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Development of Instagram-Based Digital Chemistry Teaching Materials Integrated with Batak Toba Ethnopedagogy for Acid–Base Learning

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Abstract

Scientific literacy remains one of the major challenges in chemistry education in Indonesia, particularly in acid–base learning, which involves abstract concepts and complex representations. At the same time, the widespread use of social media among students provides opportunities to develop innovative digital learning resources that are contextual and engaging. This study aimed to develop Instagram-based chemistry digital teaching materials integrated with Batak Toba ethnopedagogy for acid–base learning and to evaluate their validity and practicality. The study employed a Research and Development (R&D) approach using the ADDIE model, limited to the Analysis, Design, and Development stages. The needs analysis involved three chemistry teachers and 30 senior high school students. The developed product was validated by three expert validators and tested through a limited practicality trial involving 17 Grade XI students from MAN 1 Medan. Data were collected using interview guidelines, needs analysis questionnaires, validation sheets, and practicality questionnaires and were analyzed using percentage techniques. The results showed that the developed teaching materials achieved a material validity score of 92.00% and a media validity score of 91.85%, both categorized as very valid. The limited practicality trial resulted in an average practicality score of 76.32%, categorized as practical. These findings indicate that the developed teaching materials are valid and practical for supporting acid–base learning. The integration of Batak Toba ethnopedagogy through the Mangongkal Holi tradition provides a contextual learning environment that connects chemistry concepts with students' cultural experiences. Therefore, the developed teaching materials have the potential to support culturally responsive chemistry learning and strengthen students' scientific literacy.

Keywords: acid–base learning; Batak Toba ethnopedagogy; chemistry digital teaching materials; Instagram; scientific literacy

Introduction

Scientific literacy is one of the essential competencies that students must possess in the twenty-first century. Scientific literacy is not limited to the mastery of scientific concepts but also encompasses the ability to explain scientific phenomena, interpret data and scientific evidence, and apply scientific knowledge when making decisions regarding real-world issues. This competence has become an important indicator of a country's educational quality and is periodically assessed through the Programme for International Student Assessment (PISA) conducted by the Organisation for Economic Co-operation and Development (OECD). The PISA 2022 results revealed that Indonesian students' scientific literacy performance remained below the OECD average, with an average science score of 383 compared to the OECD average of 485 (OECD, 2023). This condition is further exacerbated by the fact that the score declined by 13 points compared to the PISA 2018 results (Bilad et al., 2024), indicating that strengthening scientific literacy remains a critical and urgent challenge in science education in Indonesia.

Chemistry is one of the subjects that plays a significant role in the development of scientific literacy. Chemistry learning requires not only conceptual understanding but also the ability to connect macroscopic, submicroscopic, and symbolic representations in an integrated manner. A systematic review of the literature indicates that Indonesian students' scientific literacy in chemistry learning consistently remains at a low level (Murti et al., 2024). This issue is partly attributed to the abstract nature of chemistry concepts and the mathematical reasoning required to understand them. Acid-base chemistry is one of the topics that frequently leads to misconceptions because it involves complex conceptual representations, including acid-base theories, pH, ionization processes, and the interpretation of everyday phenomena.

In addition to conceptual challenges, the rapid development of digital technology has created new demands for learning resources. Contemporary students belong to a digital generation characterized by extensive engagement with technology, the internet, and social media. Consequently, teaching materials that rely solely on printed textbooks often struggle to attract students' attention and sustain their learning engagement. One approach that addresses this challenge is microlearning, a learning strategy that delivers content in small, focused, and short-duration units designed to achieve specific learning objectives. This approach is aligned with cognitive load theory and has been shown to support deeper conceptual understanding, learner autonomy, and long-term retention (Monib et al., 2024). Therefore, digital learning media adopting microlearning principles provide a promising alternative for contemporary education.

One digital platform widely used by adolescents is Instagram. The platform offers various visual features, such as carousel posts, reels, stories, and interactive quizzes, enabling learning materials to be presented in an engaging, concise, and flexible manner consistent with microlearning principles. A Scopus-based systematic review confirmed that social media platforms, including Instagram, consistently enhance students' motivation in chemistry learning at both secondary and higher education levels (Widarti et al., 2023). Furthermore, a quasi-experimental study demonstrated that Instagram-based learning media significantly improved students' motivation and learning outcomes in reaction rate topics (Widarti et al., 2024). Instagram-based learning media have also been reported to possess high validity and considerable potential as self-directed learning resources for students (Rengganis, 2025).

On the other hand, chemistry learning should be developed in ways that are more contextual and closely related to students' everyday lives. One approach that can be employed to achieve this objective is ethnopedagogy. Ethnopedagogy is an educational approach that utilizes cultural values, cultural practices, and local wisdom as learning resources. This approach is consistent with the implementation of the Merdeka Curriculum, which emphasizes contextual learning based on local contexts (Hasibuan et al., 2023). In chemistry education, ethnochemistry serves as a bridge between scientific concepts and local cultural practices, enabling students to understand chemistry through contexts that are relevant to their daily lives and cultural environments (Daulay et al., 2025). Empirical studies have shown that integrating local wisdom into learning revitalizes ethnopedagogical practices, increases student motivation, and strengthens conceptual understanding by connecting learning materials to real-life contexts (Sakti et al., 2024). Empirical evidence indicates that ethnoscience-based learning contributes positively to students' scientific literacy, critical thinking skills, learning motivation, and conceptual understanding by integrating local wisdom into science learning contexts (Sari et al., 2025).

North Sumatra Province, particularly the Batak Toba community, possesses various cultural practices that can potentially be integrated into chemistry learning. Qualitative studies have revealed a close relationship between Batak Toba culture and chemistry, where cultural practices contain chemical elements in their preparation, mixing, and utilization processes (Simanjuntak et al., 2024). One cultural practice that can be utilized is the Mangongkal Holi tradition. This tradition involves the use of natural materials such as kaffir lime, turmeric, and lime-based compounds that are closely related to acid-base concepts. Utilizing such local cultural contexts has the potential to connect chemistry concepts with students' real-life experiences while simultaneously strengthening local cultural identity within the learning process.

Although numerous studies have investigated digital teaching materials, social media-based learning, and ethnopedagogy separately, research integrating these three aspects into the development of Instagram-based chemistry digital teaching materials for acid–base learning remains limited. Previous studies have developed local wisdom-based acid–base learning resources, such as interactive e-modules contextualized through the Poto Wua Ta'a tradition in Sikka Regency (Tiring & Janggo, 2025) and ethnopedagogical chemistry textbooks based on Batak Toba local wisdom through the Dekke Naniura context (Silaban et al., 2025). These studies demonstrated that the integration of local wisdom into chemistry learning can produce feasible and contextually relevant learning resources. However, such developments have primarily focused on e-modules and textbook-based learning resources. The integration of Batak Toba ethnopedagogy into social media-based microlearning environments, particularly Instagram, remains underexplored. The novelty of this study lies in the integration of Batak Toba ethnopedagogy, scientific literacy activities, and Instagram-based microlearning within a single chemistry digital teaching material for acid–base learning. To address this gap, the present study was guided by the following research questions:

1. How valid are Instagram-based chemistry digital teaching materials integrated with Batak Toba ethnopedagogy for acid–base learning?
2. How practical are the developed teaching materials based on students' responses during a limited trial?

Therefore, this study aimed to develop Instagram-based chemistry digital teaching materials integrated with Batak Toba ethnopedagogy for acid–base learning and to evaluate the validity and practicality of the developed product through expert validation and a limited practicality trial.

This study is expected to produce valid, contextual, and learner-centered digital teaching materials that align with the characteristics of twenty-first-century learners while contributing to the advancement of culturally responsive chemistry education and the strengthening of scientific literacy in Indonesia.

Method

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). However, the present study was limited to the Analysis, Design, and Development stages because its primary objective was to produce a valid and practical prototype of Instagram-based chemistry digital teaching materials integrated with Batak Toba ethnopedagogy. The Implementation and Evaluation stages will be conducted in subsequent studies to investigate the effectiveness of the developed product in improving students' scientific literacy and learning outcomes. The research procedures adopted in this study are presented in Figure 1.

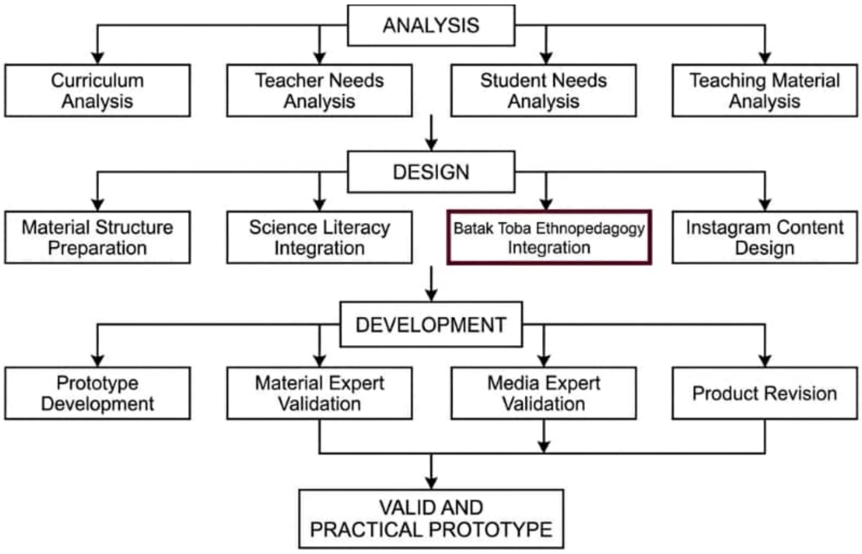

Figure 1. Research Flowchart of Instagram-Based Chemistry Digital Teaching Material Development Integrated with Batak Toba Ethnopedagogy

As shown in Figure 1, the development process consisted of three stages, namely Analysis, Design, and Development. The Analysis stage included curriculum analysis, teacher needs analysis, student needs analysis, and teaching material analysis. The Design stage involved preparing the material structure, integrating scientific literacy components, incorporating Batak Toba ethnopedagogy, and designing Instagram learning content. The Development stage focused on prototype development, expert validation, product revision, and limited practicality testing to produce a valid and practical prototype.

Analysis Stage

The Analysis stage aimed to identify the need for developing Instagram-based digital teaching materials. This stage consisted of curriculum analysis, teacher needs analysis, student needs analysis, and teaching material analysis. Curriculum analysis was conducted based on the Merdeka Curriculum for Grade XI Chemistry, particularly on acid–base topics. The analysis focused on learning outcomes related to students' understanding of acid–base concepts, interpretation of scientific phenomena, and application of scientific reasoning in everyday contexts.

Teacher needs analysis involved three chemistry teachers from SMA Negeri 2 Percut Sei Tuan, SMA Negeri 9 Medan, and MA Tahfizh Azhar Centre Labuhanbatu Utara. Semi-structured interviews were conducted to identify challenges in acid–base instruction, the availability of teaching materials, the integration of local culture into chemistry learning, and the need for digital learning resources.

Student needs analysis was conducted using a questionnaire administered to 30 senior high school students. The questionnaire explored students' learning preferences, experiences in learning acid–base concepts, use of social media, and expectations regarding digital learning resources.

Teaching material analysis was conducted to identify the strengths and limitations of existing acid–base learning resources used in schools. The analysis focused on content presentation, contextual relevance, scientific literacy integration, and the incorporation of local cultural contexts. The results indicated the need for digital teaching materials that integrate chemistry concepts, scientific literacy, and Batak Toba local wisdom through an accessible social media platform.

Design Stage

The Design stage involved planning the structure, content, and visual appearance of the teaching materials. Ethnopedagogy served as the primary educational framework guiding the instructional design, while ethnochemistry was utilized as a contextual approach to connect acid–base concepts with Batak Toba cultural practices.The learning materials were designed using Instagram features, including carousel posts, infographics, visual illustrations, quizzes, and scientific literacy-oriented learning activities. The Mangongkal Holi tradition was selected as the cultural context because it incorporates natural materials such as kaffir lime, turmeric, and limestone, which are closely related to acid–base chemistry concepts.

Scientific literacy components were embedded throughout the teaching materials based on the OECD (2023) scientific literacy framework, including observing scientific phenomena, interpreting scientific evidence, analyzing information, and evaluating scientific claims. The design process also adopted microlearning principles to ensure that content was presented in concise, focused, and visually engaging formats suitable for social media-based learning environments.

Development Stage

The Development stage focused on producing the prototype, conducting expert validation, revising the product, and implementing a limited practicality trial. The resulting product consisted of an Instagram learning account containing acid–base learning materials, ethnopedagogical content, visual learning resources, and scientific literacy-oriented learning activities.

a. Product Development

The product was developed using Instagram as a digital learning platform. Learning content was organized into thematic carousel posts presenting acid–base concepts, cultural contexts, and scientific literacy activities. Visual elements, illustrations, and color schemes were designed to enhance readability and student engagement. The developed teaching materials integrated scientific concepts with Batak Toba local wisdom to create contextual and culturally responsive learning experiences.

b. Validator Profiles

The validation process involved three expert validators selected based on their academic qualifications and expertise relevant to chemistry education and instructional material development. Two validators were Assistant Professors with expertise in educational evaluation and chemistry learning, respectively, while one validator was a Lecturer (Lektor) specializing in digital learning media development. The validators were responsible for evaluating content accuracy, instructional design quality, language appropriateness, visual presentation, and media quality of the developed teaching materials. Cultural appropriateness of the Batak Toba ethnopedagogical content was established through an extensive review of published literature related to the Mangongkal Holi tradition and Batak Toba local wisdom.

Table 1. Validator Profiles

Validator	Academic Position	Area of Expertise
Validator 1	Assistant Professor	Educational Evaluation
Validator 2	Assistant Professor	Chemistry Learning
Validator 3	Lecturer (*Lektor*)	Digital Learning Media

c. Validation Procedure

The developed prototype was validated by the three expert validators. Material validation focused on content accuracy, scientific relevance, instructional quality, language appropriateness, and ethnopedagogical integration. Media validation focused on visual design, accessibility, usability, presentation quality, and technical aspects of the Instagram-based learning materials. The validation aspects and number of indicators are presented in Table 2.

Table 2. Validation Aspects of the Developed Product

Validation Type	**Aspect**	**Number of Indicators**
Material Validation	Content Feasibility	9
	Language Feasibility	3
	Presentation Feasibility	8
Media Validation	Graphical Feasibility	9

Validators provided both quantitative ratings and qualitative suggestions for improvement. The validation results were used to determine the validity level of the developed product and identify aspects requiring revision before the practicality trial.

d. Product Revision

Product revision was conducted based on feedback and recommendations provided by the validators. Revisions included improvements to content presentation, language clarity, visual design, scientific accuracy, and ethnopedagogical integration. The revised product was subsequently used in the limited practicality trial.

Limited Practically Trial

A limited practicality trial was conducted with 17 Grade XI students from MAN 1 Medan. Participants were selected purposively because they represented the target users of the developed product and had previously studied prerequisite chemistry concepts.

The purpose of the limited trial was to obtain initial user responses regarding the practicality of the teaching materials rather than to evaluate instructional effectiveness. During the trial, students accessed the Instagram learning account, explored the learning materials, completed the provided learning activities, and subsequently responded to the practicality questionnaire.

Instruments

1. Data were collected using four research instruments:
2. Semi-structured interview guidelines for teacher needs analysis.
3. Student needs analysis questionnaire.
4. Expert validation sheets for material and media validation.
5. Student practicality questionnaire.

The validation instrument consisted of five aspects, namely content quality, presentation, language, graphics, and media design. The practicality questionnaire consisted of six aspects: content clarity, visual appearance, ease of use, accessibility, learning engagement, and support for scientific literacy.

The practicality questionnaire was developed to evaluate students' perceptions after using the developed product. The instrument consisted of 24 statement items distributed across six aspects: ease of use, material clarity, ethnopedagogy integration, scientific literacy support, learning efficiency, and product usefulness. Each aspect was represented by four statement items using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The practicality questionnaire structure is presented in Table 3.

Table 3. Practicality Questionnaire Aspects

Aspect	Number of items	Item Numbers	Description
Ease of Use	4	1-4	Ease of accessing and operating the Instagram-based teaching material
Material Clarity	4	5-8	Clarity and comprehensibility of the learning content
Ethnopedagogy Integration	4	9-12	Relevance and attractiveness of Batak Toba cultural integration
Scientific Literacy Support	4	13-16	Support for observation, analysis, interpretation, and evaluation skills
Learning Efficiency	4	17-20	Flexibility and effectiveness of learning using the product

Product Usefulness	4	21-24	Benefits of the product in understanding acid-base concepts

Data Analysis

Quantitative data obtained from validation and practicality questionnaires were analyzed using percentage scores. The percentage score was calculated using Equation (1):

$$P = \frac{\sum X}{\sum X_{max}} x\ 100\ \%$$

where P is the percentage score, X is the obtained score, and Xmax is the maximum possible score.

The resulting percentages were interpreted using the criteria adapted from Akbar (2017), as presented in Table 4.

Table 4. Product Validity Criteria

Percentage (%)	Interpretation
81.01–100.00	Very Valid / Very Practical
61.01–80.00	Valid / Practical
41.01–60.00	Fairly Valid / Fairly Practical
21.01–40.00	Less Valid / Less Practical
0.00–20.00	Invalid / Impractical

Source: Adapted from Akbar (2017)

In addition to quantitative data, qualitative comments and suggestions provided by validators were analyzed descriptively and used as the basis for revising the developed teaching materials prior to the limited practicality trial.

Results and Discussion

Needs Analysis

The needs analysis was conducted through interviews with three chemistry teachers and questionnaires administered to 30 senior high school students. The analysis aimed to identify learning challenges, students' characteristics, and the need for digital teaching materials integrated with Batak Toba ethnopedagogy.

a. Teacher Needs Analysis

The results of teacher interviews are summarized in Table 5.

Table 5. Summary of Teacher Needs Analysis

Findings	Description
Difficulties in understanding acid-base concepts	Reported by all teachers
Limited integration of local culture	No specific ethnopedagogical teaching materials available
Conventional learning resources	Learning mainly relies on textbooks and worksheets
Need for digital teaching materials	Strongly recommended by teachers
Need for scientific literacy-oriented learning	Required to improve students' contextual understanding

The interview results revealed that acid–base concepts remain challenging for students because many concepts are abstract and require connections between symbolic, macroscopic, and microscopic representations. Teachers reported that classroom learning still relies heavily on textbooks and worksheets, which often present concepts in a decontextualized manner. Similar findings have been reported by Murti et al. (2024), who found that students frequently experience difficulties in understanding chemistry concepts due to the abstract nature of chemistry learning.

Teachers also highlighted the lack of learning resources integrating local culture into chemistry instruction. Although contextual learning is encouraged within the Merdeka Curriculum framework, specific teaching materials connecting chemistry concepts with local cultural practices remain limited. Consequently, teachers expressed a strong need for innovative teaching materials capable of integrating scientific literacy, digital learning, and local cultural contexts.

b. Student Needs Analysis

The results of the student needs analysis are presented in Table 6.

Table 6. Results of Student Needs Analysis

Aspect	Percentage (%)
Difficulties in understanding chemistry concepts	85.6
Difficulties in scientific literacy skills	81.1
Interest in digital learning media	90.8
Interest in social media-based learning	93.3
Interest in local cultural integration	77.8
Need for digital teaching materials	95.0

The findings indicate that students experience considerable difficulties in understanding chemistry concepts and applying scientific literacy skills. More than 80% of students reported challenges in connecting chemistry concepts to everyday phenomena. This finding supports previous studies indicating that Indonesian students' scientific literacy remains relatively low and requires instructional innovations that promote contextual learning experiences (OECD, 2023; Bilad et al., 2024).

At the same time, students demonstrated strong interest in digital learning media and social media-based learning environments. The high percentage of students interested in Instagram-based learning (93.3%) suggests that social media platforms may provide learning environments that are familiar, accessible, and engaging for contemporary learners. These findings support the integration of Instagram as a microlearning platform capable of delivering concise and visually attractive learning content.

Development of Instagram-Based Chemistry Digital Teaching Materials

Based on the needs analysis results, an Instagram-based chemistry digital teaching material was developed. The product was designed as an educational Instagram account containing acid–base learning materials, scientific literacy activities, quizzes, reflections, and Batak Toba ethnopedagogical contexts.

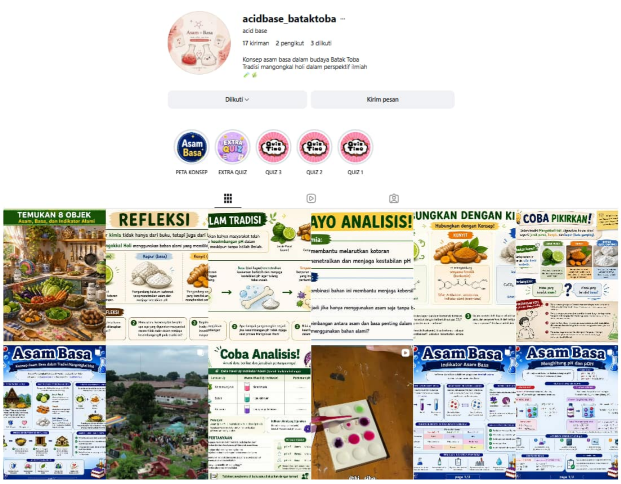

Figure 2. Homepage of the Instagram-Based Chemistry Digital Teaching Material

The homepage demonstrates the organization of learning content through carousel posts and highlighted features. The account contains learning topics, scientific literacy activities, quizzes, and ethnopedagogical content intended to facilitate independent learning. The use of Instagram aligns with microlearning principles by presenting information in concise and visually structured formats that can be accessed anytime through mobile devices.

Integration of Batak Toba Ethnopedagogy in Acid–Base Learning

The developed teaching material integrated Batak Toba ethnopedagogy through the Mangongkal Holi tradition. Kaffir lime was associated with acidic properties due to the presence of citric acid, turmeric was introduced as a natural acid–base indicator because of its curcumin content, and limestone was associated with basic properties due to its calcium carbonate content.

Figure 3. Integration of Batak Toba Ethnopedagogy into the Instagram-Based Acid–Base Learning Materials. (a) Overview of the Mangongkal Holi Tradition. (b) Kaffir Lime as an Acid Source. (c) Turmeric as a Natural Acid–Base Indicator. (d) Limestone as a Base Material

The integration of local cultural contexts was intended not only to introduce cultural knowledge but also to facilitate conceptual understanding through familiar real-life phenomena. According to ethnopedagogical principles, learning becomes more meaningful when scientific concepts are connected to learners' cultural environments (Hasibuan et al., 2023; Sakti et al., 2024). Furthermore, ethnochemistry serves as a bridge between scientific concepts and local cultural practices, enabling students to interpret scientific phenomena within authentic cultural contexts (Daulay et al., 2025).

Importantly, the use of Mangongkal Holi as a learning context was conducted with the intention of appreciating and preserving local cultural heritage rather than reducing its spiritual significance to scientific content. Only observable cultural elements directly related to acid–base phenomena were incorporated into the learning materials.

Product Validation

a. Material Validation Results

The material validation was conducted to evaluate the accuracy, relevance, presentation quality, language appropriateness, and ethnopedagogical integration of the developed teaching materials. Three expert validators assessed the product using the validation instrument described in the Method section. The results of the material validation are presented in Table 7.

Table 7. Material Validation Results

Validator	Percentage (%)
Validator 1	92.00
Validator 2	90.00
Validator 3	94.00
Average	92.00

The material validation results showed an average score of 92.00%, indicating that the developed teaching material was categorized as Very Valid. The validators agreed that the content was scientifically accurate, curriculum-aligned, and appropriately integrated with Batak Toba ethnopedagogical contexts. The high validity score suggests that the integration of local cultural contexts did not compromise scientific accuracy. Instead, it enhanced contextual relevance and supported the presentation of chemistry concepts through meaningful examples. Similar findings were reported by Silaban et al. (2025), who found that Batak Toba local wisdom could be effectively integrated into acid–base teaching materials while maintaining scientific validity.

b. Media Validation Results

Media validation was conducted to assess the visual appearance, readability, accessibility, usability, and overall suitability of Instagram as a learning platform. The evaluation was carried out by three expert validators with expertise in educational media and chemistry learning. The results of the media validation are presented in Table 8.

Table 8. Madia Validation Results

Validator	Percentage (%)
Validator 1	97.78
Validator 2	82.22
Validator 3	95.56
Average	91.85

The media validation results obtained an average score of 91.85%, categorized as Very Valid. Validators highlighted the attractiveness of the visual design, readability of content, compatibility with mobile devices, and suitability of Instagram as a learning platform.

The findings indicate that Instagram can function not only as a social networking platform but also as a learning environment capable of supporting chemistry instruction. The visual and interactive characteristics of Instagram align with previous studies demonstrating the effectiveness of social media in enhancing learning engagement and motivation (Widarti et al., 2024; Rengganis et al., 2025).

Product Practicality

Following the validation and revision stages, the developed product was implemented in a limited practicality trial involving 17 Grade XI students from MAN 1 Medan. The practicality evaluation aimed to determine students' perceptions regarding the usability, clarity, effectiveness, and usefulness of the developed teaching materials. The practicality results are presented in Table 9.

Table 9. Product Practicality Results

Aspect	Percentage (%)	Category
Ease of Use	76.18	Practical
Material Clarity	80.29	Practical
Ethnopedagogy Integration	73.82	Practical
Scientific Literacy Support	73.24	Practical
Learning Efficiency	76.18	Practical
Product Usefulness	78.24	Practical
Average	76.32	Practical

The practicality results showed an average score of 76.32%, indicating that the developed teaching material was categorized as Practical. Students generally perceived the product as easy to access, useful, and supportive of learning acid–base concepts.

The highest score was obtained in the material clarity aspect (80.29%), suggesting that students found the learning content understandable and well organized. This result indicates that the microlearning format successfully presented chemistry concepts in concise and accessible forms.

Conversely, the lowest score was observed in the scientific literacy support aspect (73.24%). This finding suggests that students were less familiar with activities involving scientific reasoning, evidence interpretation, and evaluation of scientific claims. Although students responded positively to the learning materials, literacy-oriented tasks required cognitive processes that are not commonly emphasized in conventional chemistry instruction.

This finding is consistent with national and international reports indicating that scientific literacy remains one of the major challenges in science education (OECD, 2023). Therefore, the relatively lower score should not necessarily be interpreted as a weakness of the product but rather as an indication that students require more extensive exposure to scientific literacy-oriented learning experiences.

Comparison of Validity and Practicality

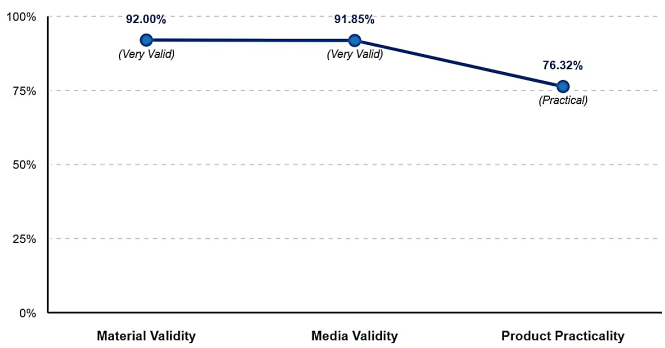

Figure 4. Comparison of Material Validity, Media Validity, and Product Practicality

The comparison between material validity (92.00%), media validity (91.85%), and practicality (76.32%) reveals that practicality scores were lower than expert validation scores. This difference is reasonable because expert validation evaluates the quality and appropriateness of the product from a professional perspective, whereas practicality reflects students' actual experiences when interacting with the product.

The lower practicality score may also indicate that students required adaptation to the integration of scientific literacy activities and ethnopedagogical content within a social media-based learning environment. Nevertheless, the practicality score remained within the practical category, indicating that the developed teaching material is feasible for use in chemistry learning.

The findings collectively demonstrate that Instagram-based chemistry teaching materials integrated with Batak Toba ethnopedagogy are both valid and practical. The integration of local cultural contexts and scientific literacy activities offers a promising approach for supporting contextual, culturally responsive, and meaningful chemistry learning.

Conclusion

This study successfully developed Instagram-based chemistry digital teaching materials integrated This study successfully developed Instagram-based chemistry digital teaching materials integrated with Batak Toba ethnopedagogy for acid–base learning through the Analysis, Design, and Development stages of the ADDIE model. The developed product incorporated scientific literacy activities and contextualized chemistry concepts through the Mangongkal Holi tradition and related cultural practices.

The validation results demonstrated that the developed teaching materials achieved a material validity score of 92.00% and a media validity score of 91.85%, both categorized as Very Valid. Furthermore, the limited practicality trial involving 17 Grade XI students of MAN 1 Medan resulted in an average practicality score of 76.32%, categorized as Practical. These findings indicate that the developed teaching materials are suitable for use in chemistry learning and have the potential to support contextual and culturally responsive instruction on acid–base topics.

The study contributes to chemistry education by demonstrating how Instagram can be utilized as a microlearning platform to integrate scientific literacy and Batak Toba ethnopedagogy into chemistry learning materials. The integration of local cultural contexts provides meaningful learning experiences that connect scientific concepts with students' cultural environments.

A limitation of this study is that the development process was restricted to the Analysis, Design, and Development stages of the ADDIE model and involved only a limited practicality trial with 17 students. Consequently, the effectiveness of the developed teaching materials in improving students' scientific literacy, conceptual understanding, and learning outcomes has not yet been examined. Therefore, future studies should proceed to the Implementation and Evaluation stages and involve larger and more diverse student populations to investigate the effectiveness of the developed teaching materials in broader educational settings.

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