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Development of Science Literacy Integrated Reading Materials Using a Scientific Approach on Factors Affecting Reaction Rates

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Abstract

This study was conducted to respond to the need for strengthening science literacy in the Merdeka Curriculum, particularly in chemistry learning on reaction rate concepts, which require contextual and technology-supported learning resources. The purpose of this research was to develop and evaluate the validity, practicality, and effectiveness of digital reading materials integrated with science literacy using a scientific approach. The research followed a Research and Development (R&D) model adapted from Sugiyono, involving needs analysis, product design, expert validation, and classroom trials with grade XI students. Validation by material, media, and practitioner experts indicated that the product met the criteria of "very valid." Practicality tests involving teachers and students showed that the reading materials were easy to use and supported learning activities effectively. The effectiveness of the product was demonstrated through improved student science literacy, as shown by moderate N-gain scores and a very large effect size. These findings indicate that the developed digital reading materials can enhance students' science literacy and support more meaningful learning of reaction rate concepts. The product offers an alternative digital resource that aligns with current educational demands and technology use in Indonesian secondary schools.

Keywords: reading materials, science literacy, factors affecting reaction rates.

Pengembangan Bahan Bacaan Terintegrasi Literasi Sains dengan Pendekatan Saintifik pada Materi Faktor-Faktor yang Mempengaruhi Laju Reaksi

Abstrak

Penelitian ini dilakukan sebagai respons terhadap kebutuhan penguatan literasi sains dalam Kurikulum Merdeka, khususnya pada pembelajaran kimia materi laju reaksi yang menuntut sumber belajar kontekstual dan berbasis teknologi. Tujuan penelitian ini adalah mengembangkan serta mengevaluasi validitas, kepraktisan, dan keefektifan bahan bacaan digital terintegrasi literasi sains dengan pendekatan saintifik. Penelitian menggunakan metode Research and Development (R&D) model Sugiyono melalui tahapan analisis kebutuhan, perancangan produk, validasi ahli, serta

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uji coba kelas pada siswa kelas XI. Hasil validasi oleh ahli materi, media, dan praktisi menunjukkan bahwa produk memenuhi kriteria "sangat valid." Uji kepraktisan oleh guru dan siswa menunjukkan bahwa bahan bacaan mudah digunakan dan mendukung aktivitas pembelajaran secara efektif. Keefektifan produk ditunjukkan melalui peningkatan literasi sains siswa berdasarkan nilai N-gain kategori sedang dan effect size kategori sangat besar. Temuan ini menunjukkan bahwa bahan bacaan digital yang dikembangkan mampu meningkatkan literasi sains siswa dan mendukung pembelajaran laju reaksi secara lebih bermakna. Produk ini menjadi alternatif sumber belajar digital yang sesuai berkembangnya kebutuhan pendidikan dan pemanfaatan teknologi di sekolah menengah.

Kata kunci: bahan bacaan, literasi sains, faktor-faktor yang mempengaruhi laju reaksi.

INTRODUCTION

Literacy has long been regarded as one of the central foundations of Indonesian education. Over the past decade, the attention toward science literacy has grown significantly, particularly as national curriculum reforms increasingly emphasize meaningful, flexible, and student-centered learning (Listiani & Tarakan, 2025) . Scientific literacy, which originated with Hurd's ideas in 1958, has become a critical competency in contemporary science education discourse, reflecting one's ability to evaluate scientific information and construct evidence-based reasoning (Haruna & Kenta, 2024; Qadar et al., 2022). These competencies lie at the heart of deep learning, where learners are expected not only to recall information but to analyze, integrate, and apply knowledge in various real life contexts.

However, Indonesia's performance in international assessments shows that such competencies remain difficult to achieve. The PISA 2022 results indicate that Indonesian students still struggle with science literacy, ranking among the lower-performing countries (OECD, 2023) . More importantly, the data underline a deeper issue: students have not fully developed the capacity to understand scientific concepts comprehensively or apply them in problem-solving situations, two key indicators of deep learning (Hmelo-Silver, 2004) . This situation highlights the urgent need for learning approaches that move beyond surface level knowledge and instead promote conceptual understanding, critical thinking, and knowledge transfer.

One pedagogical model that aligns with the principles of deep learning is the scientific approach, which consists of observing, questioning, collecting information,

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reasoning, and communicating (Permendikbud, 2014) . Through these stages, learners are encouraged to build conceptual understanding through inquiry and reflection, fostering the kind of active and meaningful engagement required for deep learning. Empirical studies confirm that the scientific approach strengthens inductive reasoning and supports holistic conceptual growth (Suprihatin et al., 2023; Wahyono et al., 2017). Despite this potential, numerous studies still show that students' scientific literacy across Indonesian high schools remains low, averaging only around 50% nationwide (Suwandi & Supriyanti, 2021) and even lower in regions such as Kutai Kartanegara and Samarinda (Pasapan et al., 2020; Wardi & Mukhayyarotin, 2023).

These national patterns are also reflected in the local context. Observations at MAN 1 Samarinda and SMAN 2 Tenggarong Seberang reveal limitations in the availability of comprehensive chemistry learning resources, both physical and digital. Questionnaire results further indicate that 78.1% of students perceive chemistry lessons as only sometimes enjoyable. This suggests not only a resource shortage but also a lack of learning materials that actively support scientific literacy development and encourage deeper conceptual engagement. Therefore, improving learning resources becomes essential to better align classroom practices with the goals of deep learning.

At the same time, rapid technological advancements in the era of Society 5.0 bring new opportunities to address these challenges. Digitalization has transformed how information is accessed and utilized, enabling more flexible, efficient, and sustainable learning environments (Manalu, 2019; Song et al., 2025). Digital reading materials, for example, offer advantages such as lower production costs, environmental friendliness (Pálsdóttir, 2019) , and improved engagement due to their interactive nature and accessibility (Sumedi et al., 2025).As most students today own smartphones (Gandari & Jaya, 2024), digital resources can help overcome the limitations of traditional textbooks and expand opportunities for students to engage in deep, reflective, and self-paced learning.

Although recent studies have proposed digital learning materials to support science literacy development, most focus on general digital platforms or subject-specific multimedia (Agustina & Okmarisa, 2023; Fauziah et al., 2024; Mulyani et al., 2024) . Very few explicitly integrate scientific literacy components into chemistry reading materials using a systematic scientific approach, and even fewer link these efforts to

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deep learning outcomes. Moreover, existing studies rarely consider local needs or contextual relevance, both of which are essential for helping students connect chemistry concepts to real-life issues, another hallmark of deep learning.

This creates a clear research gap. No previous studies have specifically developed digital-based chemistry reading materials that integrate scientific literacy, apply the scientific approach, and are tailored to the learning context of students in Samarinda and Tenggarong Seberang. At the same time, field data show that nearly all students possess smartphones, indicating strong potential for mobile-based digital materials to support more meaningful and accessible learning. These findings highlight the novelty of the present study.

Based on the gaps identified, several problems emerge: the scarcity of chemistry reading materials that integrate scientific literacy and the scientific approach; the limited opportunities for students to engage in deep learning; and the lack of accessible digital resources suited to regional needs. To address these issues, this study proposes the development of digital-based chemistry reading materials integrated with scientific literacy using the scientific approach as an innovative learning medium. The purpose of this research is to design, validate, and evaluate the practicality and effectiveness of such materials in enhancing students' scientific literacy and promoting deep learning in secondary school chemistry.

RESEARCH METHODS

This study employed a Research and Development (R&D) design adapted from the ten-step model proposed by Sugiyono (2013) . The model was selected because it provides operational stages suitable for developing educational products that require both qualitative and quantitative evaluation. The advantage of this model is that it provides systematic steps from planning to implementation (Rahayu, 2025) . In this research, the development process was carried out through seven stages: (1) analysis of potential and problems, (2) needs analysis, (3) product design, (4) expert validation, (5) product revision, (6) limited product trial, and (7) evaluation of practicality and effectiveness. The final stages of broader implementation and mass production were not conducted, as the scope of this study focused on product feasibility testing.

The preliminary study, consisting of needs analysis and problem identification, was

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conducted in the 2022/2023 academic year at MAN 1 Samarinda. The participants included 73 students from three Grade XI science classes and a chemistry teacher. This phase aimed to gather data about students' learning difficulties, resource availability, and the suitability of learning materials.

The product trial was conducted in the 2024/2025 academic year at SMAN 2 Tenggarong Seberang. The population consisted of 262 Grade XI students enrolled in chemistry specialization classes. A purposive sampling technique was applied to select classes with stable internet access and consistent instructional schedules. Two classes (XI A1 and XI A2), consisting of 72 students, were chosen for the practicality and effectiveness testing of the developed reading materials. The learning material developed focused on the chemistry topic "Factors Affecting Reaction Rates". This topic was selected because it combines conceptual understanding, mathematical reasoning, and real-life applications, making it suitable for integrating science literacy components (content, context, and competencies) and the scientific approach. The research and development model is presented in Figure 1.

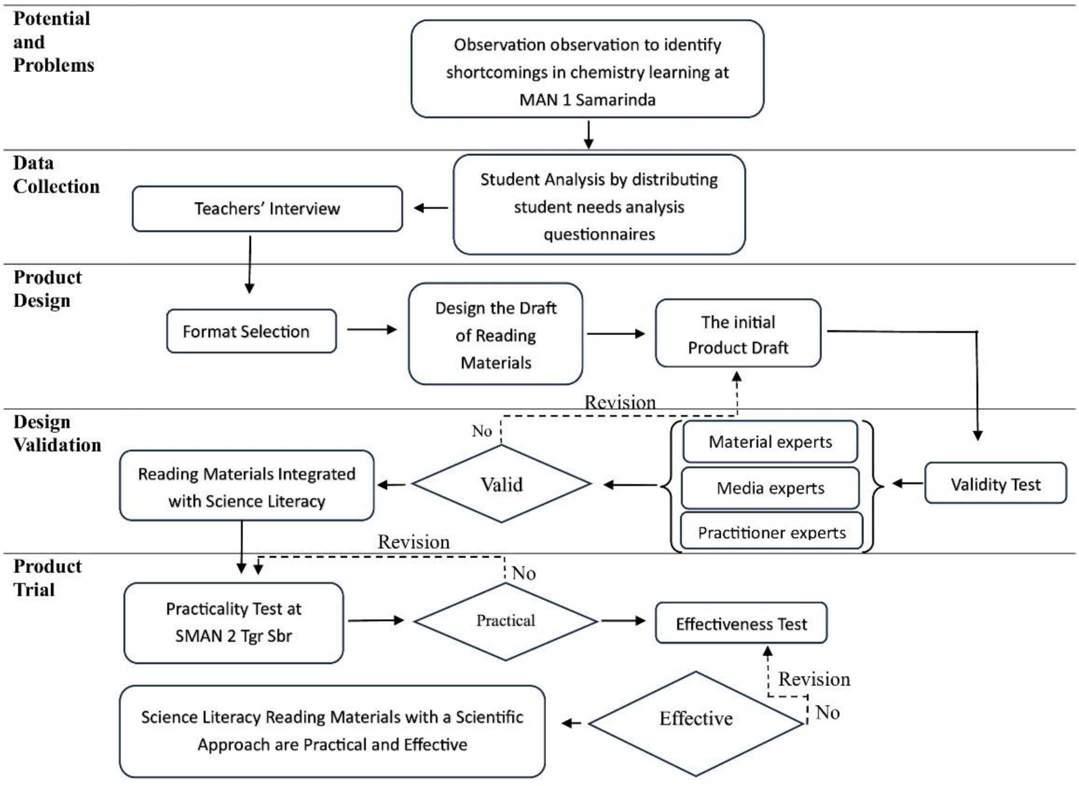

Figure 1. Research And Development Model Scheme

Several instruments were used to evaluate the feasibility of the developed product. Expert validation sheets were employed to assess the validity of the reading materials in terms of content, language, presentation, and graphics. Validity refers to the degree to which a tool measures what it is intended to measure (Andersson et al., 2024). These sheets were evaluated by two material experts, two media experts, and two practitioner experts, with indicators referring to the criteria stated in Permendikbud No. 8/2016. The validation results were presented in percentage scores. The formula used is as follows:

$$\text{Content Validity Achievement} = \frac{\text{Total expert score}}{\text{Total maximum score}} \times 100\%$$

For data analysis, expert validation results were converted into percentage values and interpreted using the criteria by Novianti & Susilowibowo (2019). The percentage of student validation scores is interpreted according to Table 1.

Table 1. Validity Interpretation Criteria

Percentage	Criteria
$75\% < X \leq 100\%$	Very valid
$50\% < X \leq 75\%$	Valid
$25\% < X \leq 50\%$	Less Valid
$0\% < X \leq 25\%$	Invalid

To support the needs analysis process, two additional instruments were used a student questionnaire that identified learning preferences, media needs, and learning difficulties, and a teacher interview guide designed to explore instructional challenges and curriculum alignment. The practicality of the product was assessed through a teacher practicality questionnaire, a student practicality questionnaire, and observation sheets documenting teacher and student activities during the implementation phase. These instruments measured readability, ease of use, usefulness, and the overall quality of implementation.

To determine the effectiveness of the reading materials, a science literacy test (pretest and posttest) was developed, which included items measuring three dimensions of science literacy: content (knowledge), context (application), and competencies (interpreting data and analyzing phenomena). To find out the score of students' science literacy per aspect can be calculated using the following formula:

$$X = \frac{\text{Total score}}{\text{Total maximum score per aspect}} \times 100$$

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Students' science literacy scores are interpreted according to Table 2.

Table 2. Interpretation Criteria for the Science Literacy Scores

Interval Score	**Criteria**
86-100	Very Good
72-85	Good
58-71	Good Enough
43-57	Low
≤ 43	Very Low

A student response questionnaire was also used to collect data on material clarity, student motivation, media usability, and learning engagement. Before being used in the study, all instruments underwent a validation process consisting of expert judgment for content validity, revisions based on feedback, and reliability testing, particularly for the pretest–posttest instrument, which was analyzed using Cronbach's Alpha in SPSS. Only validated and reliable instruments were used for data collection. Practicality data from questionnaires and observations were analyzed descriptively using percentage scores and interpreted according to the categories proposed by Akbar (2017) and Akbar & Usman, 2006). The percentage of practicality is interpreted according to Table 3.

Table 3. Practicality Questionnaire Interpretation Of Reading Materials By Teachers And Students

Percentage (%)	**Category**
$80 < P \leq 100$	Very Practical
$60 < P \leq 80$	Practical
$40 < P \leq 60$	Average
$20 < P \leq 40$	Less Practical
$P \geq 20$	Not Practical

The percentage of teacher and student activities during learning was calculated using the formula by (Akbar & Usman, 2006) as follows:

$$X = \frac{\text{Average sum of total scores}}{\text{Total maximum score}} \times 100\%$$

The percentage of student learning activities is interpreted according to Table 4.

Table 4. Interpretation Category for Student Learning Activities

Percentage (%)	**Category**
$75 < X \leq 100$	Very Good
$50 < X \leq 75$	Good
$25 < X \leq 50$	Enough
$0 < X$	Poor

The percentage of teacher activity was then interpreted according to Table 5.

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Table 5. Interpretation Category for Teacher Learning Activities

Percentage (%)	**Category**
0-20	Not Applied
21-40	Less Applied
41-60	Moderately Applied
61-80	Applied
81-100	Highly Applied

Effectiveness was analyzed using N-gain to measure improvement between pretest and posttest, and Effect Size (Cohen's d) to determine the magnitude of the treatment effect, while student response data were interpreted using criteria from Zahidah et al., (2023). The effectiveness of reading materials was analyzed by statistical tests of N-gain and Effect Size using the SPSS program supported by student response questionnaire data analyzed using the Microsoft Excel program (Hake, 2002) . The formula used is as follows:

$$\text{N-Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Prestest score}}$$

N-gain values are categorized according to Table 6.

Table 6. The Interpretation of N-Gain Index

N-Gain Index	**Interpretation**
$G > 0,7$	High
$0,3 < G \leq 0,7$	Moderate
$G \leq 0,3$	Low

Effect size calculated using the formula:

$$\text{Effect Size (ES)} = \frac{\text{Mean of posttest} - \text{Mean of pretest}}{\text{Standard deviation}}$$

Effect Size values are categorized according to Table 7.

Table 7. The Interpretation of Effect Size (ES)

Value	Interpretation
$ES \leq 0,15$	Very Small
$0,15 < ES \leq 0,40$	Small
$0,40 < ES \leq 0,75$	Moderate
$0,75 < ES \leq 1,10$	Large
$ES > 1,10$	Very Large

The percentage of student responses is categorized according to Table 8.

Table 8. Interpretation Category for Student Response to Learning

Percentage (%)	**Category**
$80 < RS \leq 100$	Very Good
$60 < RS \leq 80$	Good
$40 < RS \leq 60$	Enough
$20 < RS \leq 40$	Fair
$RS \leq 20$	Poor

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Additionally, qualitative data from teacher interviews and open-ended student responses were analyzed using thematic coding to identify learning needs, challenges, and suggestions for product improvement. Through this combination of quantitative and qualitative analyses, the study systematically measured the validity, practicality, and effectiveness of the digital reading materials integrated with science literacy and the scientific approach.

RESULTS AND DISCUSSION

This development research produced digital reading materials integrated with science literacy through a scientific approach designed to support Grade XI students in learning about factors affecting reaction rates. The results at each stage of the research are presented and discussed as follows: The initial needs analysis at MAN 1 Samarinda revealed several instructional challenges. Students reported difficulties understanding reaction rate concepts due to abstract explanations and the absence of contextual learning materials. Teachers relied mainly on e-books projected in class, which were not aligned with current curriculum demands nor integrated with scientific approach stages. These findings are consistent with (Prayunisa, 2022) , who reported that chemistry learning often becomes less engaging when learning media are limited.

The absence of literacy-oriented materials supports the argument that students do not yet engage in deep learning, as they lack opportunities to observe, analyze, interpret, and communicate scientific ideas. This situation aligns with national studies showing that Indonesian students' science literacy remains low (Suwandi & Supriyanti, 2021; Wardi & Mukhayyarotin, 2023). Therefore, the development of contextual and inquiry-based reading materials is essential.

The needs analysis strengthened the rationale for developing new learning materials. Questionnaire results showed that 100% of students owned smartphones and 96.6% were permitted to bring smartphones or laptops to school, and 72.6% reported using the internet during chemistry lessons. Although students were allowed to bring devices, they still required a stable internet connection to access existing digital resources, as many e-books depend on continuous connectivity (Masuudi et al., 2024). Despite having access to technology, learning remained dominated by conventional texts. A total of 69.9% of students stated that the media used in chemistry learning were not interesting, 60.3% found available learning resources difficult to understand, and

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63% felt that the content and visuals of existing materials were unattractive. Furthermore, 90.4% indicated that they needed alternative learning media beyond what teachers typically provided, while 82.2% believed that hands-on practice was the most effective way to understand chemistry concepts. These findings emphasize the urgency of developing digital reading materials that are engaging, contextual, and capable of supporting visualization and data interpretation, needs that are also highlighted in studies by Indriani et al., (2023) & Khoirunnisa & Prajawinanti (2023).

Teacher interviews further revealed that students often struggle with chemistry, particularly with reaction rate concepts, due to the combination of abstract ideas and mathematical requirements. This aligns with Sanjiwani et al., (2020), who reported that students experience significant difficulty when learning chemistry topics involving conceptual reasoning and formula-based calculations. To address these challenges, the developed e-book incorporates practice questions and inquiry-based tasks in the "Let's Experiment" section. Teachers also reported that chemistry lessons often feel less enjoyable because learning media are rarely used and innovative approaches are not consistently applied, even though varied and visually appealing media are essential for helping students understand and retain complex content (Ummahati & Suprihatiningrum, 2024; Widarti et al., 2023) . In the reaction rate chapter, concepts such as collision theory and the application of factors influencing reaction rates require contextual examples to support comprehension (Sugiharti & Hasibuan, 2017). Teachers noted that students tend to be more active during practicum sessions than during traditional instruction, indicating that inadequate media limit student engagement. In this context, integrating a scientific approach into digital learning materials offers a promising solution, as such an approach allows students to explore concepts through observing, questioning, experimenting, reasoning, and communicating, processes that enhance active involvement and foster intrinsic motivation to learn science independently (Saputro et al., 2020). Overall, the results of the needs analysis justify the development of science-literacy-integrated digital reading materials that are accessible, engaging, and aligned with students' learning characteristics.

At this stage, the author designs the best teaching modules to improve or create new schemes as solutions to the above problems (Kusumowardhani & Maharani, 2022).The reading material format consists of a cover, material on factors affecting the

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reaction rate, and learner activities. The format of the developed reading material contains science literacy and scientific approaches. Science literacy in this reading material consists of knowledge aspects, context aspects, and competencies aspects, while the scientific approach in the developed reading material consists of aspects of observing, questioning, collecting data information, reasoning, and communicating.

The initial design of the science literacy–integrated reading material was developed as an electronic book (e-book) comprising several components to support students' understanding of reaction-rate concepts while simultaneously promoting scientific literacy skills. The main components of the product include the cover page, concept map, contextual exploration activities, comprehension tests, and author information. Each component was designed to support different aspects of scientific literacy, including context, knowledge, and competencies.

1) Cover
2) Concept map

(a) (b)

Figure 2. (a) Cover of the science literacy–integrated e-book; (b) Concept map illustrating the relationship among reaction rate concepts.

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3) Chemically Related Information

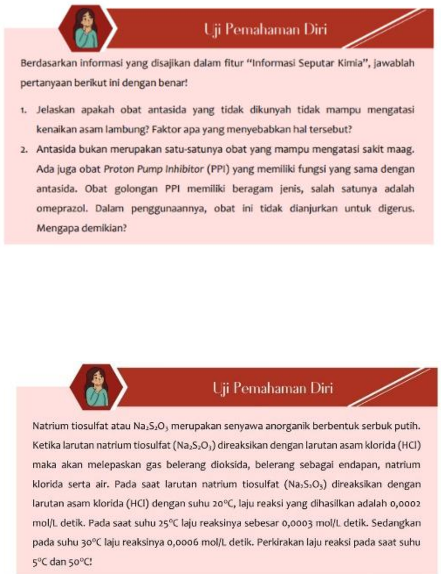
(a)

4) Explore!

(b)

Figure 3. (a) Chemistry-related information presented in the e-book; (b) "Let's Explore" section designed to introduce contextual problems related to students' daily experiences (context dimension of scientific literacy).

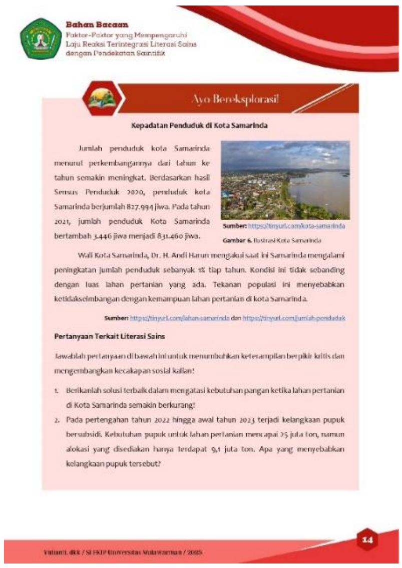
5) Comprehension Test



(

a)

6) The Questions Related to Science Literacy



(b)

Figure 4. (a) Self-understanding test designed to assess students' scientific competencies;

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(b) science literacy–based questions embedded in the "Let's Explore" section to support the knowledge dimension.

Figures 2, 3 and 4 are examples of these design choices were meant to promote deep learning, as students do not merely read but are guided to explore, analyze, and interpret scientific information. The inclusion of contextual tasks and data interpretation is aligned with recommendations by (Suprihatin et al., 2023) , who highlight the importance of inquiry-based stages in fostering conceptual understanding.

The results of validation phases 1 and 2 by validators 1 and 2, material experts, are presented in Table 9.

Table 9. Validation Result by Validators 1 and 2 Material Experts

No	Aspect	Phase 1				Phase 2			
		Validator 1	Validator 2	Average	Criteria	Validator 1	Validator 2	Average	Criteria
1	Content Feasibility	75%	81,25%	78,13%	Valid	87,5%	93,75%	90,63%	Very Valid
2	Language Use	75%	87,50%	81,25%	Very Valid	87,5%	100%	93,75%	Very Valid
3	Component Presentation	75%	78,57%	76,79%	Valid	82,14%	96,43%	89,29%	Very Valid

Table 9 presents the validation result by material experts according to research by Novianti & Susilowibowo (2019). Validation scores improved from "valid" in Phase 1 to "very valid" in Phase 2 after revisions. Material experts emphasized clarity of concepts, accuracy of scientific content, and coherence of presentation. The high scores indicate that the reading materials met curricular and scientific standards.

The results of validation phases 1 and 2 by validators 1 and 2 media experts are presented in Table 10.

Table 10. Validation Result by Validators 1 and 2 Media Experts

No.	Aspect	Phase 1				Phase 2			
		Validator 1	Validator 2	Average	Criteria	Validator 1	Validator 2	Average	Criteria
1	Graphics	93,75%	89,58%	91,67%	Very Valid	97,92%	97,92%	98,96%	Very Valid
2	Language Use	100%	100%	100%	Very Valid	93,75%	100%	96,88%	Very Valid

Table 10 presents validation result by media experts according to research by Novianti & Susilowibowo (2019). Media experts evaluated layout, graphics, readability, and navigation. The product achieved "very valid" criteria in both phases. The improvements, such as clearer infographics and consistent typography, aligned with multimedia learning principles that increase readability and attention.

The results of validation phases 1 and 2 by validators 1 and 2 practitioner experts, are presented in Table 11.

Table 11. Validation Result by Validators 1 and 2 Practitioner Experts

No.	Aspect	Validator 1	Validator 2	Average	Criteria
1	Content Feasibility	100%	100%	100%	Very Valid
2	Language Use	100%	100%	100%	Very Valid
3	Component Presentation	92,86%	100%	96,43%	Very Valid
4	Graphics	95,83%	100%	97,92%	Very Valid

Table 11 presents validation result by practitioner experts according to research by Novianti & Susilowibowo (2019). Practitioners rated the product as "very valid," confirming its readiness for classroom application. Their feedback supports Andersson et al., (2024), who state that high validity enhances a product's credibility and usability. The consistent "very valid" ratings demonstrate that the product is structurally strong, pedagogically appropriate, and feasible for implementation. This meets the novelty requirement, as few existing reading materials explicitly combine science literacy with a scientific approach.

The developed e-book was evaluated by expert validators comprising a materials expert, a media expert, and a practitioner. Their feedback informed improvements to the product before further implementation. The suggestions provided by the validators, along with the researchers' revisions, are summarized in Table 12.

Table 12. Suggestions and Revisions from Expert Validators

Suggestion (Notes)	Before	After
Improving the clarity of experiments on reaction rate factors (material expert)	Several experiments and graphs (surface area and concentration effects) were confusing or not feasible to implement in school settings.	Experiments and graphs were revised using feasible procedures and clearer visual representations to prevent misconceptions.
Revising scientific terminology and concepts related to catalysts (material expert)	Some terms and explanations related to catalysts (e.g., enzymes and reaction products) were inaccurate or ambiguous.	Scientific terminology and explanations were corrected to align with accepted chemistry concepts.
Enhancing visual	Font size, color contrast,	Font types and sizes were adjusted,

Suggestion (Notes)	Before	After
readability and layout of learning materials (media expert)	formulas, and worksheet layout reduced readability and visual appeal.	formulas highlighted, color contrast improved, and worksheets redesigned for better readability.
Improving accessibility of digital features (media expert)	Some URLs could not be accessed, and feature labels were unclear.	Broken links were replaced with accessible URLs and feature labels were revised for clearer navigation.
Adding explanatory labels to experimental graphs (practitioner)	Graphs in the surface area experiment lacked sufficient explanation, making them difficult for students to interpret.	Graphs were supplemented with clear labels and descriptions to support student understanding.

Table 12 summarizes the suggestions provided by the expert validators regarding improvements to the developed e-book (Cahyono et al., 2025) . These suggestions included revisions to experimental procedures, clarification of scientific terminology, improvements in visual design, enhanced digital accessibility, and the addition of explanatory information to support students' understanding. All recommendations were carefully considered and incorporated into the product revision process to ensure that the e-book meets both pedagogical and scientific standards. One of the major revisions suggested by the validators concerned the feasibility of the experimental activity. The initial experiment was considered difficult to implement in a typical school laboratory setting. Therefore, the experiment was redesigned using simpler materials and procedures to make it more applicable in classroom practice. An example of the revision showing the comparison between the initial and revised versions of the experiment is presented in Figure 6.

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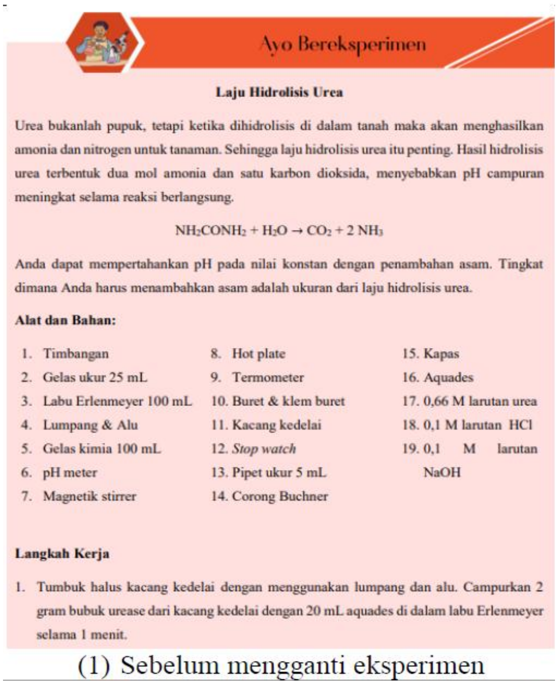

Ayo Bereksperimen

Laju Hidrolisis Urea

Urea bukanlah pupuk, tetapi ketika dihidrolisis di dalam tanah maka akan menghasilkan amonia dan nitrogen untuk tanaman. Sehingga laju hidrolisis urea itu penting. Hasil hidrolisis urea terbentuk dua mol amonia dan satu karbon dioksida, menyebabkan pH campuran meningkat selama reaksi berlangsung.

$$NH_2CONH_2 + H_2O \rightarrow CO_2 + 2\ NH_3$$

Anda dapat mempertahankan pH pada nilai konstan dengan penambahan asam. Tingkat dimana Anda harus menambahkan asam adalah ukuran dari laju hidrolisis urea.

Alat dan Bahan:

1. Timbangan
2. Gelas ukur 25 mL
3. Labu Erlenmeyer 100 mL
4. Lumpang & Alu
5. Gelas kimia 100 mL
6. pH meter
7. Magnetik stirrer
8. Hot plate
9. Termometer
10. Buret & klem buret
11. Kacang kedelai
12. *Stop watch*
13. Pipet ukur 5 mL
14. Corong Buchner
15. Kapas
16. Aquades
17. 0,66 M larutan urea
18. 0,1 M larutan HCl
19. 0,1 M larutan NaOH

Langkah Kerja

1. Tumbuk halus kacang kedelai dengan menggunakan lumpang dan alu. Campurkan 2 gram bubuk urease dari kacang kedelai dengan 20 mL aquades di dalam labu Erlenmeyer selama 1 menit.

(1) Sebelum mengganti eksperimen

Figure 6. Example of experimental activity revision in the developed e-book based on expert validation: (a) experiment before revision

Ayo Bereksperimen!

Pengaruh Konsentrasi Terhadap Laju Reaksi

Alat dan Bahan:

1. Balon 3 buah
2. Soda kue ($NaHCO_3$)
3. Asam cuka
4. Botol plastik 3 buah
5. *Stopwatch*
6. Timbangan
7. Corong
8. Label

Langkah Kerja:

1. masukkan soda kue sebanyak 5, 10, dan 15 gram ke dalam masing-masing balon.
2. Masukkan sebanyak 50 mL larutan asam cuka ke dalam botol A, B, dan C.
3. Masukkan masing-masing balon ke leher botol (hindari tumpahnya soda kue ke dalam botol saat memasukkan balon).
4. Masukkan soda kue dari balon ke dalam botol secara bersamaan dan nyalakan *stopwatch*.

(2) Setelah mengganti eksperimen

Figure 6. Example of experimental activity revision in the developed e-book based on expert validation: (b) experiment after revision.

Figure 6 provides an example of the improvement process carried out by researchers based on input from expert validators, in this case, improving the research tools and materials items that must be included.

The practicality score results per indicator are presented in Table 13.

Table 13. Average Score of the Practicality Questionnaire of Reading Materials by Teachers and Students

No.	Indicator	Teacher		Student	
		Value	Criteria	Value	Criteria
1	Readability	93,33%	Very Practical	83,39%	Very Practical
2	Easy to Use	97,14%	Very Practical	83,53%	Very Practical
3	Usefulness	97,14%	Very Practical	81,03%	Very Practical
Average		95,87%	Very Practical	82,65%	Very Practical

Table 13 presents average score of the practicality questionnaire of reading materials by teachers and students according to Akbar (2017). Both teacher and student practicality scores fell into the “very practical” category. Teachers found the materials easy to use, clear, and helpful for supporting lesson implementation. Students perceived the materials as engaging, accessible, and supportive of independent learning. This is because reading materials function as learning media that are easily accessible, suitable for independent and collaborative learning, also the content is presented communicatively (Pratiwi et al., 2019a) . Reading materials that contain various assignments can encourage student activeness and interest students to learn and experience directly the material being studied (S.Sirate & Ramadhana, 2017) . Futhermore, a good layout design helps make it easier for students to identify relevant information because the layout of a good textbook affects the visual level, readability, and student attention while reading (Afersa et al., 2022).

Practicality of reading materials integrated with science literacy is supported by data on teacher and student activities during classroom learning. Data on teacher and student activities during the learning process in the classroom are shown in Figure 7.

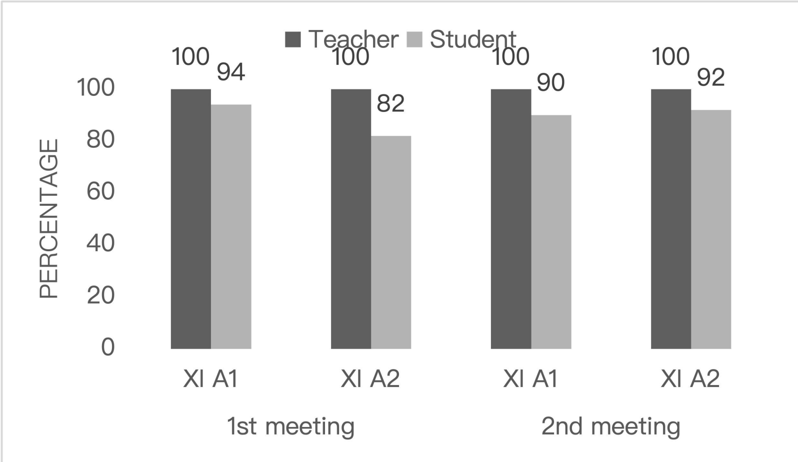

Figure 7. Percentage of Teacher and Student Activities

Figure 7 presents data on teacher and student activities during classroom learning according to Akbar & Usman (2006). These findings support Pratiwi et al., (2019), who argue that literacy-oriented learning materials improve student engagement and help learners connect content with real-life contexts. The high teacher activity score (100%) indicates that the materials were implemented consistently, while the student activity score (89.5%) shows strong learner engagement. Reading materials are said to be practical if the learning is well implemented as planned in the teaching module, and facilitates its users in learning (Yusuf et al., 2023).

High practicality aligns with the product's design purpose: facilitating inquiry and active learning through structured literacy tasks. Students' active engagement suggests alignment with deep learning characteristics, particularly exploration, reasoning, and communication. The average score of science literacy of students from class XI A1 and XI A2 is obtained from the pretest and posttest scores in Table 14.

Table 14. Student Science Literacy Score

Aspect	Class	Pretest		Posttest	
		Score	Criteria	Score	Criteria
Knowledge	XI A1	10	Very Low	77	Good
	XI A2	13	Very Low	61	Good Enough
Contexts	XI A1	16	Very Low	50	Low
	XI A2	15	Very Low	61	Good Enough
Competencies	XI A1	2	Very Low	26	Very Low
	XI A2	3	Very Low	29	Very Low

Table 14 presents science literacy score according to Erniwati et al., (2020). Posttest results showed improvements in all three aspects of science literacy (knowledge,

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context, competencies). Although competence scores remained low in absolute terms, the increase was statistically meaningful. Furthermore, the N-gain and Effect Size statistical tests were conducted. The N-gain and Effect Size values are presented in Table 15.

Table 15. N-Gain and Effect Size Values

Aspect	**Class**	**N-gain Value**	**Category**	**Average**	**Effect Size Value**	**Category**	**Average**
Knowledge	XI A1	0,6	Moderate	0,4 (moderate)	2,6	Very Large	1,7 (very large)
	XI A2				0,7	Moderate	
Contexts	XI A1	0,4	Moderate		0,9	Large	
	XI A2				1,7	Very Large	
Competencies	XI A1	0,2	Low		0,9	Large	
	XI A2				3,3	Very Large	

Table 15 presents N-gain and effect size values according to Fauziah et al., (2024) and Kurniawan & Rahman (2020). The results show that the use of science-literacy-integrated reading materials effectively improved students' science literacy across all measured aspects. In the knowledge aspect, both classes achieved an N-gain of 0.6 (moderate), while the effect size values were 2.6 (very large) for class XI A1 and 0.7 (moderate) for class XI A2. These findings indicate that the reading materials substantially enhanced understanding, with a stronger impact on class XI A1. This difference aligns with the student activity data in Figure 6, which shows that students in class XI A1 were more actively engaged during learning compared to those in XI A2, suggesting that higher engagement contributed to greater learning gains. In the context aspect, both classes obtained an N-gain of 0.4 (moderate), with effect sizes of 0.9 (large) in XI A1 and 1.7 (very large) in XI A2. The higher effect size in XI A2 may be attributed to the teacher providing more real-life examples related to science and technology, allowing students to better connect the content with everyday situations. Meanwhile, in the competency aspect, both classes achieved a low N-gain of 0.2 but demonstrated large and very large effect sizes (0.9 for XI A1 and 3.3 for XI A2), indicating that although the improvement in scores was modest, the intervention still had a substantial impact on students' ability to interpret data and analyze scientific phenomena.

Overall, the average N-gain score of 0.4 falls into the moderate category,

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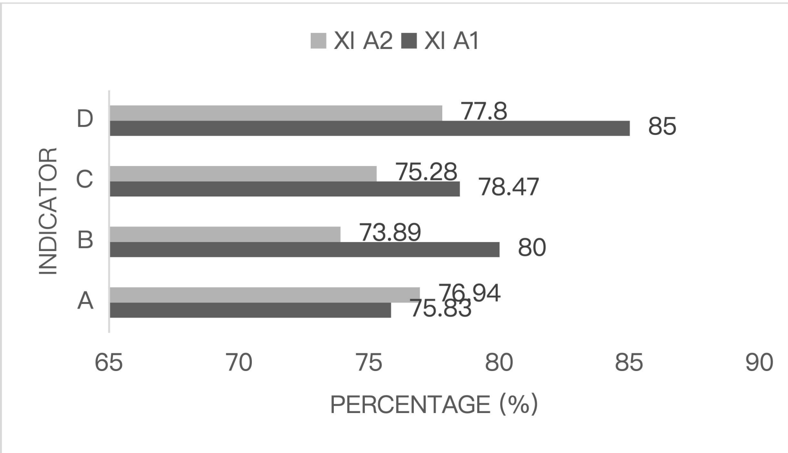
demonstrating that students' science literacy improved meaningfully after using the reading materials. The average effect size of 1.7, categorized as very large, further confirms that the reading materials exerted a strong influence on enhancing literacy skills across both classes. This combination moderate N-gain but very large effect size indicates that while mastery has not yet been fully achieved, the intervention significantly strengthens students' conceptual understanding and literacy performance. These findings are consistent with previous research by Fauziah et al., (2024) , who reported that digital contextual chemistry materials effectively enhance students' literacy and reasoning abilities.

In this study, student response questionnaires were analyzed by statistical tests using the Microsoft Excel program. The results of the student response score analysis are shown in Figure 8.



Description:
A: Ease of understanding the material
B: Student Activeness
C: Use of media
D: Student interest

Figure 8. Average Percentage of Student Response Scores

Figure 8 presents student response scores according to Zahidah et al., (2023). Student responses were mostly in the "Good" and "Very Good" categories, particularly in interest and engagement. Students appreciated the contextual examples and scientific approach-based activities. The improvement in students' science literacy scores demonstrates that integrating content, context, and competencies within the reading materials effectively promotes deeper conceptual understanding. The consistently strong effect size further indicates that the developed materials support learning more powerfully than traditional instruction, particularly by engaging students in inquiry-oriented activities aligned with scientific-approach stages. Nevertheless, the relatively low gains in competency aspects suggest that students still require more structured opportunities to practice interpreting data, analyzing phenomena, and constructing

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scientific explanations, areas that warrant refinement in future iterations of the product. It is consistent with the research by Cahyani et al., (2025) that there is a need for strategic efforts, such as providing intensive guidance to train skills in interpreting data and explaining scientific phenomena comprehensively.

Overall, the findings show that the developed digital reading materials are valid, practical, and effective for classroom use. The integration of deep learning principles, science literacy dimensions, and the scientific approach successfully enhances student engagement and improves understanding of reaction rate concepts. This study contributes a novel prototype of digital reading materials that explicitly incorporate science literacy components, are aligned with deep learning processes, apply inquiry-based scientific stages, and are contextualized to students' real-world environments, making the materials relevant and pedagogically robust. Despite these strengths, several limitations must be acknowledged. The competency aspect of literacy still shows relatively low absolute scores, indicating the need for additional tasks focused on data interpretation and scientific reasoning. Moreover, the developed materials address only one subtopic, factors influencing reaction rates, so expanding the content to other chemistry concepts may enhance their overall impact. According to Juwitasari & Suyono (2023) subtopics that can be added is the relationship between reaction rate and concentration, reaction rate equations, collision theory, and activation energy. Finally, the implementation involved only two schools, which may limit the generalizability of the findings; thus, broader trials are recommended for future research.

CONCLUSION

Based on the results of this study, the digital reading materials integrated with science literacy and supported by a scientific approach were found to be valid, practical, and effective for use in chemistry learning, particularly on the topic of factors affecting reaction rates. Expert validations confirmed that the materials meet content, linguistic, graphic, and pedagogical standards. Practicality tests showed that both teachers and students perceived the materials as easy to use, engaging, and supportive of learning activities. The effectiveness results, indicated by moderate N-gain scores and a very large effect size, demonstrate that the materials significantly improve students' science literacy, especially in the aspects of knowledge and context. These findings suggest that

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integrating science-literacy components and scientific-approach stages can promote deeper conceptual understanding and support the development of inquiry skills. The product contributes to the availability of digital learning resources aligned with deep learning principles and the Merdeka Curriculum. However, the competency aspect of literacy still requires further development, and future studies should expand the scope of materials and test them in broader educational settings.

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