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Developing of an E-Learning Based Chemistry Textbook to Improve Students' Scientific Attitude

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Abstract

Scientific attitudes are essential in chemistry education because they support students' curiosity, open-mindedness, critical thinking, and engagement with scientific practices. However, conventional learning materials may provide limited opportunities for students to explore abstract chemical concepts and engage with scientific information interactively. This study aimed to develop a valid e-learning-based chemistry textbook and evaluate its preliminary effectiveness in improving students' scientific attitudes. The study employed a Research and Development (R&D) approach using the ADDIE model, comprising Analysis, Design, Development, Implementation, and Evaluation. Product validity was assessed through expert evaluations of chemistry subject matter, instructional media, and language using Aiken's V coefficient. Product effectiveness was evaluated using a quasi-experimental nonequivalent pretest–posttest control group design involving 19 first-semester chemistry education students at Universitas Islam Negeri Mataram, Indonesia. The experimental group consisted of 10 students who used the developed textbook, whereas the control group consisted of nine students who used conventional printed chemistry textbooks. Scientific attitudes were measured using a 34-item questionnaire. The reported Aiken's V coefficients ranged from 0.857 to 0.905, with an overall mean of 0.886, categorised as highly valid. Following the three-month intervention, the experimental group demonstrated a greater mean score improvement (40.7 points) than the control group (20.4 points). The reported independent-samples t-test indicated a statistically significant difference in normalised gain scores between the two groups ($p < 0.001$). These findings provide preliminary evidence that integrating chemistry content, multimedia representations, and instructional activities into an e-learning-based textbook may support the improvement of students' scientific attitudes. The developed textbook offers a promising instructional resource for integrating scientific attitude development into undergraduate chemistry education.

Keywords: Chemistry education; Chemistry textbook; E-learning; Scientific attitudes

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INTRODUCTION

Scientific attitudes are essential components of twenty-first-century competencies that support students' engagement in scientific practices and evidence-based decision-making. Rather than constituting a purely cognitive skill, scientific attitudes encompass intellectual and behavioural dispositions that guide individuals in acquiring, evaluating, and applying scientific knowledge. These dispositions include objectivity, critical thinking, rational thinking, open-mindedness, and curiosity (Kolomuc & Demir Saglam, 2025; Kurniawan et al., 2019). Scientific attitudes are closely associated with the development of scientific literacy, higher-order thinking skills, and informed decision-making (Crettaz von Roten & de Roten, 2023; Holbrook & Rannikmae, 2018; Julianto et al., 2022). Although scientific attitudes and attitudes towards science are conceptually distinguishable, both contribute to understanding students' engagement with scientific knowledge and practices. In the present study, scientific attitudes are operationalised through a multidimensional perspective encompassing scientific

dispositions, attitudes towards chemistry, chemistry learning experiences, and behavioural tendencies associated with scientific engagement.

Developing scientific attitudes in higher education is particularly important for establishing an academic culture that values scientific integrity, evidence-based reasoning, and intellectual openness. Students with positive scientific attitudes are encouraged to examine information objectively, prioritise scientific evidence, and respect different perspectives during scientific discussions (Aulia & Asih, 2020; Ernawati et al., 2022; Syah et al., 2023). For undergraduate chemistry education students, particularly prospective chemistry teachers, these attitudes are relevant not only to their academic development but also to their future professional responsibilities in fostering scientific thinking among learners. Therefore, chemistry instruction should provide meaningful opportunities for students to observe phenomena, formulate scientific questions, evaluate evidence, and reflect on alternative explanations. Learning environments that facilitate these activities may support the development of scientific attitudes alongside disciplinary knowledge.

Preliminary observations conducted in the Chemistry Education Study Programme at Universitas Islam Negeri (UIN) Mataram indicated that several aspects of students' scientific attitudes remained underdeveloped. The observations were conducted during laboratory activities using scientific attitude observation sheets covering curiosity, critical thinking, accuracy, objectivity, and openness to new ideas, assessed using a four-point Likert-type rubric. The results revealed that only 25% of students demonstrated adequate critical thinking skills, 25% actively asked questions, and 30% demonstrated thoroughness and discipline when conducting laboratory experiments. These findings indicate limited engagement in several practices associated with scientific attitudes and highlight the need for instructional resources that provide greater opportunities for scientific exploration, questioning, and careful observation. Addressing these limitations is particularly relevant in contemporary chemistry education, where students are expected to integrate disciplinary knowledge, critical reasoning, and digital competence to respond to increasingly complex scientific and societal challenges.

One of the fundamental challenges in chemistry education is the abstract nature of chemical concepts, which requires students to connect observable phenomena with explanations involving particles, molecular structures, and chemical processes. Although conventional printed textbooks provide systematic explanations of chemical concepts, their predominantly static representations may limit students' opportunities to explore dynamic chemical processes and complex spatial relationships. E-learning offers an alternative approach by integrating digital technology into the presentation of chemical concepts through visual, interactive, and accessible learning resources. This approach is consistent with global educational developments that increasingly emphasise the integration of digital technologies into teaching and learning environments (Esteve mon et al., 2022; Gabriel et al., 2022). The incorporation of digital technology into instructional materials provides opportunities to address contemporary educational needs and diversify learning experiences (Castro et al., 2020; Verawati et al., 2022). In chemistry education, digital representations may facilitate students' engagement with abstract concepts by presenting chemical phenomena in more accessible and comprehensible forms (Agnafia et al., 2022; Himmawan & Seruni, 2025; Verawati et al., 2022).

E-learning provides several instructional advantages through the integration of multimedia resources and flexible access to learning materials. The combination of textual explanations, images, animations, videos, and interactive resources can create more engaging learning experiences and provide students with opportunities to explore scientific information according to their learning needs (Aurora & Effendi, 2019; Cidral et al., 2018; Haka et al., 2024). Previous studies have reported various educational benefits of e-learning, including opportunities to strengthen learning motivation, engagement, learning outcomes, and science-related attitudes (Ferrer et al., 2022; Nugroho et al., 2023; Setyawan et al., 2024). These benefits suggest that the pedagogical potential of e-learning extends beyond the digital delivery

of instructional content. When accompanied by meaningful learning activities, digital resources may encourage students to observe scientific phenomena, formulate questions, explore relevant information, and reflect on scientific explanations. Such opportunities are particularly relevant to developing curiosity, open-mindedness, and engagement with scientific practices.

Nevertheless, the educational effectiveness of e-learning depends not merely on the availability of digital technology but also on the quality of its instructional design. Digital learning environments can provide opportunities for students to explore scientific phenomena, engage in virtual learning experiences, and reflect on learning outcomes independently or collaboratively (Al-Fraihat et al., 2020; Haka et al., 2024). However, poorly organised instructional materials, complex visual representations, insufficient instructional guidance, and predominantly information-oriented learning activities may limit the educational benefits of e-learning. Previous research on digital and flexible learning environments highlights the importance of instructional design, structured learning activities, and appropriate learning support (Lechner et al., 2024; Müller et al., 2023; Sherif & Amudha, 2025). Organising learning materials into coherent instructional sequences and integrating multimedia representations purposefully may help students focus on relevant scientific information. Furthermore, incorporating inquiry-oriented activities into digital learning materials may encourage students to move beyond passive information acquisition towards scientific observation, questioning, exploration, and reflection. Consequently, digital chemistry textbooks should be designed not only to communicate chemical knowledge but also to facilitate learning experiences that support scientific attitude development.

Despite the increasing integration of digital technologies into science and chemistry education, further investigation is needed into how multimedia features, pedagogical activities, and scientific attitude assessment can be coherently integrated within digital chemistry textbooks. Although previous studies have demonstrated the potential of e-learning to support cognitive and affective learning outcomes, the explicit alignment of multimedia-based learning activities with scientific attitude development and corresponding assessment indicators warrants further attention. The research gap addressed in this study therefore concerns the integration of technological features, pedagogical strategies, and scientific attitude assessment within a single instructional resource. Addressing this gap is particularly relevant to undergraduate chemistry education, where learning materials should facilitate students' engagement with abstract chemical concepts while providing opportunities to develop scientific curiosity, intellectual openness, and evidence-oriented reasoning.

To address this instructional challenge, the present study develops an e-learning-based chemistry textbook that integrates systematically organised chemistry content with multimedia learning resources and activities intended to support scientific attitudes. The proposed novelty of the developed textbook lies in the integration of three complementary dimensions: technological, pedagogical, and assessment-oriented design. The technological dimension involves the incorporation of three-dimensional chemical visualisations, reaction animations, and virtual simulations to facilitate the exploration of chemical phenomena. The pedagogical dimension emphasises inquiry-oriented learning activities intended to encourage scientific observation, curiosity, exploration, and reflection. The assessment-oriented dimension focuses on aligning the intended development of scientific attitudes with the learning activities and measurement indicators. Rather than relying solely on technological innovation, the developed textbook emphasises the integration of multimedia resources, pedagogical design, and scientific attitude assessment as its proposed instructional contribution. Through this integration, the textbook is intended to support students' engagement with chemistry concepts while providing opportunities for the development of scientific attitudes.

Based on the identified instructional needs and research gap, this study aims to develop an e-learning-based chemistry textbook using the ADDIE instructional design model, examine its validity through expert evaluation, and assess its preliminary effectiveness in supporting undergraduate chemistry education students' scientific attitudes. Specifically, this study

investigates whether the improvement in scientific attitude scores differs significantly between students using the developed e-learning-based chemistry textbook and those using conventional printed chemistry textbooks. Given the limited sample size and the use of existing classes without random assignment, the findings are intended to provide preliminary evidence of the potential effectiveness of the developed textbook rather than definitive evidence of a causal relationship. The study is expected to contribute to the development of technology-enhanced chemistry learning resources that explicitly integrate scientific attitude development as an instructional objective.

METHOD

Research Design

This study employed a Research and Development (R&D) approach to develop an e-learning-based chemistry textbook and evaluate its validity and preliminary effectiveness in supporting the development of university students' scientific attitudes. The development process followed the ADDIE instructional design model, which comprises five interrelated stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because its systematic and iterative structure facilitates the identification of instructional needs, development of learning resources, product validation, implementation, and continuous refinement of instructional materials.

The research comprised two interconnected components: product development and validation, and preliminary effectiveness evaluation. The first component focused on developing and validating the e-learning-based chemistry textbook through systematic instructional design and expert evaluation. The second component employed a quasi-experimental nonequivalent pretest–posttest control group design to examine changes in students' scientific attitude scores following the implementation of the developed textbook.

The quasi-experimental design was selected because the participants belonged to previously established classes, making individual random assignment impracticable. The experimental group received chemistry instruction supported by the developed e-learning-based chemistry textbook, whereas the control group received instruction using conventional printed chemistry textbooks. Both groups completed scientific attitude assessments before and after the three-month instructional intervention. The research design is presented in Table 1.

Table 1. Nonequivalent Pretest–Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X_1	O_2
Control	O_3	X_2	O_4

Note: O_1 and O_3 represent the pretest scores of the experimental and control groups, respectively; X_1 represents chemistry instruction supported by the developed e-learning-based chemistry textbook; X_2 represents chemistry instruction using conventional printed chemistry textbooks; and O_2 and O_4 represent the corresponding posttest scores.

Given the non-random group allocation and the involvement of only one existing class in each instructional condition, potential classroom-related influences could not be separated from the instructional treatment. Consequently, the observed differences were interpreted as preliminary evidence of effectiveness rather than definitive evidence of a causal relationship.

Research Setting and Participants

The study was conducted in the Chemistry Education Study Programme, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri (UIN) Mataram, Indonesia. The participants consisted of first-semester undergraduate students enrolled in the Chemistry Education Study Programme who were undertaking introductory chemistry learning activities.

The accessible population comprised 19 students, all of whom were included as research participants through total population sampling (saturated sampling). Participants were allocated to two groups according to their existing class membership. The experimental group consisted of 10 students who used the developed e-learning-based chemistry textbook, whereas the control group consisted of nine students who used conventional printed chemistry textbooks

commonly employed by lecturers. Although total population sampling enabled the inclusion of all students within the accessible population, the relatively small sample and institution-specific research context limited the generalisability of the findings.

Product Development

The product developed in this study was an e-learning-based chemistry textbook designed to support students' understanding of chemistry concepts while fostering their scientific attitudes. The development process followed the ADDIE instructional design model, which provided a systematic framework for integrating chemistry content, multimedia resources, instructional activities, and educational assessment. The five interconnected stages facilitated continuous evaluation and product refinement throughout the development process. The interrelationships among the five development stages are illustrated in Figure 1.

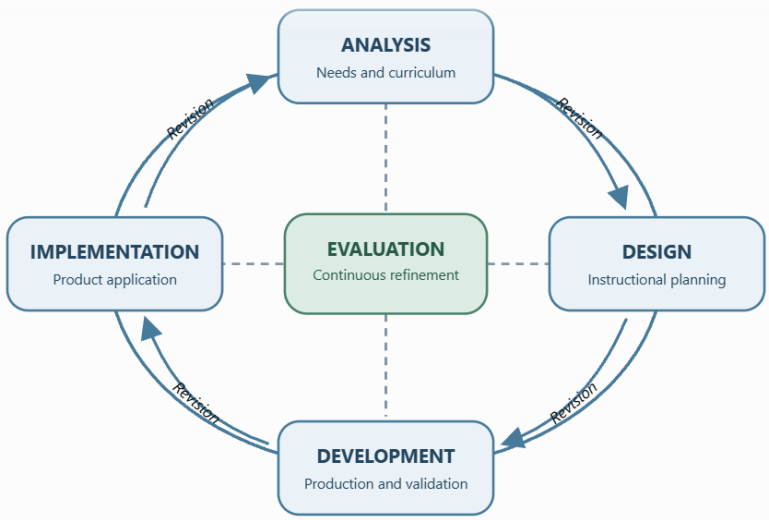

Figure 1. ADDIE instructional design model for the development of an e-learning-based chemistry textbook

Analysis

The analysis stage focused on identifying instructional needs, student characteristics, curriculum requirements, and limitations of existing chemistry learning resources. The needs analysis examined challenges associated with students' scientific attitudes and the availability of instructional materials capable of supporting scientific engagement. Student characteristics were analysed to identify the learning needs of the intended users. Curriculum and competency analyses were also conducted to ensure that the textbook content aligned with the expected course learning outcomes. The findings from this stage informed decisions regarding the scope of chemistry content, instructional structure, multimedia requirements, and pedagogical orientation of the developed textbook.

Design

The design stage involved establishing the conceptual and instructional framework of the textbook based on the findings of the analysis stage. The activities included organising chemistry content into coherent instructional sequences, selecting appropriate multimedia representations, and designing learning activities intended to support students' scientific attitudes.

The textbook covered four fundamental chemistry topics: changes in matter, separation of mixture components, the periodic table of elements, and chemical bonding. The instructional design incorporated textual explanations, visual illustrations, animations, instructional videos, and practice questions to facilitate students' engagement with abstract chemistry concepts and encourage scientific observation, curiosity, and independent exploration. A scientific attitude questionnaire was also prepared to assess changes in students' scientific attitudes following the implementation of the developed textbook.

Development

During the development stage, the instructional design was transformed into a functional electronic chemistry textbook using Flip PDF Corporate software. The development process involved integrating chemistry content with multimedia resources, organising visual representations, and establishing navigation features to facilitate access to learning materials.

The initial textbook was subsequently evaluated by experts in chemistry subject matter, instructional media, and language. Quantitative expert assessments and qualitative recommendations were used to identify product limitations and guide subsequent revisions. The revised textbook was then prepared for implementation in undergraduate chemistry learning activities.

Implementation

Following expert validation and product refinement, the developed textbook was implemented over a three-month instructional period. The experimental group participated in chemistry learning activities supported by the developed e-learning-based chemistry textbook, whereas the control group used conventional printed chemistry textbooks. During the intervention, students in the experimental group accessed digital learning materials, explored visual representations of chemical phenomena, watched instructional videos and animations, and completed the available practice questions. These activities were intended to encourage scientific curiosity, independent exploration, and engagement with scientific information.

Evaluation

The evaluation stage was integrated throughout the development process rather than being conducted exclusively at its conclusion. Formative evaluation focused on identifying and addressing product limitations through expert feedback and subsequent revisions, particularly regarding instructional content, multimedia presentation, navigation, and linguistic quality. Outcome evaluation focused on examining product validity and the preliminary effectiveness of the developed textbook in supporting students' scientific attitudes. The evaluation findings provided a basis for identifying the strengths and limitations of the product and formulating recommendations for further refinement and broader implementation.

Product Validation

The developed e-learning-based chemistry textbook underwent expert evaluation involving three specialists representing chemistry subject matter, instructional media, and language. The evaluation was intended to examine the instructional suitability of the textbook before its implementation in chemistry learning activities.

The subject matter evaluation focused on curriculum alignment, scientific accuracy, content completeness, alignment with learning objectives, systematic presentation, and the appropriateness of illustrative examples. The instructional media evaluation addressed visual design, visual quality, text readability, format consistency, ease of navigation, and compatibility with e-learning systems. The language evaluation examined sentence clarity, compliance with Indonesian language conventions, terminological accuracy and consistency, readability, and sentence effectiveness.

Quantitative expert assessments were analysed using Aiken's V coefficient to describe the validity of the developed textbook across the three evaluation domains. Qualitative comments and recommendations were used to identify aspects requiring improvement and guide subsequent product refinement.

Research Instrument and Scoring

Students' scientific attitudes were assessed using a questionnaire developed with reference to the scientific attitude indicators described by Kind et al. (2016). The questionnaire operationalised scientific attitudes as a multidimensional construct encompassing scientific dispositions, attitudes towards chemistry, learning experiences, and behavioural tendencies associated with scientific engagement.

The instrument covered seven dimensions: attitudes towards scientific research, implementation of scientific attitudes, attitudes towards chemistry, chemistry learning experiences, curiosity, open-mindedness, and behavioural tendencies in learning chemistry. Attitudes towards scientific research reflected students' willingness to accept scientific research as a means of acquiring chemistry-related knowledge, whereas the implementation of scientific attitudes concerned behavioural tendencies associated with scientific values in everyday activities. Attitudes towards chemistry reflected students' perceptions of chemistry knowledge and its contribution to society, while chemistry learning experiences encompassed classroom activities, laboratory practices, and interactions with lecturers. Curiosity referred to enthusiasm for scientific processes and interest in acquiring chemistry-related and environmental information. Open-mindedness reflected willingness to appreciate different perspectives and explore scientific information comprehensively. Behavioural tendencies in learning chemistry concerned students' willingness to devote time to reading chemistry literature and engaging in scientific research activities.

These dimensions provided a framework for assessing students' self-reported scientific attitudes and behavioural tendencies, which are considered relevant to fostering scientific behaviour and encouraging the application of scientific values in everyday life (Gading & Rohaeti, 2024; Syah et al., 2023; Tai et al., 2022).

The questionnaire consisted of 34 items assessed using a five-point Likert scale. Positively worded statements were scored from 5 (strongly agree) to 1 (strongly disagree), whereas negatively worded statements were reverse-scored to maintain a consistent direction of measurement. The scoring criteria are presented in Table 2.

Table 2. Scoring Criteria for the Scientific Attitude Questionnaire

Response Category	Positive Statements	Negative Statements
Strongly Agree	5	1
Agree	4	2
Undecided	3	3
Disagree	2	4
Strongly Disagree	1	5

Based on the number of questionnaire items and the response scale, the theoretical total raw score ranged from 34 to 170, with higher scores representing more favourable self-reported scientific attitudes.

Instrument Validity

The scientific attitude questionnaire was validated by experts to assess the relevance of the questionnaire items to the scientific attitude indicators, clarity of language, and readability. The expert evaluation was conducted to obtain preliminary evidence of the content relevance, alignment with the intended scientific attitude indicators, and linguistic suitability of the questionnaire before its administration to the research participants. The quantitative expert assessments were summarised using the mean assessment score, calculated using the following equation:

$$\bar{X} = \frac{\sum_{i=1}^{N} X_i}{N}$$

where $\bar{X}$ represents the mean assessment score, X_i represents the score for the i-th assessment item, and N represents the total number of assessment items included in the calculation. The resulting mean assessment scores were used to describe the experts' evaluation of item relevance, linguistic clarity, readability, and alignment with the intended scientific attitude indicators.

Research Procedures

The instructional intervention was conducted over a three-month period and comprised pre-intervention assessment, instructional intervention, and post-intervention assessment.

These procedures were designed to examine changes in students' scientific attitude scores following the implementation of the developed textbook. During the pre-intervention phase, students in both the experimental and control groups completed the scientific attitude questionnaire to establish their baseline scores. These scores provided a reference for examining subsequent changes in students' scientific attitudes.

During the intervention phase, the experimental group participated in chemistry learning activities supported by the developed e-learning-based chemistry textbook. Students accessed textual explanations, visual illustrations, animations, instructional videos, and practice questions covering changes in matter, separation of mixture components, the periodic table of elements, and chemical bonding. These multimedia resources were intended to encourage scientific observation, curiosity, independent exploration, and engagement with chemistry-related information. Meanwhile, the control group participated in chemistry learning activities using conventional printed chemistry textbooks commonly employed by lecturers.

Following the intervention, both groups completed the same scientific attitude questionnaire to assess changes in their scientific attitude scores. The resulting pretest and posttest data were subsequently analysed to examine the magnitude of improvement within each group and compare the observed changes between the two instructional conditions.

Data Analysis

The research data were analysed using descriptive and inferential statistical procedures to evaluate the validity of the developed textbook and its preliminary effectiveness in supporting students' scientific attitudes. The analytical procedures comprised product validity analysis, descriptive statistical analysis, normalised gain analysis, statistical assumption testing, and between-group comparison.

Product Validity Analysis

Quantitative assessments provided by the subject matter, instructional media, and language experts were analysed using Aiken's V coefficient. The resulting validity coefficients were used to describe expert evaluations of the developed textbook within each assessment domain. Qualitative comments and recommendations were used to identify aspects requiring improvement and guide product refinement.

Descriptive Statistics and Normalised Gain Analysis

Descriptive statistics, including means and standard deviations, were used to summarise students' pretest and posttest scientific attitude scores in the experimental and control groups. Changes in scientific attitude scores were further examined using the normalised gain percentage (N-Gain %), which expresses the observed improvement relative to the maximum possible improvement from the initial score. The normalised gain percentage was calculated using the following equation:

$$g(\%) = \frac{S_f - S_i}{S_{\max} - S_i} \times 100\%$$

where $g(\%)$ represents the normalised gain percentage, S_f represents the posttest score, S_i represents the pretest score, and $S_{\max}$ represents the maximum possible score on the scale used for the analysis. The resulting N-Gain percentage scores were used to compare the magnitude of improvement in scientific attitude scores between the experimental and control groups.

Statistical Assumption Testing

Prior to hypothesis testing, the N-Gain percentage scores were assessed for normality and homogeneity of variance. The Shapiro–Wilk test was employed to examine the normality of N-Gain scores within each group, whereas Levene's test was used to assess the homogeneity of variance between the groups. Both tests were conducted at a significance level of 0.05. The results of these tests were considered when interpreting the subsequent between-group statistical comparison.

Hypothesis Testing

An independent-samples t-test was conducted using SPSS to determine whether there was a statistically significant difference in N-Gain percentage scores between the experimental and control groups. The null hypothesis (H_0) stated that there was no difference in the mean normalised gain scores of scientific attitudes between students using the developed e-learning-based chemistry textbook and those using conventional printed chemistry textbooks, whereas the alternative hypothesis (H_1) stated that the mean normalised gain scores differed between the two groups. The hypothesis was tested using a two-tailed significance level of 0.05. The null hypothesis was rejected when the p-value was below 0.05, whereas a p-value equal to or greater than 0.05 indicated insufficient evidence to reject the null hypothesis.

Given the relatively small sample size, non-random group allocation, and involvement of only one existing class per instructional condition, the statistical findings were interpreted cautiously. Potential dependence among observations within each class and confounding between classroom membership and instructional treatment limited the strength of statistical and causal inference. Consequently, the observed between-group differences were interpreted as preliminary evidence of the potential effectiveness of the developed textbook rather than definitive evidence of a causal relationship.

Ethical Considerations

Permission to conduct the study was obtained from the Chemistry Education Study Programme, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri (UIN) Mataram. All participants provided consent to participate in the study. Participants' data were kept confidential throughout the research process and used exclusively for academic and research purposes.

RESULTS AND DISCUSSION

Characteristics of the Developed E-Learning-Based Chemistry Textbook

The development process resulted in an e-learning-based chemistry textbook designed to support undergraduate students' engagement with chemistry concepts and the development of scientific attitudes. The textbook was developed using the ADDIE instructional design model, which facilitated the integration of chemistry content, multimedia resources, instructional activities, and educational assessment within a systematically organised digital learning resource. The findings from the needs analysis informed the selection of instructional content and multimedia features intended to address the challenges associated with abstract chemistry concepts and students' scientific attitudes.

The developed textbook was produced in an electronic format using Flip PDF Corporate software, which enables the integration of textual explanations, visual illustrations, instructional videos, animations, and navigation features. The use of this software provides opportunities for students to access learning materials flexibly and revisit instructional content according to their learning needs (A'yun et al., 2024; Erniwati et al., 2022; Putri & Wulandari, 2022; Rosinayah, 2021). The textbook covers four fundamental chemistry topics: changes in matter, separation of mixture components, the periodic table of elements, and chemical bonding. These topics were organised into coherent instructional sequences to facilitate students' engagement with chemical information and multimedia representations.

The distinguishing instructional characteristic of the developed textbook lies in its orientation towards scientific attitude development alongside chemistry learning. Multimedia resources were incorporated to provide opportunities for students to observe scientific phenomena, explore chemical representations, and engage with chemistry-related information. Rather than functioning solely as a digital version of a conventional printed textbook, the developed product combines textual and audiovisual resources with practice questions intended to encourage independent exploration and scientific curiosity. The developed e-learning-based chemistry textbook is presented in Figure 2 and can be accessed at: https://modul.buanatechno.id/kampus/kimia/2/mobile/index.html

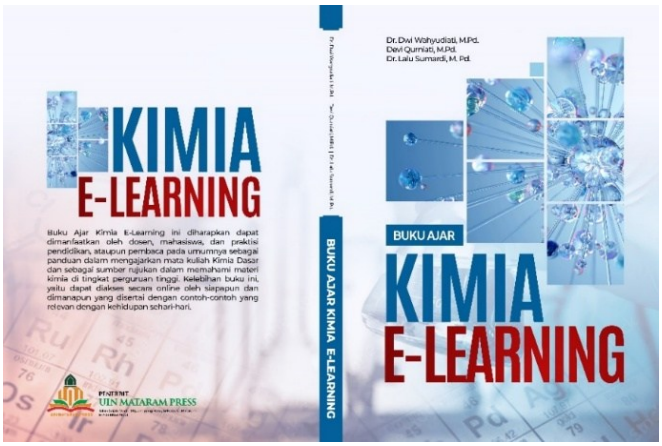

Figure 2. E-learning-based chemistry textbook

The multimedia features of the developed textbook include visual representations of chemical structures and instructional videos demonstrating laboratory procedures. Representative examples of these features are presented in Figures 3 and 4.



Figure 3. Crystal structure

As illustrated in Figure 3, the visual representation of crystal structures enables students to observe the spatial arrangement of atoms, ions, or molecules within a crystal lattice. Such representations can make abstract chemical structures more accessible by illustrating spatial relationships that may be difficult to comprehend through textual explanations alone. From an instructional perspective, visual representations provide opportunities for students to examine structural characteristics, recognise patterns, and explore relationships between microscopic arrangements and chemical properties. These opportunities may support curiosity, careful observation, and engagement with scientific explanations.



Figure 4. Video of Natural Material Extraction Method

Figure 4 illustrates the integration of instructional videos demonstrating natural product extraction procedures. The video presents laboratory activities, including sample preparation, solvent selection, stirring, heating using a Soxhlet apparatus, and extract separation. These audiovisual representations provide students with opportunities to observe experimental

sequences and examine practical aspects of chemical investigations, including the appropriate use of laboratory equipment, measurement accuracy, and laboratory safety procedures.

The availability of playback controls also allows students to pause, replay, and review specific experimental procedures according to their learning needs. Such flexibility may encourage independent exploration and more focused observation of scientific processes. Although conceptual understanding and laboratory performance were not directly assessed in this study, these multimedia features provide a pedagogical rationale for using digital textbooks as complementary resources in chemistry learning.

The integration of visual representations, instructional videos, animations, and practice questions therefore reflects the instructional orientation of the developed textbook towards scientific engagement. Its potential contribution extends beyond the presentation of chemical information by providing learning opportunities that may support curiosity, openness to scientific explanations, and willingness to engage with chemistry-related activities.

Product Validation and Refinement

The developed e-learning-based chemistry textbook underwent expert evaluation to examine its validity and instructional suitability before implementation. The evaluation involved three specialists representing chemistry subject matter, instructional media, and language. Quantitative assessments were analysed using Aiken's V coefficient, while qualitative recommendations were used to identify product limitations and guide subsequent refinement. The validation results are presented in Tables 3–5.

Table 3. Subject Matter Expert Assesment Indicators

No	Subject Matter Expert Assesment Indicators	Aiken's V Value	Category
1	Compliance of materials with CPL/CPMK	0,905	Highly Valid
2	The truth of scientific concepts	0,905	Highly Valid
3	Completeness of materials	0,857	Valid
4	Appropriateness of materials to learning objectives	0,905	Highly Valid
5	Systematic presentation of material	0,857	Valid
6	The suitability of examples with the material	0,905	Highly Valid
	Average	0,889	Highly Valid

The subject matter evaluation yielded an average Aiken's V coefficient of 0.889, with individual indicator values ranging from 0.857 to 0.905. The highest coefficients were obtained for curriculum alignment, scientific accuracy, alignment with learning objectives, and the appropriateness of examples. Meanwhile, content completeness and systematic presentation received relatively lower coefficients, although both remained within the valid category according to the classification employed in this study. These findings provided favourable expert-based evidence regarding the relevance and scientific suitability of the chemistry content. Nevertheless, the relatively lower assessments of content completeness and presentation indicated opportunities for further refinement.

Table 4. Media Expert Assessment Indicators

No	Media Expert Assessment Indicators	Aiken's V Value	Category
1	Textbook design appearance	0,905	Highly Valid
2	Visual appearance quality	0,857	Valid
3	Text readability	0,905	Highly Valid
4	Format consistency	0,857	Valid
5	Ease of navigation	0,905	Highly Valid
6	Compatibility with e-learning systems	0,905	Highly Valid
	Average	0,889	Highly Valid

The instructional media evaluation also yielded an average Aiken's V coefficient of 0.889. Textbook design, text readability, ease of navigation, and compatibility with e-learning systems received the highest coefficients of 0.905. Visual presentation quality and format

consistency obtained coefficients of 0.857, indicating aspects that could be further improved. These results suggest that the developed textbook received favourable expert evaluations regarding its visual organisation, accessibility, navigation, and technical suitability as a digital learning resource.

Table 5. Language Expert Assessment Indicators

No	Language Expert Assessment Indicators	Aiken's V Value	Category
1	Clarity of sentences	0,857	Valid
2	Compliance with Indonesian language rules	0,905	Highly Valid
3	Accuracy of terminology	0,905	Highly Valid
4	Readability of text	0,857	Valid
5	Consistency of terminology	0,905	Highly Valid
6	Effectiveness of sentences	0,857	Valid
	Average	0,881	Highly Valid

The language evaluation yielded an average Aiken's V coefficient of 0.881. Compliance with Indonesian language conventions, terminological accuracy, and consistency of terminology received coefficients of 0.905. Sentence clarity, readability, and sentence effectiveness received coefficients of 0.857. These findings indicate favourable expert evaluations of the linguistic quality of the developed textbook while identifying several aspects requiring further improvement to enhance the clarity and accessibility of instructional explanations.

Across the three evaluation domains, the reported Aiken's V coefficients ranged from 0.857 to 0.905, with an overall average coefficient of 0.886. According to the classification adopted in this study, the overall assessment was categorised as highly valid. These findings provide preliminary expert-based evidence of the textbook's suitability in terms of chemistry content, instructional media, and linguistic quality. However, expert-based validity should be distinguished from empirical effectiveness because favourable expert evaluations do not necessarily demonstrate improvements in students' learning outcomes.

The qualitative recommendations obtained from the experts informed several product refinements. Revisions to the chemistry content included adding more contextual explanations and illustrative examples and improving the systematic presentation of instructional materials. Media-related revisions focused on improving the layout, incorporating additional illustrations, enhancing format consistency, and facilitating navigation. Language-related revisions included improving sentence structure, punctuation, and compliance with Indonesian language conventions. These refinements demonstrate the role of formative evaluation in the ADDIE development process and contributed to improving the instructional suitability of the textbook before its implementation.

Collectively, the validation and refinement findings suggest that the quality of a digital chemistry textbook depends not only on the availability of multimedia features but also on the coherence of scientific content, instructional organisation, visual presentation, and linguistic accessibility. These dimensions are particularly important when digital learning resources are intended to support scientific engagement alongside the presentation of chemistry concepts.

Scientific Attitude Instrument Validation

The expert evaluation of the scientific attitude questionnaire yielded mean assessment scores ranging from 4.33 to 5.00. These scores indicated favourable expert evaluations regarding item relevance, linguistic clarity, readability, and alignment with the intended scientific attitude indicators. The findings provided preliminary expert-based evidence of the content relevance and suitability of the questionnaire for assessing students' self-reported scientific attitudes. Nevertheless, these findings should be interpreted as evidence of expert-judged instrument suitability rather than comprehensive evidence of construct validity or measurement reliability.

Preliminary Effectiveness of the Developed Textbook

Following expert validation and product refinement, the developed textbook was implemented over a three-month instructional period to examine changes in students' scientific attitudes. The experimental group received chemistry instruction supported by the developed e-learning-based chemistry textbook, whereas the control group received instruction using conventional printed chemistry textbooks. Students' scientific attitudes were assessed before and after the instructional intervention using the questionnaire described in the Method section. The distribution of pretest and posttest scientific attitude scores in the experimental and control groups is presented in Figure 5.

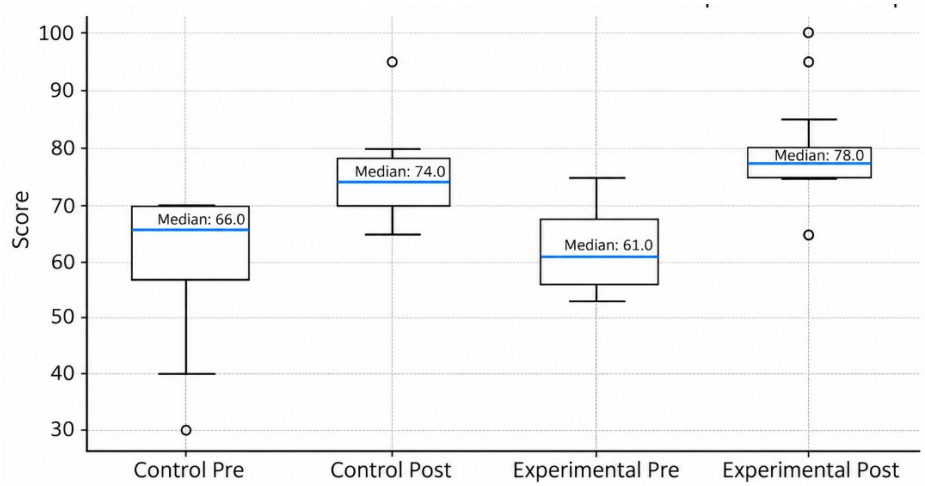

Figure 5. Box Plot of Pretest and Posttest Scientific Attitude of Students

As illustrated in Figure 5, both groups demonstrated improvements in scientific attitude scores following the instructional period, with the experimental group exhibiting a greater observed increase than the control group. The experimental group obtained a mean pretest score of 45.6 (SD = 6.2) and a mean posttest score of 86.3 (SD = 4.8). Meanwhile, the control group obtained a mean pretest score of 44.8 (SD = 5.9) and a mean posttest score of 65.2 (SD = 5.4). The experimental group demonstrated an observed mean score increase of 40.7 points, whereas the control group demonstrated an increase of 20.4 points. Consequently, the difference in observed mean score improvements between the two groups was 20.3 points. Although the groups exhibited relatively similar mean pretest scores, this descriptive similarity does not establish equivalence across all participant and classroom characteristics. Nevertheless, the greater observed improvement in the experimental group suggests that the developed textbook may have contributed to supporting students' scientific attitudes during the instructional period. Before conducting the between-group statistical comparison, the N-Gain percentage scores were assessed for normality and homogeneity of variance using the Shapiro–Wilk and Levene's tests, respectively. The reported results of the statistical assumption tests are presented in Table 6.

Table 6. The results of the prerequisite tests show normal and homogeneous data

Prerequisite Test	Class	Sig.	Keterangan
Shapiro–Wilk	Experiment	0.200	Normal
Shapiro–Wilk	Control	0.184	Normal
Levene	-	0.612	Homogen

The reported Shapiro–Wilk test results yielded p-values of 0.200 and 0.184 for the experimental and control groups, respectively. Both values exceeded the significance level of 0.05, indicating insufficient statistical evidence to reject the normality assumption. Similarly, the reported Levene's test result exceeded the significance threshold, indicating insufficient evidence to reject the assumption of equal variances. However, given the relatively small sample size, these results should not be interpreted as definitive confirmation that the

underlying statistical assumptions were fully satisfied. An independent-samples t-test was subsequently conducted to examine differences in N-Gain percentage scores between the experimental and control groups. The reported statistical comparison is presented in Table 7.

Table 7. Results of the scientific attitude of Students

		F	Sig	t	df	Sig (2-tailed)
NGain_percentage	Equal Variances Assumed	1.068	.316	8.864	17	< 0.001
	Equal Variances not Assumed			9.944	16.713	< 0.001

The reported independent-samples t-test indicated a statistically significant difference in N-Gain percentage scores between the experimental and control groups ($p < 0.001$). Based on the reported equal-variance analysis, the comparison yielded a t-statistic of 8.864 with 17 degrees of freedom. These findings were consistent with the descriptive pattern of greater observed improvements in scientific attitude scores among students using the developed e-learning-based chemistry textbook.

Although the statistical comparison suggests a substantial difference between the two instructional conditions, the findings should be interpreted within the limitations of the quasi-experimental research design. Specifically, the absence of individual random assignment and the involvement of only one existing class per instructional condition prevent the separation of potential classroom-related influences from the instructional treatment. Furthermore, individual-level statistical comparisons may not fully account for potential dependence among students within the same classroom. Consequently, the observed differences provide preliminary evidence of the potential effectiveness of the developed textbook rather than definitive evidence of a causal relationship.

Scientific Attitude Development through E-Learning-Based Chemistry Instruction

The greater observed improvement in scientific attitude scores among students using the developed textbook may be associated with the instructional opportunities provided by its multimedia features and flexible accessibility. Scientific attitudes encompass intellectual and behavioural dispositions that guide individuals in engaging with scientific information, evaluating evidence, and responding to scientific phenomena. These dispositions are closely related to curiosity, critical thinking, objectivity, openness to alternative perspectives, and scientific responsibility (Ulfa, 2016; Wahyudiati, 2022). In educational contexts, the development of such dispositions may contribute to students' engagement with scientific practices and the application of scientific values in everyday activities (Wu et al., 2021).

The findings of the present study suggest that the integration of digital resources into chemistry instruction may provide additional opportunities for developing these attitudes. Unlike conventional printed textbooks, which predominantly present information through textual explanations and static illustrations, multimedia-enhanced textbooks allow students to engage with chemical information through multiple forms of representation. Visualisations, animations, and instructional videos may encourage students to observe chemical phenomena, examine scientific explanations, and explore relationships between theoretical concepts and practical activities. These learning opportunities may be particularly relevant to supporting students' curiosity and willingness to engage with chemistry-related information.

Curiosity represents one of the important dimensions of scientific attitudes addressed by the developed textbook. The incorporation of visual representations, experimental videos, and animations provides potential stimuli for students to explore unfamiliar chemical phenomena and seek scientific explanations. Rather than merely receiving information, students are provided with opportunities to revisit learning materials and investigate aspects of chemistry that attract their interest. This instructional orientation is consistent with previous research suggesting that digitally supported inquiry and animation-based learning activities can stimulate students' curiosity and encourage engagement with scientific concepts (Noor et al., 2022).

Furthermore, the flexible accessibility of digital textbooks may encourage students to engage in independent learning and seek additional scientific information beyond scheduled classroom activities. Previous research has highlighted the potential of e-learning platforms and interactive multimedia resources to support students' engagement and curiosity through opportunities for flexible and independent exploration (Nasir et al., 2025; Wilujeng & Lestari, 2022). These instructional characteristics may help explain the greater observed improvement in overall scientific attitude scores among students using the developed textbook. However, because detailed statistical comparisons across the seven scientific attitude dimensions were not presented, the contribution of the textbook to individual dimensions, including curiosity, cannot be established independently from the overall questionnaire results.

The multidimensional nature of the scientific attitude questionnaire also requires careful consideration when interpreting the findings. The instrument encompasses attitudes towards scientific research, implementation of scientific attitudes, attitudes towards chemistry, chemistry learning experiences, curiosity, open-mindedness, and behavioural tendencies in learning chemistry. These dimensions capture different but related aspects of students' engagement with scientific knowledge and practices. Their development may be relevant to the formation of scientific behaviour and the application of scientific values in everyday activities (Ulfa, 2016; Wahyudiati, 2022; Wu et al., 2021). Nevertheless, improvements in questionnaire scores represent changes in self-reported attitudes and behavioural tendencies rather than direct observations of sustained changes in students' scientific behaviour.

The findings are consistent with previous studies highlighting the importance of active engagement, learning motivation, and flexible access within digital learning environments. Ferrer et al. (2022) emphasised the relevance of students' attitudes towards online learning in relation to motivation and engagement in higher education. Similarly, Yahiaoui et al. (2022) examined the contribution of e-learning systems to students' motivation and educational outcomes. Flexible digital learning environments may also provide opportunities for students to organise their learning activities and access instructional materials according to their individual needs (Kuluşaklı, 2025). The broader literature on e-learning adoption further highlights the importance of understanding the conditions under which digital learning systems can support educational experiences (Abdelfattah et al., 2024).

The potential contribution of the developed textbook can also be considered from the perspective of scientific observation and active learning. Digital learning environments that incorporate appropriately designed learning activities may facilitate students' engagement with scientific information and observational practices (Lechner et al., 2024). Interactive virtual practicum experiences and active online learning approaches have also been associated with opportunities to support scientific attitudes and related educational competencies (Kusumastuti & Sutinah, 2025; Rossi et al., 2021). These findings support the instructional rationale for integrating multimedia resources with activities that encourage students to observe, explore, and reflect on scientific phenomena rather than relying exclusively on the passive presentation of instructional content.

Another instructional advantage of e-learning-based textbooks is their flexibility in providing access to learning materials beyond conventional classroom settings. Digital resources can enable students to review instructional content repeatedly and engage with scientific information at times that suit their learning needs (Aparicio et al., 2016). Research on e-learning in higher education has also highlighted the relevance of flexible access, student interaction, and technology-supported learning experiences (Carmi, 2024). In the context of chemistry education, such flexibility may be particularly valuable because students often require repeated exposure to abstract representations and experimental explanations. Opportunities to revisit visual and audiovisual materials may encourage students to explore chemical phenomena more independently and develop greater engagement with scientific information.

Despite these potential advantages, the effectiveness of e-learning is influenced by instructional quality, technological readiness, and the availability of appropriate learning support. Adarkwah (2021) identified technological and accessibility challenges that may limit students' participation in online learning. Such challenges suggest that access to digital resources alone does not guarantee favourable educational outcomes. Poorly organised instructional materials, excessive information, insufficient guidance, and limited access to technological infrastructure may reduce the educational benefits of digital learning. Therefore, the integration of multimedia resources within coherent instructional sequences is an important consideration in the development of digital chemistry textbooks.

From an instructional design perspective, the greater observed improvement in scientific attitude scores in the experimental group may be associated with the combined opportunities for visual observation, independent exploration, repeated access to scientific information, and engagement with chemistry-related activities. These mechanisms provide a plausible theoretical explanation for the observed findings. However, the present study did not directly examine cognitive load, learning motivation, conceptual understanding, or engagement as mediating variables. Accordingly, these mechanisms should be interpreted as potential explanations rather than empirically established pathways through which the developed textbook influenced scientific attitudes.

Product Evaluation and Educational Implications

The evaluation findings highlight the importance of integrating product quality and pedagogical considerations in the development of e-learning-based chemistry textbooks. The favourable expert assessments indicate that the developed textbook received positive evaluations in terms of chemistry content, instructional media, and linguistic suitability. Meanwhile, the preliminary implementation findings demonstrate greater observed improvements in scientific attitude scores among students using the developed textbook compared with those using conventional printed textbooks. Together, these findings suggest that multimedia-enhanced chemistry textbooks may provide a promising complementary resource for supporting scientific attitudes in undergraduate chemistry education.

The instructional contribution of the developed textbook lies in its explicit orientation towards scientific attitude development through the integration of chemistry content, multimedia representations, learning activities, and educational assessment. Rather than treating technological integration as an educational objective in itself, the developed textbook illustrates an approach in which digital resources are intended to support meaningful engagement with scientific information. This orientation is particularly relevant to chemistry education, where students are expected not only to acquire disciplinary knowledge but also to develop curiosity, intellectual openness, and willingness to participate in scientific practices.

From a practical perspective, the developed textbook may serve as an alternative or complementary learning resource for lecturers seeking to incorporate digital technology into undergraduate chemistry instruction. Its visual and audiovisual features can be used to introduce chemical phenomena, reinforce classroom explanations, and provide opportunities for independent review of instructional materials. Furthermore, the textbook may be integrated into blended learning environments that combine digital exploration with classroom discussions and hands-on laboratory activities. Such integration represents a potential direction for instructional implementation rather than an empirically established superiority of blended learning, because the present study did not directly compare different models of instructional delivery.

The findings also provide implications for developers of chemistry learning resources. Digital textbook development should consider the alignment of instructional objectives, scientific content, multimedia features, learning activities, and assessment procedures. Appropriate technological infrastructure, accessibility, and instructional guidance are also important considerations for broader implementation. These factors may influence the extent

to which digital learning resources can provide meaningful opportunities for scientific attitude development across different educational contexts.

Research Limitations and Future Directions

Several limitations should be considered when interpreting the findings of this study. The research involved a relatively small sample of 19 undergraduate students from a single chemistry education study programme, limiting the generalisability of the findings. Furthermore, the quasi-experimental design involved non-random group allocation and only one existing class per instructional condition. Consequently, potential differences in classroom characteristics, student interactions, and other contextual factors could not be separated from the instructional treatment. These limitations restrict the strength of causal and statistical inference regarding the effectiveness of the developed textbook.

Another limitation concerns the measurement of scientific attitudes using a self-report questionnaire. Although the instrument underwent expert evaluation, self-reported responses may be influenced by social desirability, response tendencies, and students' interpretations of questionnaire statements. Moreover, the reported expert evaluations provide preliminary evidence of content relevance but do not establish comprehensive psychometric evidence regarding construct validity and measurement reliability. The findings should therefore be interpreted as changes in self-reported scientific attitude scores rather than direct evidence of changes in observable scientific behaviour.

The present study also evaluated the developed textbook as an integrated instructional resource. Consequently, the individual contributions of visual representations, instructional videos, animations, practice questions, and flexible digital accessibility could not be independently determined. Furthermore, the study did not include a reported follow-up assessment to examine whether the observed improvements were sustained beyond the three-month instructional period.

Future research should involve larger and more diverse samples across multiple institutions and include several classrooms within each instructional condition. Stronger research designs, including random assignment where feasible, would help reduce potential classroom-related confounding and strengthen causal inference. Further studies should also provide more comprehensive psychometric evidence for the scientific attitude questionnaire and incorporate observational or behavioural measures to complement self-reported assessments. Investigating changes across individual scientific attitude dimensions and examining the sustainability of these changes over time would provide a more comprehensive understanding of the educational contribution of digital chemistry textbooks.

CONCLUSION

This study developed an e-learning-based chemistry textbook using the ADDIE instructional design model to support the improvement of students' scientific attitudes. The developed textbook integrated systematically organised chemistry content, visual representations, animations, instructional videos, and practice questions to provide opportunities for scientific observation, curiosity, independent exploration, and engagement with chemistry-related information. Expert evaluations yielded Aiken's V coefficients ranging from 0.857 to 0.905, with an overall mean coefficient of 0.886, categorised as highly valid. These findings provided favourable preliminary evidence of the textbook's validity in terms of chemistry subject matter, instructional media, and linguistic quality.

The implementation of the developed textbook demonstrated greater observed improvements in scientific attitude scores among students in the experimental group than among those in the control group. The reported statistical comparison also indicated a significant difference in normalised gain scores between the two groups. The principal contribution of this study lies in the integration of digital technology, chemistry content, and instructional design explicitly oriented towards scientific attitude development. These findings suggest that the developed textbook may serve as an alternative or complementary instructional

resource for supporting scientific attitude development in undergraduate chemistry education. Nevertheless, given the relatively small sample size, non-random group allocation, and involvement of only one existing class per instructional condition, the findings should be interpreted as preliminary evidence of effectiveness rather than definitive evidence of a causal relationship.

RECOMMENDATION

The developed e-learning-based chemistry textbook is recommended as a complementary instructional resource for lecturers seeking to improve students' scientific attitudes through technology-supported chemistry instruction. Its multimedia features may be integrated with classroom discussions, inquiry-oriented learning activities, and hands-on laboratory experiences to provide meaningful opportunities for scientific observation, curiosity, independent exploration, and reflection. Educators and instructional material developers are encouraged to consider the alignment of chemistry content, multimedia representations, instructional activities, scientific attitude indicators, and assessment procedures when developing digital learning resources.

Future research should involve larger and more diverse samples across multiple institutions and include several classrooms within each instructional condition to strengthen the generalisability and robustness of the findings. Further investigations should employ stronger experimental designs, provide more comprehensive evidence of instrument validity and reliability, and examine improvements across individual dimensions of scientific attitudes. The incorporation of observational and behavioural assessments alongside self-reported measures is also recommended. Longitudinal investigations are encouraged to determine the sustainability of students' scientific attitude development and establish the broader educational effectiveness of e-learning-based chemistry textbooks.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Devi Qurniati	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Dwi Wahyudiati	✓	✓		✓		✓				✓	✓	✓	✓	✓

CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no financial or non-financial interests that may be perceived as influencing the conduct of the study, the interpretation of its results, or the writing of this manuscript.

ETHICAL APPROVAL

Permission to conduct this study was obtained from the Chemistry Education Study Programme, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri (UIN) Mataram, Indonesia. All participants provided informed consent to participate in the study. The confidentiality of participants' personal information and research data was maintained throughout the study, and the collected data were used exclusively for academic and research purposes.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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