suitability with the curriculum and scientific concept accuracy. The aspect of suitability with the curriculum received a score of 86% in the feasible category, indicating that the material is generally in line with basic competencies and learning outcomes, but still requires minor adjustments in terms of depth or sequence of material presentation. Meanwhile, the scientific concept accuracy aspect received the lowest percentage of 75%, indicating the need for improvement in the clarity of concept explanations, the accuracy of physics terms, and the strengthening of the relationship between the concept of evaporation and the principles of thermodynamics.

Based on these findings, the accuracy of scientific concepts and alignment with the curriculum were made the main focus of improvements in the revision stage prior to final validation. Revisions were made to ensure that the material presented was not only visually and contextually appealing, but also scientifically accurate and fully aligned with the curriculum requirements. With improvements made in these aspects, it is hoped that the

quality of learning materials in AR-based E-LKPD can be comprehensively improved and support the optimal achievement of students' conceptual understanding.

The results of the assessment by subject matter experts, both Widyaswara KGTK Riau Islands and teachers in validation II, are shown in Table 4 below.

Table 5. Results of the Second Validation Expert Assessment

Aspect	Total Score		Average	Maximum Score	Category
	KGTK Kepri Lecturer	Teacher			
Curriculum Alignment	14	151	14.5	15	96
Scientific Concept Accuracy	9	10	9.5	10	95
Completeness of Materials	13	13	13	13	100
Integration of Local Wisdom	251	25	25	25	100
Language and Readability	10	10	10	10	100

Based on the assessment by two subject matter experts, the average results for the aspects of Curriculum Alignment were 96%, Scientific Concept Accuracy 95%, Material Completeness 100%, Local Wisdom Integration 100%, and Language and Readability 100% with the criteria "highly valid/highly feasible". The material validation sheet calculations can be seen in the appendix on Page.

Product Validation Results by Experts

The E-LKPD *AR (Augmented Reality)* containing local wisdom that has been developed was validated theoretically by validators consisting of 2 material experts and 2 media experts. The results of the validation and assessment of the E-LKPD *AR (Augmented Reality)* containing local wisdom are explained as follows:

Media Expert Assessment of E-LKPD *AR (Augmented Reality)* with Local Wisdom Content

Media assessment has been carried out by teachers and lecturers who have the ability and experience in developing learning media. The assessment carried out by media experts consists of aspects of interface design, interactivity, visual display, AR technology stability, integration with other media, and digital format consistency. The results of the assessment by media experts, both lecturers and teachers, are shown in Table 5 below.

Table 6. Media Expert Assessment Results

Aspect	Total score			Maximum Score	Category
	Lecturer	Teacher	Average		
User Interface Design	14	15	14.5	15	96
Interactivity	8	9	8.5	10	85
Visual Display	15	14	14.5	15	96
AR Technology Stability	8	9	8.5	10	85
Integration with other media	9	9	9	10	90
Digital Format Consistency	18	20	19	20	95

Based on assessments by two media experts, the average results for the Interface Design aspect were 96%, Interactivity 85%, Visual Display 96%, AR Technology Stability 85%, Integration with Other Media 90%, and Digital Format Consistency 95%, with the criteria "highly valid/highly feasible". The media validation sheet calculations can be seen in the appendix on Page.

Material Expert Assessment of *AR (Augmented Reality)* E-LKPD containing Local Wisdom

The material assessment was conducted by teachers and lecturers who have the ability and experience in physics education. The assessment conducted by material experts consisted of learning and material aspects. The results of the assessment by material experts, both lecturers and teachers, are shown in Table 6 below.

Table 7. Results of Material Assessment

Aspect	Total Score			Maximum Score	Category
	KGTK Kepri Lecturer	Teacher	Average		
Curriculum Alignment	14	15	14.5	15	96
Scientific concept accuracy	9	10	9.5	10	95%
Completeness of Materials	13	13	13	13	100
Integration of Local Wisdom	25	25	25	25	100
Language and Readability	10	10	10	10	100

Based on the assessment by two subject matter experts, the average results for the aspects of Curriculum Alignment were 96%, Scientific Concept Accuracy 95%, Material Completeness 100%, Local Wisdom Integration 100%, and Language and Readability 100% with the criteria "highly valid/highly feasible". The material validation sheet calculations can be seen in the appendix on Page.

E. Conclusion

This study aimed to develop and determine the validity of an Augmented Reality (AR)-based electronic student worksheet (E-LKPD) integrated with local wisdom on thermodynamics, particularly the evaporation topic for grade XI high school students. The development process followed the ADDIE model, focusing on the development and evaluation stages through expert validation. The validation results from media experts and subject matter experts indicate that the developed E-LKPD achieved a high validity level, meaning that the product is appropriate for use as a learning medium in physics instruction. The validation process also provided constructive feedback that contributed to improving several aspects of the product, including visual design, menu structure, and user experience. After revisions, the E-LKPD interface was enhanced with more contextual visual elements reflecting the coastal environment of Bintan, as well as a more structured navigation system consisting of learning objectives, achievement indicators, AR-based evaporation exploration, discussion questions, reflections, character values, and evaluation components.

The integration of Augmented Reality technology with local wisdom content provides an innovative approach to presenting abstract thermodynamics concepts in a more interactive and contextual manner. Therefore, the developed AR-based E-LKPD has the potential to support more engaging and meaningful physics learning experiences for students. Future studies are recommended to conduct implementation and effectiveness testing in classroom settings to examine the impact of this learning media on students' conceptual understanding and learning outcomes.

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