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Guided-Inquiry E-Module for Critical Thinking in Reaction-Rate Learning

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Abstract
This study aimed to develop a guided-inquiry e-module for reaction-rate learning and determine its validity, practicality, and initial effectiveness in fostering critical-thinking skills. The 4D research-and-development model was employed, followed by a limited one-group pretest–posttest trial involving 19 eleventh-grade science students at SMAN 1 Labuapi. The product, response questionnaires, and four-item essay test were reviewed by two chemistry-education lecturers and one chemistry teacher. The novelty of the product lies in the explicit alignment of each guided-inquiry stage with the critical-thinking indicators of interpretation, analysis, evaluation, and inference. Validity was analyzed using Aiken's V, inter-rater reliability using Percentage of Agreement, practicality using response percentages, and learning improvement using normalized gain. The e-module achieved a mean Aiken's V of 0.89 and 89% reliability. The teacher and student questionnaires achieved Aiken's V values of 0.93 and 0.89 and reliability values of 94% and 89%, respectively; the critical-thinking test achieved an Aiken's V of 0.93 and 92% reliability. Practicality was rated at 91% by the teacher and 85% by students. The mean N-Gain of 0.59 indicated a moderate improvement. Therefore, the e-module was highly valid, highly practical, and demonstrated initial effectiveness in the limited trial.

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INTRODUCTION

Twenty-first-century education emphasizes not only mastery of knowledge but also higher-order thinking, creativity, communication, and collaboration (Baehaqi & Andriyani, 2023). Among these competencies, critical thinking is essential because it enables students to interpret information, analyze relationships, evaluate reasons and evidence, and formulate logical conclusions (Facione, 2015; Subro & Fawaid, 2025). Learning should therefore be designed so that students do not merely receive information but actively construct and examine their understanding.

Advances in information technology have expanded opportunities to use e-modules as digital learning materials that integrate text, images, audio, video, animation, and interactive activities. E-modules can be accessed flexibly through electronic devices, support self-directed learning, and increase student engagement (Febriana & Sakti, 2021; Laili et al., 2019). Flipbook-based digital materials can also support twenty-first-century skills when their structure, navigation, and activities are aligned with user needs (Sari & Atmojo, 2021; Wibowo et al., 2025). Contextual and local-wisdom-based e-modules have also been studied for online learning, practicality, critical thinking, and digital literacy (Aminah et al., 2024; Putri et al., 2026).

In chemistry education, this need is particularly evident in reaction-rate learning. Reaction-rate concepts involve connections among macroscopic, submicroscopic, and symbolic representations; consequently, students often struggle to relate observable phenomena, collision theory, and mathematical representations (Pikoli et al., 2022). Instruction that relies excessively on memorizing formulas may restrict

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students' ability to analyze factors affecting reaction rates and explain phenomena using evidence (Muliaman & Mellyzar, 2020). Visualization, contextual examples, and inquiry activities are therefore required to make abstract concepts more comprehensible (Wijayadi & Putra, 2019).

The needs analysis at SMAN 1 Labuapi involved semi-structured interviews with one chemistry teacher on November 7, 2025, and three eleventh-grade science students on November 12, 2025, together with an analysis of the learning materials in use. Responses were summarized thematically according to learning conditions, learning difficulties, student participation, device availability, and learning-material needs. Classroom instruction remained dominated by teacher explanations supported by textbooks, worksheets, and PowerPoint. Students tended to memorize formulas, were rarely asked to justify their answers, and experienced difficulty analyzing problems and drawing conclusions. All three students owned smartphones and expressed interest in using digital learning materials. The learning-material analysis also identified limited microscopic visualization, contextual examples, inquiry activities, and digital-media integration.

Guided inquiry is relevant to these needs because it allows students to conduct investigations with teacher-provided questions and scaffolding. The stages of orientation, problem formulation, hypothesis generation, data collection, hypothesis testing, and conclusion drawing can facilitate interpretation, analysis, evaluation, and inference (Dahlia, 2021; Nurdyansyah & Fahyuni, 2016).

Active involvement in these processes is important for developing critical-thinking skills (Ivansyah et al., 2025). From a cognitive perspective, orientation requires students to identify and interpret relevant information; problem formulation and data collection require analysis of relationships; hypothesis testing requires evaluation of claims against evidence; and conclusion drawing requires inference from the available data. This alignment provides the theoretical basis for embedding Facione's indicators within the guided-inquiry learning sequence.

Previous studies have produced valid and practical guided-inquiry e-modules for periodic properties, colligative properties of solutions, and colloids (Cheva & Zainul, 2019; Widyawati & Ardhana, 2023; Yunus et al., 2022). A mobile-learning e-module was also reported to improve critical-thinking skills in chemical-equilibrium learning (Amalya & Lutfi, 2024), whereas an inquiry-based electronic worksheet for reaction rates was designed to train critical thinking (Putri & Sukarmin, 2023). The validity of an ethnophysics-integrated problem-based science e-module for science-process and critical-thinking skills has also been examined (Damayanti et al., 2026). However, these studies differ in topic, product format, measured indicators, and the degree of integration between inquiry stages and critical-thinking activities. Some products primarily emphasize learning outcomes or general product quality, whereas the explicit mapping of each inquiry stage to interpretation, analysis, evaluation, and inference has not always been clearly described.

The novelty of this study lies in integrating Facione's four critical-thinking indicators into the activities of each guided-inquiry stage in the reaction-rate e-module. Videos and illustrations prompt interpretation; problem formulation and data collection support analysis; hypothesis testing facilitates evaluation; and conclusion drawing develops inference. This study aimed to develop a guided-inquiry e-module for reaction-rate learning and determine its validity, practicality, and initial effectiveness in a limited trial.

METHOD

Research Design and Participants

This study employed research and development using the 4D model, comprising the define, design, develop, and disseminate stages (Thiagarajan et al., 1974). It was conducted during the second semester of the 2025/2026 academic year at SMAN 1 Labuapi. The validators were two chemistry education lecturers and one chemistry teacher. The practicality assessment involved one chemistry teacher and 19 eleventh-grade science students. The product trial involved 19 students selected purposively because they had studied reaction rates. The inclusion criterion was prior completion of reaction-rate instruction, whereas students who had not completed the topic were not included. The sample size reflected the limited-trial purpose of the develop stage and was

not intended to represent the wider student population.

Initial effectiveness was examined using a one-group pretest–posttest design. Critical-thinking skills were measured before and after students used the e-module, without a comparison group. Accordingly, the analysis was used to describe improvement in the limited trial and was not intended as causal evidence or as a basis for generalization to a broader population.

Development Procedures

During the define stage, the researchers conducted preliminary, student, and concept analyses, needs interviews, and an analysis of the existing learning materials. The design stage included media selection, format development, mapping inquiry stages to critical-thinking indicators, and producing the initial prototype with Canva, Liveworksheet, and Heyzine. The develop stage included expert validation, inter-rater reliability analysis, product revision, a limited trial, and final revision. Dissemination was limited to providing the chemistry teacher at SMAN 1 Labuapi with access to the product. The define stage produced a needs profile and content map; the design stage produced the course structure, activity blueprint, assessment plan, and Prototype 1; the develop stage produced validation evidence, practicality and initial-effectiveness data, and Prototype 2; and the disseminate stage documented restricted product access for the participating teacher. These outputs provided traceability from the identified needs to the features and evaluation of the final product.

Instruments and Data Analysis

Qualitative data were obtained from needs interviews and validator feedback. Quantitative data were collected using the product-validation sheet, teacher and student response questionnaires, and a critical-thinking test. The test comprised four essay items representing interpretation, analysis, evaluation, and inference. Each item was scored using a 1–4 rubric. Explanation and self-regulation were not measured because they require more specialized observation or interview procedures (Facione, 2015).

Table 1. Validity and Reliability of Research Instruments

Instrument	Aiken's V	Category	PA (%)	Category
E-module	0.89	Highly valid	89	Reliable
Teacher response questionnaire	0.93	Highly valid	94	Reliable
Student response questionnaire	0.89	Highly valid	89	Reliable
Critical-thinking test	0.93	Highly valid	92	Reliable

Content validity was analyzed using Aiken's V, $V = \Sigma s/[n(c-1)]$, where $s = r - l_0$, r is the validator's score, l_0 is the lowest possible score, c is the number of rating categories, and n is the number of validators (Antara, 2020). Values of $V < 0.40$ were categorized as less valid, $0.40 \leq V \leq 0.80$ as valid, and $V > 0.80$ as highly valid (Irawan, 2021). Inter-rater reliability was analyzed using Percentage of Agreement, $PA = [1-(A-B)/(A+B)]\times 100\%$, and was considered reliable when $PA \geq 75\%$ (Liani et al., 2021).

Practicality was calculated as $P = (f/N)\times 100\%$, where f is the obtained score and N is the maximum score (Firjatillah et al., 2020). Percentages of 0–20% were categorized as impractical, 21–40% as less practical, 41–60% as moderately practical, 61–80% as practical, and 81–100% as highly practical (Hanisah et al., 2022).

Improvement in critical-thinking skills was calculated using normalized gain, $g = (Xpost - Xpre)/(Xmax - Xpre)$. Values of $g \geq 0.70$ were categorized as high, $0.30 \leq g < 0.70$ as moderate, and $g < 0.30$ as low (Hake, 1998). Descriptive statistics for the pretest and posttest comprised the mean, standard deviation, minimum, and maximum. Raw scores from the four items (range 4–16) were converted to a 0–100 scale.

RESULTS AND DISCUSSION

Define Stage

The preliminary analysis showed that instruction remained dominated by teacher explanation, while students mainly took notes and completed exercises. The teacher estimated that only about 30% of students actively asked or answered questions. Students reported difficulty understanding chemistry concepts and calculations and therefore tended to memorize formulas rather than justify their reasoning. These findings indicate that critical-thinking skills had not been optimally facilitated; they do not establish that

students definitively had low critical-thinking ability. Learning opportunities that allow students to observe, ask questions, analyze information, and draw conclusions are needed to increase engagement (Ivansyah et al., 2025).

The student analysis showed that all three interviewees owned smartphones and supported the use of an e-module. The concept and learning-material analyses indicated that basic reaction-rate content was available; however, coverage of collision theory, factors affecting reaction rates, particle-level visualization, contextual examples, collaborative activities, and digital resources remained limited. The product was therefore designed as an interactive flipbook integrating visuals, videos, exercises, and inquiry activities. These characteristics align with the need for flexible digital learning materials that support independent learning (Amalya & Lutfi, 2024; Sari & Atmojo, 2021).

Table 2. Needs-Analysis Findings and Design Decisions

Finding	Design decision	E-module feature
Teacher-centered learning	Promote active learning	Guided-inquiry activities
Difficulty connecting concepts and formulas	Provide contextual and visual representations	Videos, images, particle-level illustrations
Limited reasoning and conclusion tasks	Integrate measurable critical-thinking indicators	Interpretation, analysis, evaluation, and inference prompts
Material not sufficiently systematic	Sequence content by objectives and inquiry stages	Structured learning units and navigation
Students have smartphones	Provide flexible digital access	Heyzine flipbook and Liveworksheet

Design Stage

The e-module was designed in Canva and converted into a flipbook using Heyzine. Content was sequenced from the concept of reaction rate and collision theory to the effects of concentration, surface area, temperature, and catalysts. Videos, images, and illustrations were used to visualize abstract concepts, while Liveworksheet supported inquiry and assessment activities. Visual representations and digital media can clarify chemistry concepts and increase learner engagement (Djarwo et al., 2025; Wijayadi & Putra, 2019).

Figure 1. QR code for Prototype 1 (Prototype 1 access: https://heyzine.com/flip-book/e05e680f43.html)

Each activity linked an inquiry stage to a critical-thinking indicator: orientation to interpretation; problem formulation and data collection to analysis; hypothesis testing to evaluation; and conclusion drawing to inference. This explicit mapping differentiates the product from e-modules that integrate inquiry only procedurally or assess general learning outcomes.

Develop Stage

Product Validity and Revision

Table 3. E-module Validity Results

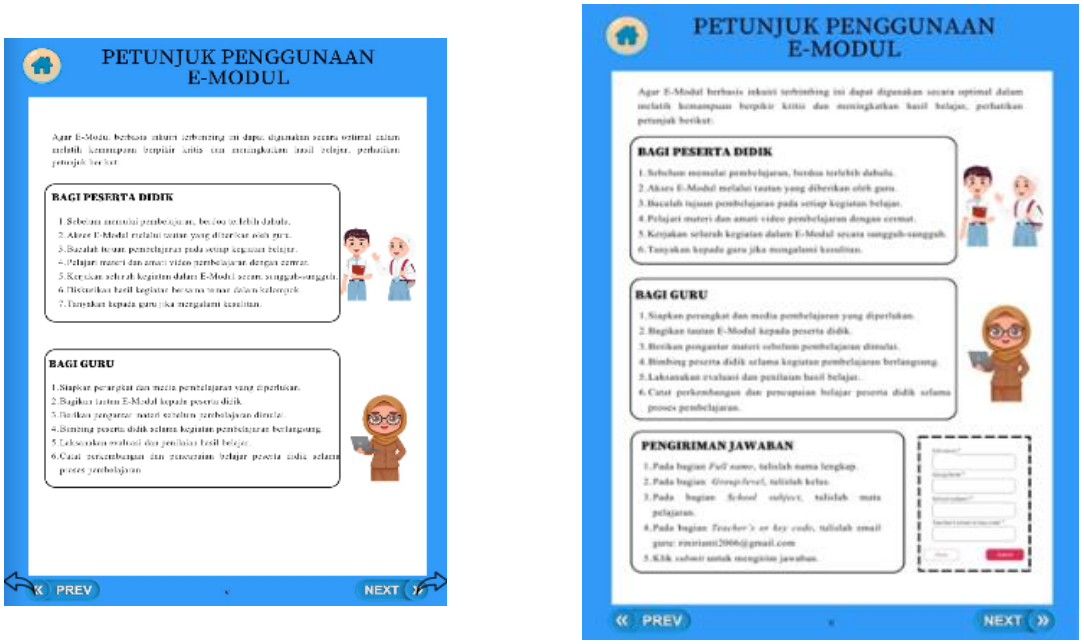
Aspect	Aiken's V	Category
Graphics	0.87	Highly valid
Presentation	0.85	Highly valid
Content feasibility	0.90	Highly valid
Language	0.96	Highly valid
Mean	0.89	Highly valid

All aspects were categorized as highly valid, with a mean Aiken's V of 0.89. Language received the highest score (0.96), indicating communicative and consistent wording. Presentation received the lowest score (0.85), although it remained highly valid. Validator feedback primarily concerned distinguishing objectives from instructions, adding guidance at the end of the orientation stage, citing video sources, consistently formatting foreign terms, and providing instructions for submitting answers through Liveworksheet. These findings confirm that

alignment among objectives, content, activities, and assessment is essential to the quality of learning materials (Ardiansyah, 2020; Cheva & Zainul, 2019).

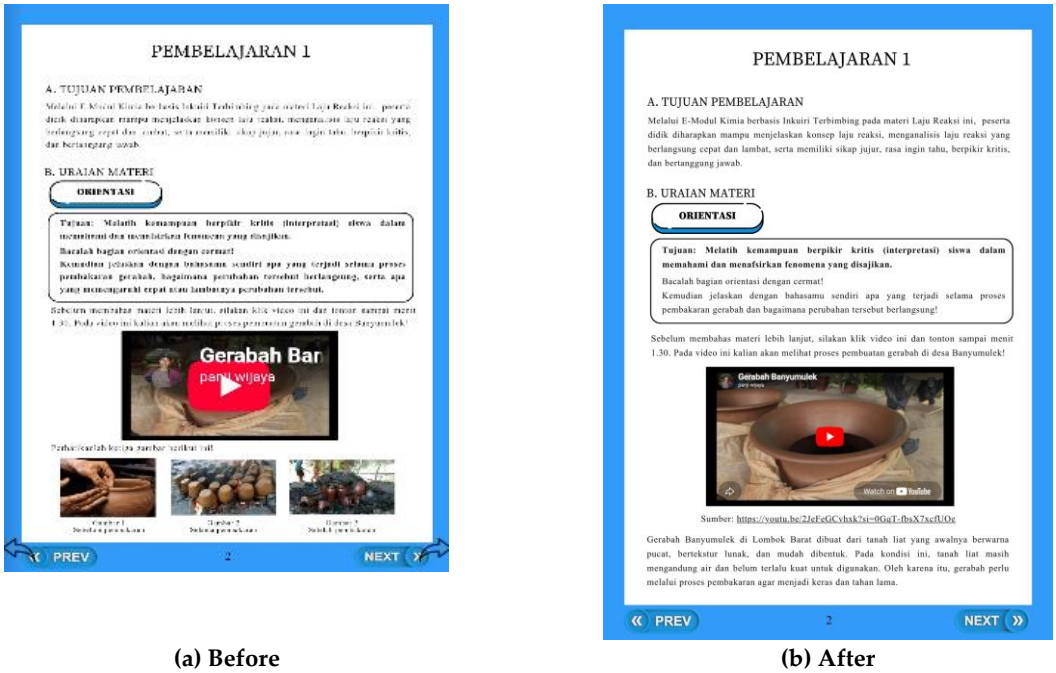
Table 4. Summary of Revisions based on Validator Feedback

Validator suggestion	Revision made
Differentiate learning objectives from instructions	Objectives were bolded and instructions retained in regular type.
Clarify transition after orientation	A guiding instruction was added before students proceeded to the next inquiry stage.
Provide sources for learning videos	Video sources and links were added.
Standardize foreign terms	Foreign terms were italicized consistently.
Clarify Liveworksheet submission	Step-by-step answer-submission guidance was added.



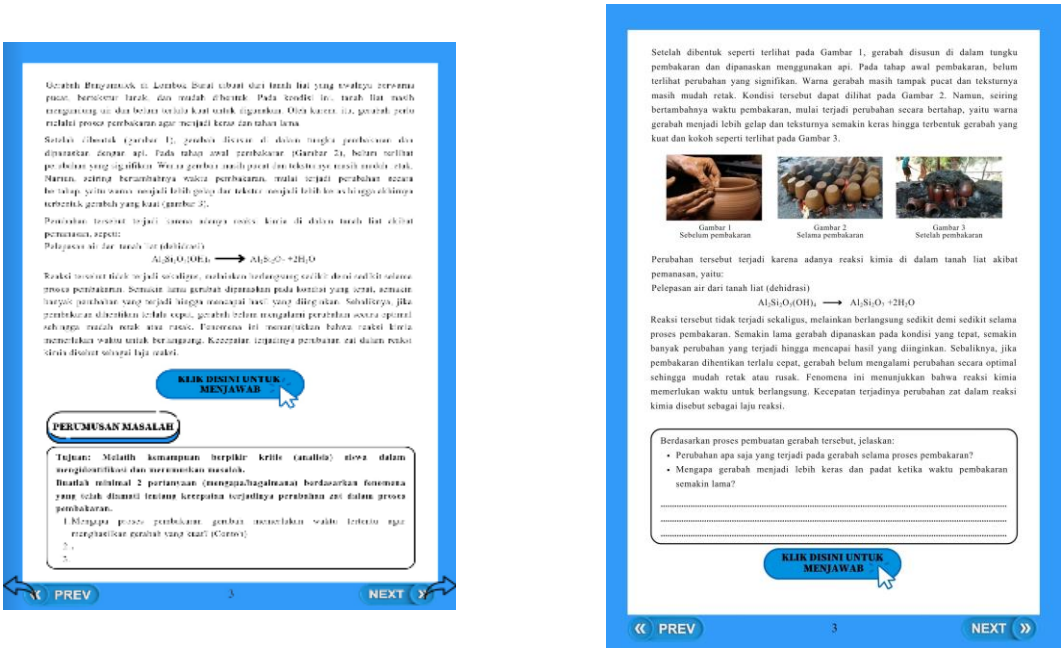
(a) Before **(b) After**

Figure 2. Revision of The e-Module Usage Instructions



(a) Before **(b) After**

Figure 3. Revision of The Video Source Information



(a) Before **(b) After**

Figure 4. Addition of Guidance at The Orientation Stage

The revisions did not alter the content or inquiry stages; instead, they improved readability, the clarity of the learning flow, accountability for media sources, and ease of use. The revised product became Prototype 2.

Figure 5. QR code for Prototype 2

Prototype 2 access: https://heyzine.com/flip-book/2d3673636f.html

Practicality

Table 5. Practicality of The e-Module

Aspect	Teacher response	Student response
Ease of use	90%	84%
Clarity of material	95%	87%
Alignment with learning objectives	90%	84%
Usefulness	90%	86%
Mean	91%	85%

The teacher rated practicality at 91%, and students rated it at 85%; both values were categorized as highly practical. Clarity of material received the highest scores from the teacher (95%) and students (87%). The teacher reported that the systematic presentation, images, videos, and Liveworksheet facilitated classroom management. Students reported that the e-module was easily accessible through smartphones, provided clear instructions, and supported conceptual understanding through a more engaging display. These findings are consistent with studies reporting that guided-inquiry e-modules are practical because they are easy to use and support independent learning (Widyawati & Ardhana, 2023; Yunus et al., 2022).

The six-percentage-point difference between teacher and student responses indicates that the teacher perceived greater pedagogical benefits than students experienced during use. Although both ratings were highly practical, student responses for ease of use and alignment remained at 84%. This finding suggests the need for user orientation, adaptation time, and simplified navigation when the product is implemented in larger classes.

Initial Effectiveness

The mean score increased from 42.76 on the pretest to 75.66 on the posttest. The standard deviations were similar (14.62 and 14.86),

indicating that score variability at the group level remained relatively stable; however, this descriptive pattern alone does not establish that every student improved to the same extent. Individual improvement would require examination of paired student-level scores. The minimum score increased from 25.00 to 43.75, and the maximum increased from 75.00 to 93.75.

Table 6. Descriptive Statistics of Critical-Thinking Scores

Measure-ment	Mean	SD	Minimum	Maximum
Pretest	42.76	14.62	25.00	75.00
Posttest	75.66	14.86	43.75	93.75

Table 7. N-Gain by Critical-Thinking Indicator

Indicator	N-Gain	Category
Interpretation	0.52	Moderate
Analysis	0.70	High
Evaluation	0.72	High
Inference	0.42	Moderate
Overall mean	0.59	Moderate

The mean N-Gain of 0.59 represented a moderate improvement and provided initial evidence of effectiveness in the limited trial. The highest gains occurred in evaluation (0.72) and analysis (0.70). Data collection and hypothesis testing allowed students to connect information, compare predictions with evidence, and judge the adequacy of explanations. These activities therefore supported analysis and evaluation more directly. This explanation is a pedagogical interpretation of the activity design and should be tested further using process data or comparison-group evidence.

Interpretation achieved an N-Gain of 0.52 and inference 0.42. Interpretation developed through observing videos and images, although some students still required support to identify relevant information. Inference produced the lowest gain because it requires students to integrate data, concepts, and reasoning into a coherent conclusion. According to Facione (2015), inference involves identifying the elements needed to formulate defensible conclusions. Inference activities should therefore be strengthened through guiding questions, evidence–concept mapping tables, and progressively scaffolded conclusion-writing practice.

These findings support Triandini et al. (2021), who reported that guided inquiry can enhance critical thinking through systematic learning stages. Unlike Yunus et al. (2022), who primarily reported learner autonomy and achievement in colloid learning, this study mapped improvement across four critical-thinking indicators in reaction-rate learning. Compared with the mobile-learning product for chemical equilibrium (Amalya & Lutfi, 2024) and the inquiry-based electronic worksheet for reaction rates (Putri & Sukarmin, 2023), this product contributes an explicit connection among inquiry stages, interactive media, and indicators measured in both activities and tests. Green-chemistry problem-based learning and CINQASE have likewise been studied in relation to critical thinking and conceptual understanding (Dewi et al., 2025; Muntari et al., 2025).

Disseminate Stage

Dissemination was limited to providing the chemistry teacher at SMAN 1 Labuapi with access to Prototype 2. It did not involve implementation across schools or broad product publication. The findings therefore support product use only within the trial context and provide a basis for further testing. Limited dissemination remains important because it enables initial users to review and use the product before broader implementation (Muliati et al., 2024).

Research Limitations

The study involved 19 students from one school, used a one-group pretest–posttest design without a comparison group, and was conducted within a limited trial period. Product dissemination was also limited to one teacher at the research site. Consequently, the N-Gain results cannot be fully separated from other learning experiences and cannot be generalized. The evidence should be interpreted as initial effectiveness supporting product feasibility rather than as a comparative conclusion that the e-module is superior.

CONCLUSION

A guided-inquiry e-module for reaction-rate learning was successfully developed through the 4D model by integrating interpretation, analysis, evaluation, and inference into learning activities. The product obtained a mean Aiken's V of 0.89 and reliability of 89%, indicating high validity and

consistency among validators. The response questionnaires and critical-thinking test were also highly valid and reliable. Practicality reached 91% according to the teacher and 85% according to students. The mean critical-thinking score increased from 42.76 to 75.66, with a mean N-Gain of 0.59. These findings indicate that the e-module was highly valid, highly practical, and demonstrated initial effectiveness in the limited trial. Effectiveness cannot yet be generalized because the study did not include a comparison group and was conducted in only one class.

RECOMMENDATION

Future studies should involve larger samples, multiple schools, longer implementation periods, and a comparison group to provide stronger evidence of effectiveness. Inference activities should be enriched with guiding questions, exercises that connect evidence to concepts, and progressive feedback. Before broader implementation, the navigation and Liveworksheet instructions should be retested with users who have varying levels of digital literacy. For classroom implementation, teachers should provide an initial orientation on e-module navigation and Liveworksheet submission, organize students into small groups during inquiry activities, allocate additional scaffolding for inference tasks, and prepare offline alternatives when internet access is unstable.

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