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DEVELOPMENT OF FLIPBOOK ASSISTED BY AUGMENTED REALITY TO TRAIN STUDENTS' SCIENTIFIC PROCESS SKILL IN THE TOPIC OF REACTION RATE

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Abstract

This study aims to develop a flipbook media assisted by Augmented Reality to train students' science process skills on the material of reaction rates and to determine its feasibility in terms of validity, practicality, and effectiveness. The research is motivated by the low science process skills of students and the difficulty in understanding the abstract concept of reaction rates so that interactive learning media that supports inquiry learning are needed. The study uses the Research and Development (R&D) method with a 4-D model that includes the define, design, and develop stages. A limited trial was conducted on 36 students of grade XI of SMA Sunan Giri Menganti. The research instruments include validation sheets, observations of learning implementation, observations of student activities, response questionnaires, and pretest-posttest tests of science process skills. The results showed that the developed media obtained mode 4 with a valid category. The practicality of the media is shown by positive student responses of 96.9%, student activities during lessons in the first and second sessions is 96.66% and 96.29%, and the implementation of learning with mode 5 is categorized as very good. The effectiveness of the media is demonstrated through the results of the paired sample t-test which obtained a significance value of ≤ 0.05, so there is a difference in students' science process skills before and after using the media. Thus, the flipbook assisted by Augmented Reality declared worthy for use as a learning to train science process skills relating to the topic of reaction rates.
Keywords: flipbook, augmented reality, scientific process skill, reaction rate, guided inquiry learning

INTRODUCTION

Education plays a strategic role in preparing qualified human resources capable of competing in the global era. Education is a conscious and planned effort to create a conducive learning environment so that students can actively develop their potential in terms of noble character and the skills needed for social, national, and state life [1]. Along with the development of technology and information in the Society 5.0 era, the world of education is required to adapt so that the learning process can run optimally [2]. In response to these demands, the Indonesian Ministry of Education and Culture (Kemendikbud-Ristek) introduced a new educational paradigm aligned with 21st-century learning. This paradigm emphasizes creativity, critical thinking, collaboration, communication skills, and character formation [3], embodied through the Merdeka Curriculum designed to create creative, critical students prepared for the challenges of the digital era [4].

In line with the Merdeka Curriculum, the concept of deep learning has emerged as a complementary learning approach that strengthens students' understanding through more profound engagement. Deep learning in the educational context is not a replacement curriculum, but a learning approach that reinforces the Merdeka Curriculum by creating contextual, relevant, and meaningful learning experiences [5]. This approach is grounded in three key principles: mindful learning, meaningful learning, and joyful learning. Deep learning has been proven to improve thinking skills, active participation, and student engagement in the learning process [6]. In chemistry education, applying a deep learning approach becomes particularly relevant because it helps students not only memorize facts, but truly

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understand concepts, connect new ideas with prior knowledge, and apply those concepts to real-world situations [7].

Chemistry as a science subject covers the composition, structure of matter, and energy changes in chemical processes [8]. Its content is organized hierarchically from simple to complex concepts, meaning that if students struggle with foundational concepts, understanding more complex ones becomes increasingly difficult [8]. Furthermore, chemistry concepts are abstract and require extensive mathematical calculations, making the subject less popular among students. The difficulty of understanding chemistry is compounded by the need to simultaneously comprehend three levels of representation: macroscopic (observable phenomena), sub-microscopic (molecular level involving atoms, molecules, and ions), and symbolic (symbols, chemical formulas, and mathematical equations) [9].

These three representations come to play in the study of reaction rates, which requires understanding phenomena at these three levels. Failure to understand one representation at this level will result in conceptual errors and poor learning outcomes. This is especially the case for students who lack sufficient background in the prerequisite concepts such as stoichiometry [10]. Pre-research data collected from thirty-six grade XI students in a private school in Gresik revealed that, although most students found chemistry interesting, 33.33% of the students found concepts of reaction rates difficult and 40% found abstract concepts difficult, while 30% of the students found the explanations easy to understand. In addition, 83.33% of the students found that learning was facilitated by the use of PowerPoint, whiteboard, and textbook, while other methods were not used. The majority of the students 93.33% found learning via technology including Augmented Reality, interesting.

The pre-research also indicated that students exhibited a low level of science process skills (SPS). SPS encompasses a range of skills from basic level skills that include observing, measuring, predicting, classifying, and communicating, to more advanced integrated skills that include problem identification, hypothesis formulation, experimental planning, data interpretation, and conclusion drawing, all of which are cognitive and psychomotor skills [11]. These skills are necessary for success in chemistry and problem solving in daily life [12]. The SPS test administered to the same 36 participants exhibited low mean scores, all below 50%, on the five indicator test scores of observing (42.67%), hypothesis formulation (39.00%), variable control (39.67%), predicting (38.67%), and conclusion drawing (36.67%). Also, 63.33% of participants reported that SPS was not developed enough at school or during chemistry classes, and indicated that their knowledge of scientific skills was mostly developed through social media or the internet and not through a formal educational process.

These results necessitate the development of a learning model that is capable of developing science process skills. Guided Inquiry (GI) blends learning through student formulated questions, investigations of phenomena and evidence based explanations [13]. When compared to direct instruction, Guided Inquiry discusses and explains the scientific process to students and allows them to discover the concepts [14]. The phases of this model address the five target SPS indicators, but this model is most effective when combined with suitable learning media.

Learning media enhances the teaching and learning process [15]. Media helps when defining the meaning of the content that is being taught, and, as a result, helps when achieving the learning objectives [16]. The impact media has when teaching students relies on the quality of learning media and influences learning outcomes [17]. Modern technology based media has introduced flipbooks, which are electronic books showing audio, video, and images in a sequence which can be edited to include animations, making it a more interactive and enjoyable reading experience [18]. It presents the reading in a more interactive way through the combination of animated textual and pictorial information, as well as sound [19]. One significant example of using learning media is its ready accessibility. It can be accessed from anywhere and at anytime by students through a mobile phone [20]. This is a good example of

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aligning the technology learning media has to offer to the technology the students posses.

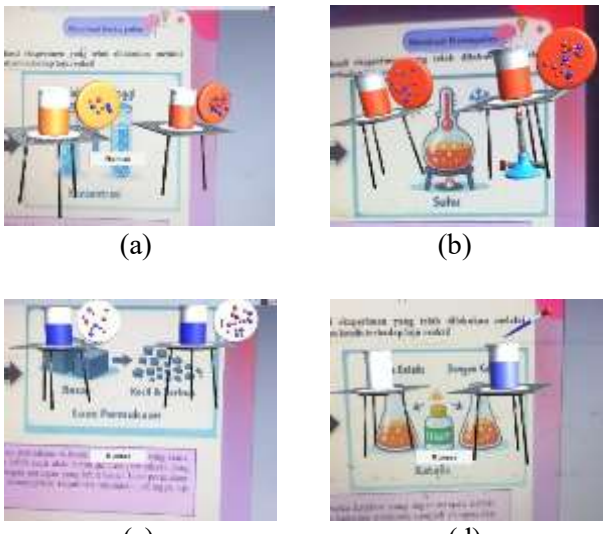
Integrating augmented reality with the flipbook could be an excellent resource to present abstract chemistry ideas to students. AR combines two three-dimensional virtual images with real-world scenes, in real time [21]. In the classroom, AR can aid students by displaying abstract ideas as three-dimensional images that they can see [22]. This technology can boost the energy level of the students and improve their understanding of the subject [23]. A flipbook with AR technology is valuable in teaching the chemical reaction rate, because this concept should be illustrated at the three different levels of chemical theory: macroscopic, submicroscopic, and symbolic. This technology, which is designed for the Android platform, allows students to work independently with their cell phones. Its use in Guided Inquiry offers a way to develop SPS through the structured phases of this model. Based on these ideas, the study designed an AR technology-based flipbook integrated with Guided Inquiry with the goal of developing the science process skills of Grade XI students in the area of reaction rates, in order to solve the problem of low SPS and the level of understanding of the students at a private high school in Gresik.

METHOD

This research used the Research and Development (R&D) method with the 4D model (Define, Design, Develop, Disseminate) [24]. Given the constraints of time, personnel, and funding, research was limited to the Develop step, including expert evaluations, revisions, and some pilot research. This study was conducted at a private high school in Gresik, and the subjects were 36 Grade XI IPA students, as they had already learned about reaction rates and were representative of the target population.

The research was conducted in three phases and used the 4D Model. In the Define Phase, front-end analysis was done using teacher interviews and pre research questionnaires to help identify learning issues and curricular and student needs. Analyze Learners focused on students' cognitive development and academic ability, and the knowledge they bring to the classroom. Analyze Tasks explained the skills learners should possess based on the Merdeka Curriculum's Learning Achievement (CP) and Learning Objective Flow (ATP). Analyze Concepts centered on reaction rate and the SPS framework. This research outlined learning goals, which were included in the flipbook design.

In the Design Phase, the flipbook format was selected and the flipbook was designed and constructed using the tools Canva and Microsoft Word. It consists of one main flipbook and four topic specific sub-flipbooks, one for each factor affecting reaction rate: concentration, temperature, surface area, and catalyst. Each sub-flipbook was structured around the six Guided Inquiry phases: (1) Focusing Attention and Explaining the Inquiry Process, (2) Presenting Inquiry Problems and Phenomena, (3) Formulating Hypotheses, (4) Collecting Data to Test Hypotheses, (5) Formulating Explanations and Conclusions, and (6) Reflecting on the Problem and Thinking Process. The developed augmented reality (AR) media consists of four learning topics, namely concentration, temperature, surface area, and catalysts. The interface of each AR topic is presented in Figure 1.



(a) (b) (c) (d)

Figure 1. (a) AR Concentration (b) AR Temperature (c) AR Surface Area (d) AR Catalyst

AR elements were embedded at key phases to visualize sub-microscopic phenomena such as molecular collisions and particle behavior.

The Develop stage comprised three steps: (1) review and revision by the supervising lecturer, (2) expert validation by three validators (two chemistry lecturers from Universitas Negeri Surabaya and one experienced chemistry teacher from one private high school in Gresik, and (3) limited trials with 36 grade XI students across two learning meetings (May 25–26, 2026). During the trials, students were divided into six groups of six. Five observers monitored each meeting, completing learning implementation and student activity observation sheets.

Data collection was conducted through five instruments: (1) validation sheets (Likert scale 1–5) to assess content and construct validity; (2) learning implementation observation sheets to assess the practicality of the inquiry-based learning process; (3) student activity observation sheets to assess student involvement in each Guided Inquiry phase; (4) student response questionnaires using the Guttman scale (Yes = 1, No = 0); and (5) pretest-posttest SPS tests consisting of 10 multiple-choice and 6 essay questions assessing all five SPS indicators in the context of reaction rate material. The science process skills indicators measured in this study are presented in Table 1.

Table 1. Science Process Skills Indicators Measured

No.	SPS Indicator	Description
1.	Observing	Identifying and understanding phenomena presented in flipbook
2.	Formulating Hypotheses	Constructing testable hypotheses based on observed phenomena
3.	Controlling Variables	Identifying and managing independent, dependent, and controlled variables
4.	Predicting	Estimating outcomes based on observed data patterns
5.	Drawing Conclusions	Synthesizing experimental evidence into scientific generalizations

Validity data were analyzed using mode, as the data are ordinal and cannot be processed mathematically. The flipbook is declared valid if the mode score ≥ 4 with good to very good criteria [25]. Practicality of the learning implementation and student activity observations was likewise analyzed using mode with the same criteria. Student response data were analyzed using the percentage formula:

% Response = (Total score obtained / Number of respondents) × 100%

Practicality is met if the student response percentage ≥ 61% [25]. For effectiveness, the pretest-posttest SPS data were first tested for normality using the Shapiro-Wilk test. If both datasets were normally distributed (significance > 0.05), a paired sample t-test was applied to determine whether there was a statistically significant difference between pre- and post-instruction SPS scores at significance level $\alpha = 0.05$ [26]. The flipbook is declared effective if the paired sample t-test yields significance ≤ 0.05, indicating H_0 is rejected and H_1 is accepted confirming a significant improvement in student SPS following the use of the developed flipbook.

RESULTS AND DISCUSSION

The research followed the 4D model stages (Define, Design, Develop). Below is a comprehensive description of each stage and the resulting data.

Define Stage

The define stage had several components which included the following four analyses: front-end analysis, learner analysis, task analysis, and concept analysis. In the front-end analysis, it was discovered that the private high school in Gresik practiced the Merdeka Curriculum, using a minimum grade standard (KKM) of 83 for grade XI. In Gresik, the primary method of classroom instruction was the lecture method, which was supplemented with orthodox PowerPoint presentations and text books, with no guided inquiry or creative teaching media. An AR assisted flipbook had never been implemented there.

In the learner analysis, it was concluded that grade XI students, aged between 16 and 18, have the cognitive capacity for abstract, systematic, and logical thinking, despite the fact that the SPS pre-research test results showed low scores on all five indicators: observing (42.67%), formulating hypotheses (39%), controlling variables (39.67%), predicting (38.67%), and drawing conclusions

(36.67%), with all scores being below 50%. The survey data revealed that 83.33% of students found the concept of reaction rate difficult, 90% of the students stated that the only teaching aids used were PPT, the whiteboard and textbooks, and 93.33% of the students showed a great deal of interest in the use of AR.

Design Stage

According to the define stage, the flipbook integrated the six phases of Guided Inquiry with the SPS indicators. In total, there was one main flipbook, which included an introduction, concept maps, learning, and material summaries, and four other flipbooks, which covered the topics of concentration, temperature, surface area, and catalysts. The main flipbook, and the flipbooks on surface area and catalysts, were created in Canva, while the remaining three flipbooks were edited in Microsoft Word. The remaining three flipbooks were accessed via Augmented Reality (AR) through Android smartphones. Each of the SPS indicators was aligned to the six phases of Guided Inquiry. The learning activities were conducted according to the phases of the learning model. The implementation phases are presented in Figure 2, 3, 4, 5, 6, and 7.

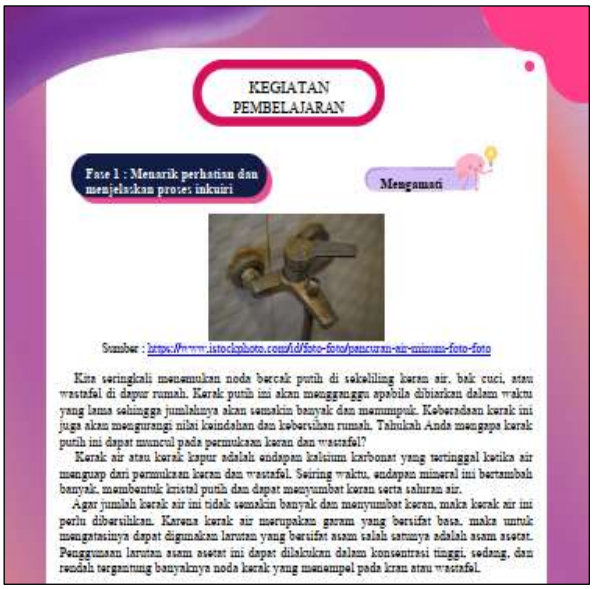


Figure 2. Phase 1 (Focusing Attention) for Observing



Figure 3. Phase 2 (Presenting Inquiry Problems) for Observing

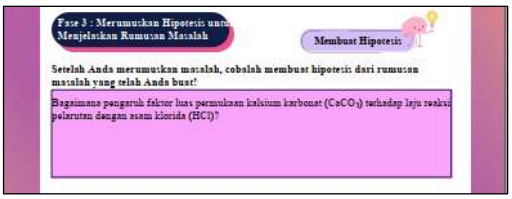


Figure 4. Phase 3 (Formulating Hypotheses) for Hypothesis Formulation

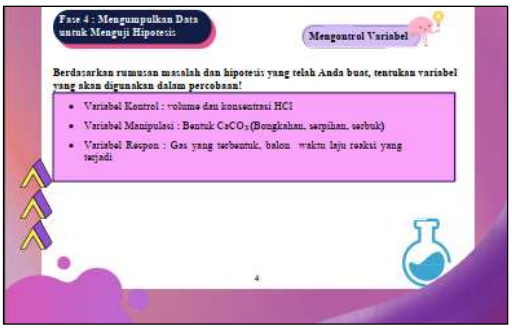


Figure 5. Phase 4 (Collecting Data) for variable Control

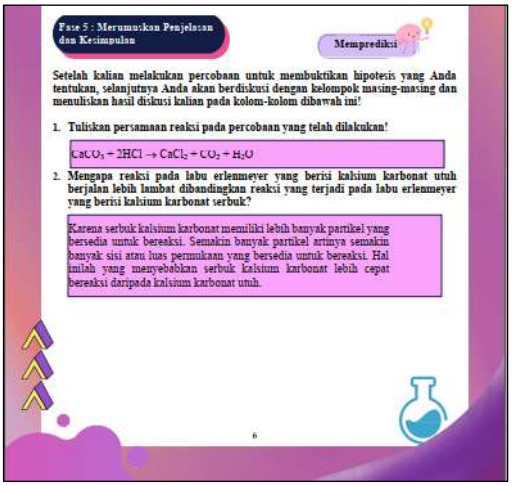


Figure 6. Phase 5 (Formulating Explanations) for Predicting



Figure 7. Phase 6 (Reflecting) for Drawing Conclusions

Develop Stage

1. Validity

Validation of the flipbook was conducted by three validators (2 chemistry lecturers from Universitas Negeri Surabaya and a chemistry teacher from a private high school in Gresik). The results of the validation are presented in Table 2.

Table 2. Validity Assessment Result of Flipbook

No	Assessed Aspect	V1	V2	V3	Mode	Category
	Content Validity					
1	Suitability of flipbook with Learning Achievement (CP) and Learning Objective Flow (ATP)	5	4	5	5	Good
2	Sequential suitability with the Merdeka Curriculum	5	4	5	5	Good
3	Alignment with Guided Inquiry model phases	4	4	5	4	Good
4	Flipbook trains SPS: Observing	4	4	5	4	Good
5	Flipbook trains SPS: Formulating Hypotheses	4	4	5	4	Good
6	Flipbook trains SPS: Controlling Variables	4	4	5	4	Good
7	Flipbook trains SPS: Predicting	4	4	5	4	Good
8	Flipbook trains SPS: Drawing Conclusions	4	4	4	4	Good
	Construct Validity					
9	Language aspect (PUEBI compliance, unambiguous, effective sentences)	4	4	4	4	Good
10	Presentation aspect (completeness of components)	5	5	5	5	Very Good
11	Graphic aspect (layout, typography, color combination)	5	4	5	5	Very Good
	Overall Validtity Mode				4	Good

As illustrated in Table 2, the flipbook received a mode score of 4 (valid) upon review from all aspects of content validity. This indicates that the flipbook was aligned with the learning goals, the Guided Inquiry model, and the five SPS indicators. The evaluation of construct validity also scored in the range of 4 to 5 (valid to very valid) and indicated that the language, presentation, and graphic design of the flipbook were good. The presentation of graphics scored the highest, with a mode of 5, due to the use of a gradient purple design, chemistry laboratory icons, and SPS indicator boxes that were color coded to aid in visual distinction. This also supports cognitive load theory, which posits that instructional materials that have extraneous design elements removed enable learners to concentrate on the learning of the material (referring to the balance of laboratory instruction and SPS elements presented) [28]. In addition, the previous validation studies on AR-based interactive chemistry media reported a similar high degree of validity with regard to content, design, and graphics when the design was focused on Learning Order Objectives within a curriculum [29]. In this case, the high degree of construct validity was likely due to the clear mapping of each SPS indicator associated with each of the Guided Inquiry model phases.

2. Practicality

Practicality was assessed by three tools: student questionnaires, learning implementation observations, and student activity observations. Limited trials were conducted over two meetings at one private high school in Gresik (May 25-26, 2026) with 36 grade XI students divided into 6 groups of 6.

The results of the student response questionnaire are presented in Table 3.

Table 3. Student Response Questionnaire Results

Statement	Percentage (%)	Criteria
Responses to Flipbook		
Flipbook motivates learning	100.00	Very Good
Flipbook stimulates curiosity	94.44	Very Good
Systematic presentation, easy to understand	94.44	Very Good
Material clearly and logically presented	91.66	Very Good
Flipbook improves understanding of reaction rate	97.22	Very Good
Attractive cover design (color and images)	100.00	Very Good
Scientific language easy to understand	83.33	Very Good
Usage instructions easy to follow	100.00	Very Good
Tables, layout, and illustrations appropriate	100.00	Very Good
Responses to SPS Development		
Flipbook helps observe reaction rate phenomena	88.88	Very Good
Flipbook helps identify experimental variables	86.11	Very Good
Flipbook helps formulate hypotheses	100.00	Very Good
Flipbook helps predict experimental results	97.22	Very Good
Flipbook helps draw evidence-based conclusions	100.00	Very Good
Average Overall Student Response	96.9	Very Good

Table 3 shows that 96.9% of students responded very positively to the flipbook. Notably, 100% confirmed the flipbook was motivating, had an attractive cover, clear usage instructions, and appropriate layout. The highest SPS-related responses were for hypothesis formulation and conclusion drawing (100%), reflecting the effectiveness of the structured Guided Inquiry phases. The 86.11% response for variable identification is still in the very practical category but indicates this is the most cognitively demanding skill for students consistent with Piaget's operational formal theory that multi-variable thinking develops gradually [27]. The results of the observations on learning implementation and student activities are presented in Table 4.

Table 4. Learning Implementation and Student Activity Observation Results

Instrument	Meeting 1	Meeting 2	Category
Learning Implementation (Mode)	5	5	Very Good
Student Activity - Observing (%)	100%	100%	Very Good
Student Activity - Hypothesizing (%)	93.33%	91.67%	Very Good
Student Activity - Variable Control (%)	96.67%	96.67%	Very Good
Student Activity - Predicting (%)	88.33%	90.00%	Very Good
Student Activity - Concluding (%)	91.67%	95.00%	Very Good

Learning implementation observation showed a mode score of 5 (very good) for both meetings, confirming consistent execution of all six Guided Inquiry phases. Student activity observation showed percentages ranging from 80% to 100%, with mode 5 for both meetings. These results align with Lutfi [25], who states that media is considered practical if the mode score is ≥ 4 and student response percentage is ≥ 61%.

3. Effectiveness

Effectiveness was measured through pretest-posttest of students' science process skills. The test consisted of 10 multiple-choice questions and 6 essay questions, designed to assess all five SPS indicators within the context of reaction rate material. The pretest and posttest values reported in Table 5 are percentage scores, calculated by dividing the total score students obtained on each SPS indicator by the maximum possible score for that indicator and multiplying by 100%; they therefore represent the degree of achievement of each SPS indicator rather than raw test scores.

Table 5. Pretest-Posttest SPS Results Summary

Description	Pretest	Posttest
Average Score	Low (< 50%)	High (> 80%)
Observing	42.67%	95.00%
Formulating Hypotheses	39.00%	90.00%
Controlling Variables	39.67%	88.00%
Predicting	38.67%	87.50%
Drawing Conclusions	36.67%	91.00%
Normality Test (Sig.)	0.6039 > 0.05 (Normal)	0.3293 > 0.05 (Normal)
Paired Sample t-test (Sig.)	0.000 ≤ 0.05	0.000 ≤ 0.05

The findings presented in Table 5 indicate that there is significant progress with all SPS indicators after the application of the Guided Inquiry learning with the AR assisted flipbook. The highest progress occurred in the indicators related to drawing conclusions (from 36.67% to 91.00%) and the ability to observe (from 42.67% to 95.00%). The largest gains likely came from the flipbook's design. In the previous research, students had difficulties dealing with multiple variables presented. Most of the students were unable to construct reaction time and reaction rate, which are indirectly related, and confused which affects which. Most students misunderstood the reaction of temperature with the movement of the molecules and the collision. In Phase 1 and Phase 2 (Focusing Attention and Presenting Inquiry Problems), the AR assisted animations of molecular collisions allowed students to make repeated observations of phenomena which are normally at the realm of the invisible to the naked eye. Furthermore, in Phase 6 (Reflecting on the Problem and Thinking Process), students were provided with guided steps to reflect upon and interpret their results, and to construct a conclusion.

These issues describe what are called alternative conceptions: beliefs that build upon the generalized aspects of everyday experiences, that deviate from scientifically accurate explanations [10]. In Guided Inquiry, students engaged in active experiments that allowed them to confront these beliefs with evidence in order to help them adjust their conceptual frameworks. An example of students' conclusions regarding the effect of temperature on the reaction is presented in Figure 8.

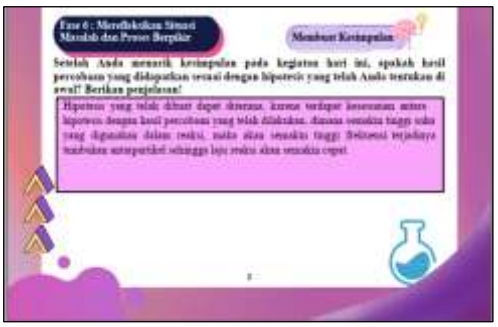
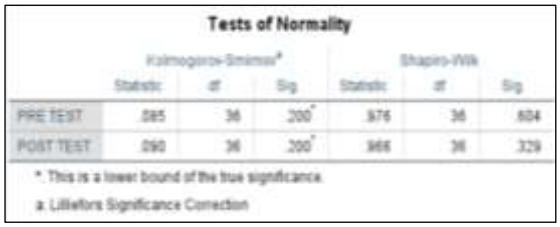


Figure 8. SPS (Conclusion) for Temperature Factors

For instance, after observing the $CaCO_3$ + HCl reaction at varying temperatures, students understood that a temperature greater than room temperature means greater kinetic energy, therefore there would be more effective collisions, thus the reaction would proceed at a greater rate. The results of the Shapiro Wilk normality test are presented in Figure 9.



Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PRE TEST	.085	36	.200*	.976	36	.604
POST TEST	.090	36	.200*	.968	36	.329

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Figure 9. Normality Test Shapiro Wilk

Normality tests indicated that the pretest and posttest data were normally distributed ($p = 0.604$ and $p = 0.329$, respectively, $p > 0.05$). Therefore, the application of a paired sample t-test was justified. The t-test indicated a significant difference between the pre- and post-instruction SPS scores with a p-value of 0.000 ($p \leq 0.05$). The results of the paired samples t-test are presented in Figure 10.



Figure 10. Result of Paired Sample T-Test

This demonstrates the effectiveness of the AR assisted flipbook and Guided Inquiry in developing students' SPS.

Constructivist theory of learning can also be used to explain this. Piaget [27] indicated that Guided Inquiry allows students to assimilate the alternative conception into their cognitive structure and then leads to balancing the cognitive structure with scientifically correct understanding (accommodation, or equilibration). It can also be said that the different phases of the flipbook along with teacher guidance were adequate scaffolding to postulate that students were able to reach cognitive levels beyond their ZPD [30].

The AR component employed a technique that, according to reports from the research team, changed abstract concepts, including those covering molecular behavior, small-scale phenomena, and particle collisions, into something concrete. Research from the past has shown that augmented reality can help students deal with complex concepts and view them as three-dimensional models. This, in turn, can help with motivation and improve understanding of the concepts [31].

There are three different components that, when working together, help determine how effective the AR assisted flipbook was. The flipbook guided students through the six phases of Guided Inquiry in a self-paced manner. Each phase in the flipbook was directly linked to a specific SPS indicator, as illustrated in Table 1. The Guided Inquiry approach helps students develop their own questions, theories, and conclusions, which promotes the development of the individual skills that the approach is designed to teach. The AR component assisted students in visualizing the sub microscopic concepts that are involved in the study of reaction rates. Without these concepts, the students would have been limited to the macroscopic approach, which is symbolic and abstract. Previous research has shown that abstract sub microscopic concepts play an important role in developing misconceptions about the study of reaction rates. Each of the components (the flipbook, Guided Inquiry, and the AR component) together help set the pedagogy. When taken as a whole, the AR assisted flipbook helped improve the teaching of the science process skills through augmented reality and instructional design.

CONCLUSION

Based on research results and data analysis, the Augmented Reality-assisted Flipbook for training science process skills on reaction rate material is declared feasible for educational use. This is demonstrated by: (1) validity mode score of 4 (valid category) for both content and construct validity, confirmed by three expert validators; (2) practicality average student response of 96.9% (very practical), learning implementation observation mode 5 (very good), and student activity observation mode 5 (very good) for both meetings; and (3) effectiveness normality test values > 0.05 (normal distribution) and paired sample t-test significance of $0.000 \leq 0.05$, confirming a statistically significant improvement in students' science process skills after using the flipbook. The AR-assisted flipbook can therefore serve as an effective alternative learning medium to enhance science process skills on reaction rate material in Indonesian senior high schools.

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