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DEVELOPMENT OF GAS KINETIC THEORY LEARNING TOOLS: 5E & BRICK MAKING FOR COMPUTATIONAL THINKING

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Abstract :
This research aims to (1) develop feasible learning tools for the kinetic theory of gases and (2) create effective physics learning tools for students. The research employs the ADDIE model. The data analysis to evaluate the feasibility and practicality of the learning tools uses a standard scale, while the validity of the question instrument is assessed using Aiken's V and item analysis with the Partial Credit Model (PCM). To measure the effectiveness of the tools in enhancing students' computational thinking skills, a repeated-measures MANOVA is conducted using the General Linear Model (GLM) with a significance level of 0.05. The findings indicate that (1) the developed learning tools are deemed feasible for use in improving computational thinking skills, as assessed by media experts, material experts, and practitioners. Moreover, (2) the analysis shows a significance value of 0.000 < 0.05, meaning there is a noticeable difference in computational thinking abilities between the experimental and control groups. Additionally, the effect size obtained was 0.813, which is categorized as large. These results suggest that the learning tools developed are both feasible and effective. In conclusion, this research demonstrates the potential of these tools to enhance students' computational thinking abilities in physics education, specifically in the context of the kinetic theory of gases, making them a valuable resource for future learning activities.

Keywords: Computational Thinking, Learning Cycle 5E, Learning Tools

INTRODUCTION

The main purpose of education is to prepare learners to contribute effectively to the world of work and social life, which is one of the biggest challenges of the 21st century. Facing this era, education should focus on developing 21st-century skills. This is necessary so that students are not only able to adapt to rapid changes but also become agents of change who can provide innovative solutions to global problems (Arafat et al., 2024; Priyohutomo, 2025). The Partnership for 21st Century Learning (P21) has formulated a framework that emphasizes the development of 6C skills in learners, namely creativity and innovation, critical thinking and problem solving, communication, collaboration, character, and citizenship (Kereluik et al., 2013; Kirbas & Bulut, 2024). Rapid technological development, globalization, and changing social and economic dynamics have created a new landscape that demands rapid adaptation of the education system (Isma et al., 2023). Given that digital technology is essential to supporting 21st-century skills, integrating technology through innovative learning is crucial.

According to the Decree of the Ministry of Education, Culture, Research, and Technology Number 56 of 2022, the government advocates the implementation of the Independent Curriculum. The independent curriculum emphasizes a student-centered learning approach and the integration of technology in learning, by the demands of the digital era (Bonfiglio-Pavisich, 2018). However, the implementation of the Merdeka Curriculum is not free from challenges. One of them is the readiness of teachers to adopt new learning approaches and utilize technology effectively (Kereluik et al., 2013; Kirbas & Bulut, 2024). In addition, the teacher-centered learning culture that is still strong in Indonesian schools needs to be changed so that the Merdeka Curriculum can be implemented optimally (Kusmahardhika et al., 2023). One way to realize this is to implement learning tools that are in line with the times (Haynes et al., 2024; Sugiyanto et al., 2024). Thus, innovation in learning tools is a crucial factor in achieving national education goals optimally.

Over the past two decades, academics and educational practitioners have increasingly recognized the importance of developing two skills: computational thinking and compassion. The increasing need for skills relevant to 21st-century competencies has triggered this (Çelik & Bati, 2025; Guggemos, 2023). The ability to think computationally is one way to optimize the learning process, especially concerning physics fields of study (Fayanto et al., 2024; Herlina et al., 2025). Therefore, it is expected that students can master both skills, including the basics of computational thinking.

Computational thinking is an important skill to support global competition. According to (Richardo et al., 2025), Computational thinking is an ability that includes decomposition, pattern identification, abstraction, and algorithmic thinking. This ability is considered important because it can help students to develop creative ideas, express themselves in new ways, and understand the evolving world with a more critical way of thinking (Çelik & Bati, 2025; Gunawan et al., 2025; Yadav & Berthelsen, 2022). The computational thinking process is essential to develop understanding and a coherent train of thought from the initial to the final stages of a process (Chen et al., 2023). Therefore, the ability to think computationally is very important for students to own, especially in physics learning, where many experimental activities involve several stages from beginning to end.

Preliminary research conducted in several senior high schools using a scale indicates that high school students' computational thinking abilities are predominantly in the low category, at 29.05%. The primary factors contributing to this low level of computational thinking skills include learning activities that do not incorporate computational thinking and a lack of practice problems designed to foster these skills. This finding aligns with the research by Chen et al., (2023) highlights that insufficient learning tools are a key factor in low computational thinking skills. Additionally, Muliyati et al., (2022) It suggests that a student worksheet designed to enhance computational thinking skills in physics is necessary. Consequently, teachers must understand how to develop learning tools that support the improvement of computational thinking skills.

The Regulation of the Minister of Education and Culture No. 16 of 2022 emphasizes the importance of using a scientific approach in the learning process, with one key method being research-based inquiry learning. The 5E learning cycle, which consists of five interconnected stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation, represents one such model in inquiry learning (Djadir et al., 2021). Moreover, the focus on regional potential is a central component in education content standards. One aspect of this is the integration of local materials that reflect regional characteristics in the curriculum, which is also aligned with the Pancasila student profile in the independent curriculum (Madrin & Ratnawati, 2024). This approach aims to cultivate a capable, character-driven generation and foster the development of 6C skills, making learning more engaging and meaningful for students. However, while the urgency of the scientific approach, the richness of local wisdom, and the need for 21st-century skills such as computational thinking are increasingly recognized, no teaching tools currently comprehensively integrate the 5E learning cycle, local wisdom, and computational thinking. This gap creates challenges in holistically optimizing students' learning potential and making it relevant to the demands of the times.

One of Indonesia's local wisdom is bricks. Bricks are among the cultural heritage owned by the Indonesian people since before the emergence of the Majapahit Kingdom. Bricks were the primary building material for structures during the Majapahit period, including kedaton, puri, candi, pura, bale, and other sacred sites. The process of making bricks, from mixing raw materials to molding, drying, and burning, involves several physical concepts, such as temperature, heat, and thermodynamics, as well as the gas kinetic theory of sub-materials (Lumantarna et al., 2017; Nuroso et al., 2018). The concept of gas kinetic theory is evident in the brick-making process, namely when bricks are dried, where the drying temperature is held constant, which corresponds to Boyle's law.

The application of local potential-based approaches in learning Physics is not only applied in Indonesia, but also in Nigeria, which has adopted it. Another study conducted in high schools in Enugu State Education Zone, Nigeria, showed that the use of local potential-based learning tools can improve students' physics learning outcomes (Widyaningtyas et al., 2024). Based on these needs, the development of teaching tools is needed as a guideline to achieve graduate competencies, content standards, and process standards that have been set. Teaching tools vary in their properties, including learning content, methods, interpretation, and evaluation techniques, and are arranged systematically and creatively to achieve learning objectives. The novelty of this research lies in integrating the local wisdom of the brick-making process with the 5E learning cycle model into the learning tools. It is hoped that the development of learning devices based on the 5E learning cycle integrated with the brick-making process can improve computational thinking skills. The purpose of this research is to develop a learning tool for gas kinetic theory integrated with the brick-making process, using the 5E learning cycle model, that is feasible, practical, and effective for improving computational thinking skills.

RESEARCH METHOD

Research Design

This research is a Research and Development (R&D) study using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) as proposed by Branch, (2009). The ADDIE model was selected for its widespread recognition and strong recommendation for developing educational tools. The product development stages followed the ADDIE process in sequence, as illustrated in Figure 1.

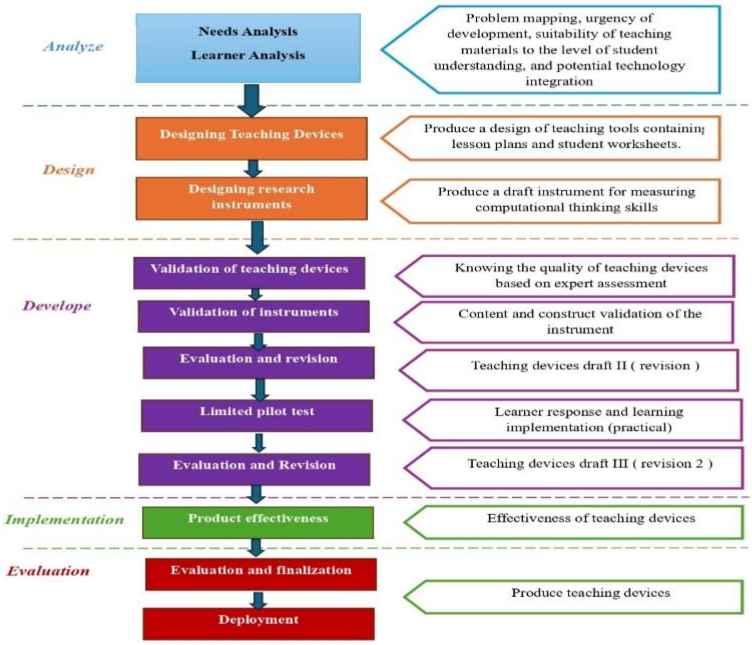

Figure 1. Product development flow

The experimental design used was a quasi-experiment with a nonequivalent control group design. A more detailed design can be seen in Table 1.

Table 1. Field trial experiment design

Group	Y_1			Y_2		
	Pretest	Treatment	Posttest	Pretest	Treatment	Posttest
Experiment	O_1	X_1	O_2	O_1	X_1	O_2
Control	O_1	X_3	O_2	O_1	X_3	O_2

Table 1 provides the structure of the field trial experiment, showing that both the experimental and control groups underwent a pretest, received different treatments, and completed a posttest in two parallel measurement sets.

Time and Place of Research

The subjects of this study were media experts, material experts, and students of class XI-1 IPA at SMA Negeri 1 Ende. The object of this study was the development of flipbooks as a physics learning aid, especially for vector

Research Target/Subject

The target of this research is to improve computational thinking skills through learning tools integrated with local wisdom. Then, the target group in the research is XI-grade students at SMA Negeri 1 Piyungan in the even semester.

Subjects in the feasibility trial consisted of one content expert, one media expert, and five educators who teach the subject. Subjects for the empirical trial consisted of XII-grade students with a Physics specialization from three schools in Yogyakarta, sorted into high, middle, and low grades. Then, a limited trial was conducted in class XI specialization in Physics, comprising one class. The subjects in the field trial were odd semester XI-grade students from 3 classes.

Research Procedure

In this field trial, the experimental design was a quasi-experiment with a nonequivalent control group design. A more detailed design can be seen in Table 1.

In the experimental class, students received treatment with the developed learning tools—specifically, gas-kinetic theory materials designed using the 5E learning cycle model and integrated with local wisdom from the brick-making process. Meanwhile, the control class used conventional learning tools that did not incorporate elements of local wisdom.

Instruments and Data Collection Techniques

Data collection was carried out through both test and non-test methods. The test method involved a set of questions to assess students' computational thinking abilities. The non-test methods included observation sheets and interview guidelines for preliminary analysis, validation instruments from content and media experts, teacher evaluation sheets for the learning tools, and student questionnaires to measure practicality.

Analysis of product feasibility using computational thinking instrument validation data, conducted by testing content validity and empirical validity. The instrument feasibility validation sheet uses four interval scales and includes feasibility based on material and media aspects. Furthermore, the conversion from ordinal to interval data was performed using the method of successive intervals (MSI). The conversion results can then be analyzed using the SBi scale, as shown in Table 2.

Table 2. Feasibility assessment guidelines

No	Score Range	Category
1.	$X \geq \bar{X}_i + 1{,}5\ SBi$	Very Feasible
2.	$\bar{X}_i < X \leq \bar{X}_i + 1{,}5\ SBi$	Feasible
3.	$\bar{X}_i - 1{,}5\ SBi < x \leq \bar{X}_i$	Not Feasible
4.	$X \leq \bar{X}_i - 1{,}5\ SBi$	Very Unfeasible

The feasibility of the question instrument based on expert judgment is carried out through the following Aiken's V test:

$$v = \sum \frac{s}{[n(c-1)]}$$

Then compare the value obtained with the value in Aiken's V table for the number of raters in the study (six people) and the number of rating scales (four categories). The product eligibility table according to Aiken's V (Aiken, 1985) is as follows:

Table 3. Product feasibility criteria

No.	Score Range	Category
1.	$0,8 < V \leq 1$	Very Feasible
2.	$0,6 < V \leq 0,8$	Feasible
3.	$0,4 < V \leq 0,6$	Not Feasible
4.	$0,2 < V \leq 0,4$	Very Unfeasible

Item analysis was carried out to assess three aspects: (1) item fit, (2) reliability, and (3) level of difficulty. The feasibility of the question instrument was tested empirically in three separate schools, involving a total of 108 respondents, to analyze the quality and characteristics of the items. An item is considered valid if it meets the INFIT mean square (INFIT MNSQ) criteria, which must fall within the range of 0.77 to 1.30, as shown in Table 4.

Table 4. INFIT MNSQ value parameters

INFIT MNSQ Value	Parameter	Fit Level
$> 1,30$	Invalid	Not Suitable
$0,77 - 1,30$	Valid	Fit
$< 0,77$	Invalid	Not Suitable

In addition to the validity test, a reliability test was also conducted. Reliability describes the extent to which the instrument is consistent when used in data collection. A measuring instrument is considered reliable if it consistently produces the same results when measuring the same quantity at different times. Good reliability is categorized if it has a value above 0.70 (Gliem & Gliem, 2003). The reliability value can be found in the Summary of Item Estimates section, under the Reliability of Estimate subsection. The level of item reliability is shown in Table 5.

Table 5. Interpretation of the level of reliability of items

Reliability Coefficient	Reliability Category
$R \geq 0,80$	Highly Reliable
$0,60 < R \leq 0,80$	Reliable
$0,40 < R \leq 0,60$	Moderately Reliable
$0,20 < R \leq 0,40$	Somewhat Reliable
$R \leq 0,20$	Less Reliable

Table 5 presents the categories of item reliability based on the reliability coefficient. An instrument is considered highly reliable if its coefficient is ≥0.80. Values between 0.60 and 0.80 are categorized as reliable, while coefficients ranging from 0.40 to 0.60 are classified as moderately reliable. Coefficients between 0.20–0.40 indicate somewhat reliable items, and values ≤0.20 reflect less reliable items.

Data Analysis Technique

Improvement in computational thinking skills was assessed using pretest and posttest scores. The pretest and posttest results were expressed as standardized gain. The standardized gain value can be calculated using the following equation:

$$g = \frac{\bar{x}_{posttest} - \bar{x}_{pretest}}{x - x_{pretest}}, \quad (2)$$

The standardized gain value can be interpreted using Table 6 to classify the level of improvement in students' computational thinking skills.

Table 6. N-Gain value category

N-Gain Value	Category
$g \geq 0{,}70$	High
$0{,}70 > g \geq 0{,}30$	Medium
$g < 0{,}30$	Low

The effectiveness of the product was assessed through a descriptive analysis of pretest and posttest data on computational thinking skills. Subsequently, a General Linear Model (GLM) statistical test was performed using a Multivariate Analysis of Variance (MANOVA). Prior to the statistical testing, prerequisite tests were conducted to ensure the data met the assumptions of normality and homogeneity (Freund & Wilson, 2003). The normality test was performed using the Shapiro-Wilk test, where a significance value greater than 0.05 indicates that the data is normally distributed. The homogeneity test was conducted using Box's M test to assess whether the sample came from a homogeneous population. If the probability value is greater than 0.05, the sample is considered homogeneous.

Once the prerequisite tests were satisfied, the MANOVA test was used to determine if there was a significant difference in computational thinking abilities between the experimental and control groups. The decision was based on the Hotelling Trace output, where a higher value indicates greater media influence. The null and alternative hypotheses are as follows:

Ho : There is no significant difference between the computational thinking skills of students in the experimental and control classes.

Ha : There is a significant difference in the computational thinking ability between students in the experimental class and those in the control class.

The results obtained from the Hotelling Trace are then compared with the formulated hypothesis. If the sig value. <0.05 then Ho is rejected, and Ha is accepted.

Effect size is used to determine how much the effectiveness (influence) of the learning device for gas kinetic theory, based on the 5E learning cycle, is integrated with the local wisdom of the brick-making process to improve computational thinking skills. Effect size is determined by multivariate analysis on the general linear model (GLM). Effect size is obtained based on the calculation of Cohen's f value from the results of the partial eta square value at the GLM output, with the equation:

$$ES = \sqrt{\frac{\eta^2}{1-\eta^2}},$$

Then the effect size (ES) value obtained can be interpreted in several categories, as in Table 7 (Cohen, 1988).

Table 7. Effect size interpretation

Effect Size (ES)	Interpretation
$0{,}00 \leq ES < 0{,}20$	Ignored
$0{,}20 \leq ES < 0{,}50$	Small
$0{,}50 \leq ES < 0{,}80$	Moderate
$0{,}80 \leq ES < 1{,}30$	Large
$1{,}30 \leq ES$	Very Large

Table 7 outlines the interpretation of effect size values. Effect sizes below 0.20 are considered ignored, while values from 0.20 to 0.50 indicate a small effect. Effect sizes between 0.50 and 0.80 are categorized as moderate, and those between 0.80 and 1.30 are categorized as large. Effect sizes of 1.30 or higher are classified as very large.

RESULTS AND DISCUSSION

This study addresses two research questions: (1) What is the feasibility of the learning tools? (2) How effective are the learning modules in improving computational thinking skills? The results related to the first question are summarized in Tables 8, 9, 10, and 11. These tables present the findings from the assessment of the product's feasibility, including teaching modules, student worksheets, and assessment instruments designed to assess computational thinking skills.

Table 8. Results of the feasibility assessment of teaching modules

No	Aspects	Component Values	Description
1	Completeness of teaching module identity	93,60	Very Good
2	Suitability of learning indicators with the material to achieve computational thinking skills	90,32	Very Good
3	Appropriateness of material to school level, grade, and computational thinking skills	95,47	Very Good
4	Appropriateness of model selection and learning scenarios	89,14	Very Good
5	Accuracy of language use	89,93	Very Good
	Mean Score	91,70	Very Good

Table 8 presents the results of the SBi scale analysis, with interpretation based on Table 2. According to the analysis in Table 8, all assessed aspects received excellent scores, with an average score of 91.70 (very good). In other words, the teaching module developed based on the SBi analysis is highly suitable for use in the learning process of gas kinetic theory. This evaluation indicates that the teaching module meets several essential criteria for supporting effective and efficient learning.

Table 9. Student worksheet feasibility assessment results

No	Aspects	Assessment results	Criteria
Material			
1	Completeness of content	95,17	Very Good
2	Suitability of the material with local wisdom	89,07	Very Good
Media			
4	Linguistics	97,31	Very Good
5	Applicability	96,66	Very Good
6	Design	90,94	Very Good
7	Visual appearance	89,78	Very Good

Table 9 presents the results of the feasibility assessment of the student worksheets, which are evaluated across several aspects, divided into two main categories: material and media. According to the validators' assessment of both the material and media aspects, all received ratings in the very good category. These results suggest that the student worksheets are of high quality in both content and presentation, making them suitable for use in the learning process.

Table 10. Feasibility Assessment Results of Computational Thinking Question Instrument

No	Question Item Number	V Aiken's	Description
1	1	1	Valid
2	2	1	Valid
3	3	0,93	Valid
4	4	1	Valid
5	5	1	Valid
6	6	1	Valid
7	7	1	Valid
8	8	1	Valid
9	9	1	Valid
10	10	1	Valid

The results of the analysis using V Aiken's on the feasibility assessment of the computational thinking instrument by the validator where there are 10 items assessed, with item numbers 1 to 10, the V Aiken's value obtained is in the category range of $0.8 < V \leq 1$, so the interpretation shows that the items to be used are very feasible or very good. Overall, the items in this instrument meet the validity criteria as assessed by the experts and are suitable for measuring students' computational thinking skills.

Table 11. Results of the feasibility assessment of the student response questionnaire

No	Statement Item Number	V Aiken’s	Description
1	1	0,92	Valid
2	2	0,92	Valid
3	3	0,92	Valid
4	4	1	Valid
5	5	1	Valid
6	6	0,92	Valid
7	7	1	Valid
8	8	0,92	Valid
9	9	1	Valid
10	10	1	Valid

The analysis of the student response questionnaire, assessed by experts, revealed that all statement items were valid, making the questionnaire suitable for gauging student responses to the learning tools used. The results of the feasibility assessment of the student response questionnaire are presented in Table 11. Based on the feasibility test analysis, experts provided several suggestions, indicating that revisions to the product were necessary.

Following the expert-based feasibility test, an empirical test was conducted to evaluate the validity and reliability of the developed question instrument designed to measure computational thinking skills. The empirical tests were carried out in three schools with varying levels of achievement: high, medium, and low. The tests were conducted with students who had studied the gas kinetic theory material. The results of the empirical test analysis evaluated the quality of the computational thinking test instrument and provided an initial assessment of students' computational thinking abilities. The findings from the empirical test of the computational thinking instrument are shown in Tables 12 and 13:

Table 12. Interpretation of the results of the question item validity

Item	INFIT MNSQ	Criteria	Outfit	Criteria	Difficulty	Criteria	Question Quality
1	1,17	Fit	1,6	Passed Item	-0.80	Medium	Good
2	1,14	Fit	1,4	Passed Item	-0,56	Medium	Good
3	0,85	Fit	-1,8	Passed Item	-0,23	Medium	Good
4	1,10	Fit	0,6	Passed Item	0,35	Medium	Good
5	1,06	Fit	0,2	Passed Item	0,28	Medium	Good
6	0,88	Fit	-1,4	Passed Item	-0,18	Medium	Good
7	0,78	Fit	-2,3	Passed Item	0,69	Medium	Good
8	0,79	Fit	-2,6	Passed Item	0,68	Medium	Good
9	1,20	Fit	2,10	Passed Item	-0,92	Medium	Good
10	1,03	Fit	0,1	Passed Item	0,23	Medium	Good

The analysis results, which aimed to assess the suitability of each test item using item response theory (IRT), indicate that all items are suitable for use as measurement instruments. The difficulty level of all questions falls within the medium range, and the quality of the questions is considered good, as the INFIT MNSQ value is within the 0.77 to 1.30 range. The interpretation of each computational thinking ability test item, compared with the IRT match, is presented in Table 12. To assess the test instrument's consistency, a reliability test was conducted, and the results are shown in Table 13.

Table 13. Reliability Analysis Results of Computational Thinking Ability Questions

Aspects	Summary of Item Estimate	Summary of Case Estimate
Computational thinking skills	0,78	0,73

Based on the analysis, the reliability of the computational thinking skills test is deemed reliable. The reliability value, as shown in the summary of item estimates and case estimates, falls within the range of 0.6 to 0.8, as presented in Table 13. Therefore, based on Tables 12 and 13, it can be concluded that the computational thinking test items are both valid and reliable, making them suitable for measuring improvements in students' computational thinking skills.

Prior to the field test, a limited trial was conducted to use its results to improve the product before proceeding to the field trial stage, enhancing the product's overall quality. The results of the readability analysis from the limited trial are presented in Table 14:

Table 14. Readability Results of Student Worksheet Learning Devices

Aspects	Mean	Presentage	Category
Applicability	3,30	82,55%	Very Good
Completeness of content	3,16	85,94%	Very Good
Material	3,15	83,59%	Very Good
Design	3,29	82,29%	Very Good
Visual appearance	3,16	82,93%	Very Good

Based on Table 14, the readability test conducted in one school with 36 students yielded very good results, with percentages above 80% for all aspects analyzed. Based on the readability test, there were some suggestions and feedback on the product in the form of learning tools. The suggestions and feedback relate to the use of words that are still wrong, so it is necessary to make improvements (revisions) to product II.

After revising product II based on the limited test, the field trial was conducted. The field trial produced data on students' responses to the developed learning tools, as well as on improvements in computational thinking skills, in the form of pretest and posttest data. The following is the data on student response results obtained after students have learning for three meetings. These results are shown in Table 15.

Table 15. Results of Student Response to Student Worksheets

No	Aspects	Mean Response	Category
1	Applicability	3,58	Very Good
2	Completeness of content	3,40	Very Good
3	Material	3,33	Very Good
4	Design	3,59	Very Good
5	Visual appearance	3,67	Very Good
	Mean	3,51	Very Good

The learning tools (student worksheets) received very positive feedback from students. The highest response was in the visual display aspect, as the images, text, and videos on the worksheets were revised based on expert suggestions, ensuring that they are clearly readable on both smartphones and laptops. The lowest response was in the material aspect, where the use of some inappropriate terms or language made it difficult for students to understand. This section requires improvements to enhance the clarity of the student worksheets for better use in learning.

In the field test, the results of the pretest and posttest on computational thinking skills, along with the standardized gain (improvement) values, are shown in Table 16.

Table 16. Pretest Posttest Results of Computational Thinking Skills

No	Class	Total students	Pretest Mean	Posttest Mean	N-Gain Mean	Category
1	Experiment	36	35,67	85,83	0,78	High
2	Control	36	32,93	71,12	0,63	Medium

The results above indicate that the experimental class's improvement in computational thinking skills is in the high category, whereas the control class falls into the medium category. The impact of using 5E learning cycle-based learning tools, integrated with the local wisdom of the brick-making process, on the improvement of computational thinking skills was analyzed using a MANOVA test.

Prior to the MANOVA test, prerequisite tests for normality and homogeneity were conducted, as shown in Tables 17 and 18.

Table 17. Normality Test Results

Class	Skills	Shapiro-Wilk		
		Statistic	df	Sig.
Experiment	Pretest computational thinking skills	0,144	36	0,074
	Posttest computational thinking skills	0,153	36	0,061
Control	Pretest computational thinking skills	0,152	36	0,209
	Posttest computational thinking skills	0,156	36	0,189

The results of the normality test in Table 17 indicate that all data have a significance level greater than 0.05, meaning that the data from the population are normally distributed. In addition to the normality test, a homogeneity test was also performed, as shown in Table 18.

Table 18. Homogeneity Test Results

Box's Test of Equality of Covariance Matrices	
Box's M	4,013
F	1,297
Df1	3
Df2	691008,000
Sig.	0,185

Based on Table 18, the homogeneity test results show a Box's M value of 4.013, an F test statistic of 1.297, degrees of freedom 1 (df1) = 3 and 2 (df2) = 69,000, and a significance value (.sig) of 0.185. Since the significance value is greater than 0.05, it can be concluded that there is no significant difference in variance between the experimental and control class samples, indicating that the data are homogeneous.

After the prerequisite tests were met, the MANOVA test was conducted. The results of the MANOVA test indicate that (1) there is a difference in the average improvement of computational thinking skills between the experimental and control classes, as shown in Table 19.

Table 19. MANOVA test results

Effect (Class)	Value	Sig.
Hotelling's Trace	0,318	0,000

Based on the MANOVA test results in Table 19, Hotelling's Trace significance value is 0.000. Since 0.000 is less than 0.05, the null hypothesis (Ho) is rejected, and the alternative hypothesis (Ha) is accepted. Therefore, there is a significant difference in the average improvement in computational thinking skills between the experimental and control classes.

The second MANOVA test results (2) show that the learning tool for gas kinetic theory, based on the 5E learning cycle and integrated with the brick-making process, is effective in enhancing computational thinking skills, as indicated by the effect size analysis in Table 20.

Table 20. Effect size analysis results

Aspects	Eta Square	ES	Category
Computational thinking	0,398	0,813	Large

Table 20 displays the effective contribution of the research variables. The effective contribution is shown in the Eta Square column, which indicates a value of 0.398, corresponding to an effect size of 0.813 (Large Effect Size). Based on these results, it can be concluded that the learning tool for gas kinetic theory, grounded in the 5E learning cycle and integrated with the local wisdom of the brick-making process, is highly effective in improving computational thinking skills, with a significant impact.

The learning tool for gas kinetic theory, based on the 5E learning cycle and integrated with the local wisdom of the brick-making process to enhance computational thinking, was developed using the ADDIE (Analyze, Design, Develop, Implement, and Evaluate) model. During the analysis phase, issues encountered in the learning process were identified through interviews with physics teachers, student questionnaires, and observations. The findings from this stage formed the foundation for designing learning tools that meet students' needs. After understanding the students' actual conditions, the initial design of the learning tools was created. The design phase aimed to develop the initial concept for the learning tools. The results from the design phase, which included the teaching modules, student worksheets, and computational thinking question instruments, were reviewed by validators. In the development phase, validators conducted theoretical validation to assess the product's feasibility. Once the product was revised based on expert feedback, it was implemented in schools. This implementation aimed to evaluate the effectiveness of the developed product. The final phase is evaluation, which focuses on both the feasibility and effectiveness of the learning tools. The evaluation not only assesses the level of effectiveness but also provides insights for further improvement. This analysis is expected to offer valuable information for future educational developments.

The analysis of learning devices for gas kinetic theory, based on the 5E learning cycle integrated with the local wisdom of the brick-making process, consists of a feasibility test and an effectiveness test. product feasibility is reviewed from the results of expert and practitioner assessments and student responses to the developed learning devices. Overall, the feasibility of learning devices is assessed from media and material perspectives. The results of the analysis show that the learning device for gas kinetic theory, based on the 5E learning cycle and integrated with local wisdom in the brick-making process, is feasible for learning and meets very good criteria in terms of media and materials, as well as student responses.

In addition to the feasibility analysis, the product's effectiveness was also assessed. The effectiveness of the product is supported by the field trial, which used the learning device for gas kinetic theory, based on the 5E learning cycle, integrated with the local wisdom of the brick-making process, in one experimental class. Then compare the improvement in computational thinking ability with that of the control class, whose learning uses tools that are not integrated with the local wisdom of the brick-making process. Improvement in these abilities can be seen in the pretest and posttest scores of students in the experimental and control classes.

The pretest and posttest scores were analyzed using MANOVA. The MANOVA test results for Hotelling's Trace showed a significance value of 0.000, which is less than 0.05, indicating a significant difference in the average improvement of computational thinking skills between the experimental and control classes. The improvement in computational thinking skills is illustrated in Figure 2.

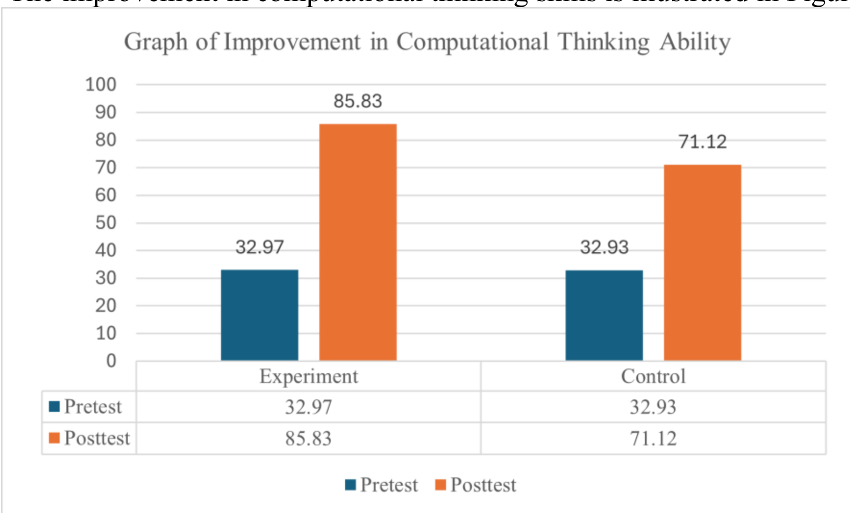

Figure 2. Graph of improvement in computational thinking ability

Figure 2 illustrates a significant improvement in computational thinking skills in the experimental class, achieving a high category. These findings align with the research, which suggests that learning tools, such as teaching modules, student worksheets, and question instruments, are effective in enhancing students' computational thinking abilities (Herlina et al., 2025; Muliyati et al., 2022; Munawarah et al., 2021; Lapawi & Husnin, 2020). Furthermore, Figure 2 shows a clear difference in the improvement of computational thinking skills between the experimental and control classes. The experimental class, which used 5E learning cycle-based tools integrated with local wisdom, demonstrated greater progress in computational thinking skills compared to the control class, which used tools not integrated with local wisdom. One factor that may influence this outcome is the specific characteristics of the learning tools used.

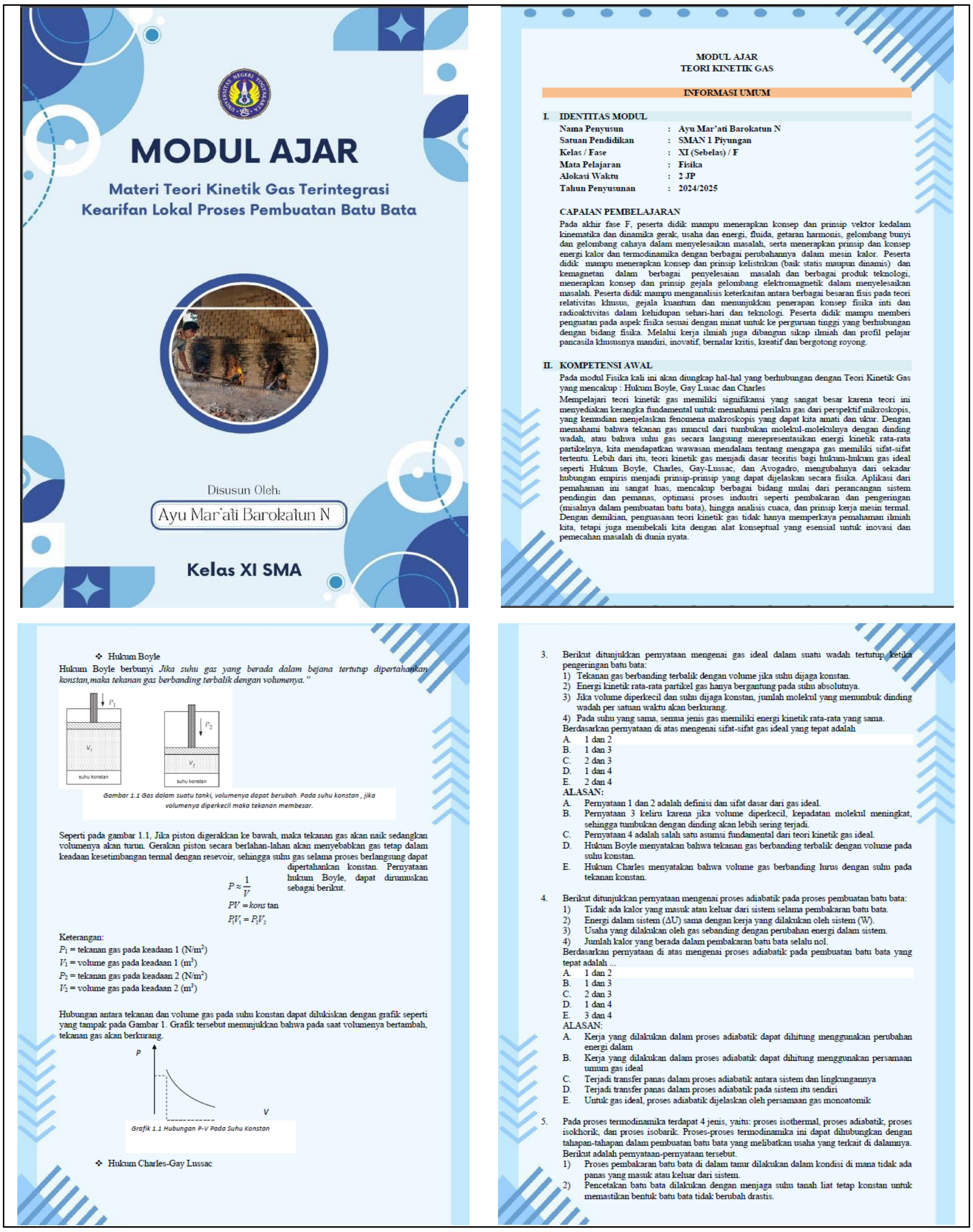

Figure 3. Product development results image

Figure 3 illustrates the results of the product development process. The learning tools, which integrate the 5E learning cycle with local wisdom, make classroom activities more contextual and help students better understand the concepts being taught (Annisah et al., 2025; Lubis et al., 2022; Pangsuma et al., 2024). These tools also enable students to apply their skills in problem-solving (Rahmasari & Kuswanto, 2023; Widyaningtyas et al., 2024), which plays a significant role in enhancing computational thinking skills (Richardo et al., 2025). The developed learning tools incorporate indicators of computational thinking skills that encourage students to break down complex problems, identify patterns in data or issues, extract relevant information, and design systematic algorithms to solve problems (Çelik & Bati, 2025; Gunawan et al., 2025). Therefore, the 5E-based learning tool, integrated with the local wisdom of the brick-making process, is highly suitable for improving students' computational thinking abilities.

This study strongly supports and extends previous research highlighting the efficacy of structured learning approaches and contextualized content. While previous studies (Herlina et al., 2025; Muliyati et al., 2022; Munawarah et al., 2021; Lapawi & Husnin, 2020) have shown the effectiveness of various learning tools, our research specifically demonstrates the added value of integrating the 5E learning cycle with local wisdom, providing a unique contribution to the literature on culturally responsive pedagogy in computational thinking education. The findings on problem-solving application (Rahmasari & Kuswanto, 2023; Widyaningtyas et al., 2024) are further substantiated, with our study providing a concrete example of how contextualized learning fosters this skill.

The practical benefits of these findings are substantial. For teachers, this research provides a validated model for developing engaging and effective learning tools that not only enhance computational thinking but also leverage local cultural contexts. Students can benefit from a more relevant and understandable learning experience, leading to deeper comprehension and improved problem-solving skills. For curriculum developers, this study offers a compelling argument for integrating local wisdom into STEM education frameworks, fostering both academic achievement and cultural appreciation. Despite its promising results, this research has certain limitations. The study's scope was limited to specific material related to the brick-making process, which may not be generalizable to all subjects or contexts. The relatively short duration of the intervention might not fully capture long-term impacts on the development of computational thinking. Furthermore, while robust, a quasi-experimental design may inherently have limitations in controlling extraneous variables compared to a proper experimental design.

Future research could investigate the long-term effects of these integrated learning tools on students' computational thinking skills across various grade levels and subject areas. Investigating the transferability of these skills to other problem domains and real-world scenarios would also be valuable. Comparative studies involving different forms of local wisdom integration or alternative learning cycle models could provide further insights. Additionally, a qualitative inquiry into students' perceptions and experiences with these learning tools could offer a deeper understanding of their engagement and learning processes. This research makes a significant scientific contribution by demonstrating the efficacy of a novel learning tool that strategically combines the established 5E learning cycle with culturally relevant local wisdom. It not only reinforces the importance of contextual learning in improving computational thinking but also provides empirical evidence for the synergistic effect of integrating traditional knowledge with modern pedagogical approaches. This study offers a robust model for developing teaching materials that are both academically rigorous and culturally sensitive, thereby enriching the field of educational technology and contributing to the holistic development of students' cognitive abilities.

CONCLUSION

The conclusions drawn from the data analysis and discussion are as follows: (1) A 5E-based learning tool, integrated with the local wisdom of the brick-making process, has been developed and is deemed feasible for use in teaching the gas kinetic theory material in physics. It received excellent ratings from material experts, media experts, practitioners, and student feedback. (2) The 5E-based learning tool integrated with local wisdom is effective in enhancing the computational thinking skills of grade XI students, with a large effect size (ES) of 0.813, which is interpreted as having a substantial impact. This research is limited to developing learning devices for gas-kinetic theory material using the 5E learning cycle model. Recommendations for future research: Develop learning devices for other physics materials using models such as problem-based learning or project-based learning.

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