Jurnal Pustaka Indonesia (JPI)
2026, Vol. 6, No. 1, 380–397
https://doi.org/10.62159/jpi.v6i1.2393

OPEN ACCESS
Research Article

Development of a Case Method-Based Interactive E-Module on Acid–Base Materials for Grade XI Senior High School Students

Sepsusilawati[1*], Jasrial[2]
[1,2] Department of Educational Technology, Universitas Negeri Padang, Padang, Indonesia

Abstract
The abstract nature of acid–base concepts often poses challenges for senior high school students in chemistry learning. To address this issue, this study aims to develop an interactive e-module based on the case method for Grade XI students and evaluate its validity, practicality, and effectiveness. This research employed a Research and Development (R&D) approach using the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation stages. Data were collected through expert validation sheets, practicality questionnaires, and learning achievement tests. Product effectiveness was examined using a one-group pretest–posttest design and analyzed through descriptive statistics and a paired-samples t-test. The developed e-module demonstrated high validity across material (96.2%), language (95.0%), and media (88.2%) aspects. Practicality testing indicated very positive student responses, with percentages ranging from 90.85% to 94.14%. In the small-group trial, the average score increased from 42.33 on the pretest to 89.17 on the posttest. During classroom implementation, the average posttest score reached 81.34, with a classical mastery level of 85.71%. Statistical analysis revealed a significant difference between students' pretest and posttest scores after using the e-module. These findings indicate that the developed e-module met the criteria of validity, practicality, and effectiveness within the context of this study. However, because effectiveness was evaluated using a one-group pretest–posttest design, the results should be interpreted as evidence of improved learning outcomes following implementation rather than definitive causal effects. The interactive case method-based e-module can therefore be considered a feasible digital teaching material for acid–base learning in senior high schools.

ARTICLE HISTORY
Received : 02 February 2026
Revised : 25 March 2026
Accepted : 25 April 2026

KEYWORDS
Acid–Base Learning; Case Method; Conceptual Understanding; Interactive E-Module; Learning Outcomes.

CORRESPONDING AUTHOR
***Sepsusilawati**, Department of Educational Technology, Universitas Negeri Padang, Padang, Indonesia. Email: sepsusilawati80@gmail.com

Introduction

Chemistry learning requires students to understand abstract concepts and relate them to observable phenomena in everyday life. One topic that consistently presents learning challenges is acid–base chemistry, as students often experience difficulties in connecting symbolic representations, microscopic processes, and macroscopic phenomena, resulting in misconceptions and low conceptual understanding (Park et al., 2020; Jauza Nareswari et al., 2024). These challenges indicate the need for learning approaches that not only facilitate conceptual understanding but also engage students in applying scientific knowledge to authentic situations.

One form of innovation widely adopted is the use of digital teaching materials, such as electronic modules (e-modules) (Nasution et al., 2025; Tumiar Sidauruk et al., 2025). Unlike printed modules, e-modules allow the integration of various multimedia elements, such as text, images, videos, animations, as well as interactive exercises and evaluations, into a single learning medium (Alyusfitri et al., 2024; Mutlu-Bayraktar, 2024). The presence of these various features makes the learning process more engaging and helps students understand the material more deeply. In addition

to providing easy access to learning resources, e-modules can also support independent learning, increase student participation during the learning process, and help them develop a more optimal understanding of concepts (Wong et al., 2024; Rahadi et al., 2025).

However, the presence of digital technology in learning has not fully addressed the challenges of developing 21st-century competencies (Liu et al., 2024; Haryaka & Khadijah Razak, 2025). Many digital teaching materials still focus on one-way delivery, thus providing little opportunity for students to develop critical thinking skills, analyze problems, and make decisions based on scientific evidence (Alcantar-Nieblas et al., 2025). However, various global education reports emphasize that critical thinking, problem-solving, collaboration, and decision-making are essential competencies that students must possess to face the complexities of life and the future world of work. Therefore, the development of digital teaching materials requires not only the ability to present information engagingly but also to be designed to facilitate higher-order thinking skills (Cong & Ironsi, 2025; Nur, 2025).

These challenges are becoming increasingly important in high school chemistry instruction. Chemistry is a branch of science characterized by its abstractness and complexity, requiring simultaneous representational skills at the macroscopic, submicroscopic, and symbolic levels (Wicaksono, 2022; Widarti et al., 2025). This situation causes many students to struggle to understand chemical concepts fully. Various studies have shown that misconceptions and poor conceptual understanding remain major problems in chemistry learning. These difficulties not only impact poor learning outcomes but also hinder students' ability to apply chemical concepts to solve real-life problems (Suresh & Vanmathi, 2024; Pratomo et al., 2025).

One chemistry topic consistently reported as challenging for secondary school students is acid–base chemistry (Damanhuri et al., 2016; Kumar, 2025). Learning difficulties in this topic extend beyond the abstract nature of the concepts and often involve persistent misconceptions related to pH, acid and base strength, degree of ionization, neutralization reactions, and the distinction between concentration and strength (Salame et al., 2022; Guerra-Reyes et al., 2024). Many students incorrectly assume that strong acids are always highly concentrated, struggle to interpret logarithmic pH scales, and experience difficulties explaining acid–base phenomena at the particulate level (Wiyantara et al., 2021; Clark et al., 2022).

These difficulties are further exacerbated by students' limited ability to connect the three levels of chemical representation macroscopic, submicroscopic, and symbolic which are essential for meaningful chemistry learning (Kapici, 2023; Widarti et al., 2025). For example, students may successfully calculate pH values using mathematical formulas while failing to explain the underlying ionization processes or the behavior of particles during neutralization reactions. Such fragmented understanding often results in procedural knowledge without deep conceptual comprehension.

Given these challenges, effective instruction should support students in linking chemical representations with authentic contexts and real-world phenomena. Contextual learning experiences that encourage learners to analyze and solve practical problems have been shown to promote deeper conceptual understanding and facilitate the application of acid–base concepts beyond the classroom (Asli et al., 2023; Omeh et al., 2025). Therefore, learning resources designed to integrate contextual cases, multiple chemical representations, and interactive learning activities may provide a promising approach to addressing persistent misconceptions in acid–base learning.

A needs analysis conducted among eleventh-grade students at SMA Negeri 1 Harau District showed that 46.5% found chemistry difficult to understand, and 63.4% experienced difficulties learning the material. Furthermore, 52.1% admitted to being less active in asking questions during the learning process. Furthermore, 97.2% of students stated they needed more interactive learning media, while none had ever used e-modules in their chemistry learning process. Formative assessment data also showed that the level of learning completion for acid-base material remained low, with completion rates ranging from 30.03% to 34.28%. These findings indicate a gap between students' needs for innovative learning and current learning practices (Awang et al., 2025; Suryani et al., 2026).

In addition to teaching materials, the learning approach also contributes to low student engagement in chemistry. Interviews with educators indicate that learning is still dominated by lectures and textbooks, leaving students as passive recipients of information. This situation prevents students' problem-solving skills from developing optimally. However, problem-solving is a key competency students must possess to face the challenges of the digital era and a knowledge-based society (Kibga et al., 2022; Setiawan et al., 2023).

One approach considered effective for developing critical thinking and problem-solving skills is the case study method (Purwanto et al., 2022; Ivan Sebastian et al., 2025). This approach places students in contextual situations that resemble real-life problems, requiring them to analyze information, identify problems, evaluate alternative solutions, and make decisions based on the scientific concepts they have learned. In the context of chemistry learning, the case study method allows abstract concepts such as acids and bases to be explored through real-life phenomena, including acid rain, agricultural soil quality, and health problems caused by pH imbalance. Thus, learning focuses not only on mastering concepts but also on applying them to solve real-life problems (Prasetia, 2023; Mardyah et al., 2024).

Previous studies have consistently reported the benefits of e-modules in supporting student engagement, self-directed learning, and academic achievement through the integration of multimedia and digital learning resources (Putra et al., 2023; Manggala et al., 2024). In parallel, case-based learning has been shown to enhance contextual understanding, analytical reasoning, and problem-solving by engaging students with authentic real-world situations (Loftus, 2022). However, existing studies have largely examined these approaches separately, with most e-module developments emphasizing content delivery, usability, and learning outcomes, while case-based instruction is commonly implemented through classroom discussions or printed learning materials.

Furthermore, limited attention has been given to the development of interactive case-based e-modules specifically for acid–based learning, despite the well-documented conceptual difficulties and misconceptions associated with this topic. Consequently, a gap remains in the instructional design literature regarding digital learning resources that integrate multimedia features, contextual case analysis, and independent learning activities within a single platform for senior high school chemistry. Addressing this gap, the present study develops and evaluates an interactive case-based e-module for acid–base learning in terms of its validity, practicality, and effectiveness.

Based on the description, this study aims to develop an interactive e-module based on the case method on acids and bases for grade XI high school students. The developed e-module is designed by integrating interactive multimedia, authentic cases, problem-solving activities, and student-centered learning principles. The novelty of this study lies in integrating the case method into an interactive

e-module specifically designed to improve problem-solving skills while strengthening understanding of acid-base concepts. Thus, this study is expected to make theoretical contributions to the development of case-based digital learning and practical contributions by providing innovative teaching materials relevant to the demands of 21st-century education.

Method

This study employed a Research and Development (R&D) approach to develop an interactive case-based e-module on acid–base concepts for Grade XI senior high school students. The development process followed the ADDIE model, which comprises Analysis, Design, Development, Implementation, and Evaluation stages (Branch, 2009). The e-module was designed using Canva and converted into a digital flipbook format accessible through computers and mobile devices. Product quality was evaluated through expert validation involving subject-matter, media, and language experts, followed by revision based on the feedback obtained. The revised product was subsequently tested through small-group and classroom implementation phases involving Grade XI students. Data were collected using validation sheets, practicality questionnaires, and learning achievement tests to evaluate the validity, practicality, and effectiveness of the developed e-module. Formative evaluation and revision were conducted throughout the development process to ensure the quality and suitability of the product for chemistry learning (Yunita Susanti & Hasanah, 2025).

The analysis stage begins with a needs analysis through observation, interviews, and questionnaires distributed to teachers and students (Aghnia Assifa Nadia et al., 2025; Sholeha, 2026). This analysis includes identifying student characteristics, the chemistry learning environment in schools, the use of available teaching materials, and the difficulties students experience in understanding acids and bases. Furthermore, a curriculum analysis is conducted to ensure the product aligns with the learning outcomes and objectives (Soleh et al., 2021; Ulandari et al., 2025). The analysis results indicate that students require digital teaching materials that are more interactive, contextual, and effective in helping them understand abstract concepts in chemistry.

The design stage focuses on developing the e-module design, including content structure, display design, navigation, learning flow, and research instrument development. At this stage, flowcharts and storyboards are developed to guide product development. The learning materials are designed based on learning outcomes on the topic of acids and bases, integrating a case method approach through the presentation of various authentic cases close to students' lives (Avargil et al., 2012; Dewi & Rahayu, 2024). Furthermore, supporting learning components, such as learning videos, illustrative images, practice questions, student worksheets, and learning evaluations, are also designed and integrated within a single digital platform.

The development phase involved designing the e-module using Canva and converting it into a digital flipbook through Flip Corporation. Canva was selected because it provides flexible design tools, multimedia integration, and user-friendly features that support the development of visually engaging learning materials, while Flip Corporation was utilized to transform the content into an interactive digital format accessible across multiple devices. The e-module incorporated various interactive features, including navigation buttons, embedded learning videos, hyperlinks, case-based learning activities, student worksheets, practice exercises, and online evaluation components. The product was designed to be compatible with computers, laptops, tablets, and smartphones, allowing students to access learning materials flexibly in both classroom and independent learning settings.

Access to the e-module was provided through a web-based link, enabling users to utilize its interactive features without requiring software installation. The completed product consisted of a cover page, user guide, learning outcomes, learning objectives, concept maps, instructional materials, learning videos, case-based activities, student worksheets, practice questions, evaluations, a glossary, and references. Following development, the product was validated by three experts a chemistry content expert, a media expert, and a language expert to evaluate content accuracy, media quality, and language appropriateness. Feedback from the validators was subsequently used to revise and refine the e-module before user testing (Nuralita et al., 2025).

The implementation phase involved practicality and effectiveness testing. The practical testing involved chemistry teachers and students to determine ease of use, clarity of material presentation, visual appeal, and the e-module's benefits in supporting the learning process. Furthermore, an effectiveness test was conducted using a one-group pretest-posttest design to measure changes in student learning outcomes after using the interactive e-module based on the case method. Before learning began, students were given a pretest to determine their initial abilities. After the entire learning series was completed, students were given a posttest to assess learning outcomes. The evaluation stage was carried out continuously throughout development. Formative evaluation was carried out during the development process through expert validation and product revision, while summative evaluation was conducted based on the results of practicality and effectiveness tests. This stage aims to ensure that the developed e-module not only meets theoretical feasibility standards but also can be used optimally for learning and has a positive impact on student learning outcomes. Research data were collected using validation sheets, practicality questionnaires, and learning outcome tests.

A set of research instruments was employed to evaluate the validity, practicality, and effectiveness of the developed e-module. Product validity was assessed using expert validation sheets covering content accuracy, instructional design, media presentation, and language appropriateness. The validation process involved three experts representing chemistry content, educational media, and language fields. Practicality data were collected through teacher and student questionnaires consisting of indicators related to ease of use, efficiency, attractiveness, and perceived usefulness, using a five-point Likert scale. Prior to implementation, all instruments underwent content validation through expert review and revision. The effectiveness of the e-module was measured using a learning achievement test on acid–base concepts, which was examined for content validity, item discrimination, difficulty level, and reliability before use. Validity and practicality data were analyzed using descriptive statistics in the form of percentages, while effectiveness data were analyzed using a paired-samples *t*-test to determine differences between pretest and posttest scores (Creswell & Creswell, 2017). The percentage score was calculated using the equation:

$$P = \frac{\sum X}{\sum X_{maks}} \times 100\%$$

P is the percentage value, ∑X is the total score obtained, and ∑X_max is the maximum possible score. The percentage value is then interpreted in light of the eligibility criteria to determine the e-module's validity and practicality. The effectiveness of the e-module was analyzed by comparing students' pretest and posttest scores. Before being used in the main study, the test instrument was tested to ensure its quality through analyses of validity, reliability, discrimination power, and question difficulty. Effectiveness testing was conducted using a paired-samples t-test to assess the

significance of differences in learning outcomes before and after using the e-module (Field, 2018). The test statistic was calculated using the equation:

$$t = \frac{\bar{d}}{\sqrt{\frac{\sum(d-\bar{d})^2}{n(n-1)}}}$$

$\bar{d}$ is the average difference between pretest and posttest scores, d is the difference in scores of each student, and n is the number of research samples. The product is declared effective if the analysis results show a significant difference between pretest and posttest scores after using the interactive e-module based on the case method. Through a series of procedures, this study produced an interactive e-module based on the case method that was developed systematically, validated by experts, tested directly by users, and evaluated based on validity, practicality, and effectiveness aspects to ensure the quality of the resulting product in supporting chemistry learning on the topic of acids and bases.

Result and Discussion

Result

The results of this study describe the quality of a case-based interactive e-module on acids and bases developed using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model (Branch, 2009). Product quality was evaluated based on three main aspects: validity, practicality, and effectiveness, which are important indicators in development research to determine the feasibility of learning products before wider implementation (Plomp & Nieveen, 2013). The development of the e-module is also based on the needs of 21st-century learning, which emphasize the integration of digital technology, contextual learning, and active student involvement in the learning process (Çeken & Taşkın, 2022; Munif & Subali, 2025). The presentation of the results begins with a description of the developed product, followed by expert validation results, practicality tests conducted by teachers and students, and effectiveness test results on student learning outcomes. The findings obtained provide an overview of the quality and feasibility of the e-module as a digital teaching material that supports chemistry learning in high schools.

Development of an Interactive E-Module Based on the Case Method

The development phase resulted in an interactive e-module based on the case method on acids and bases for 11th-grade high school students. The product was developed using the ADDIE model, which includes analysis, design, development, implementation, and evaluation. The e-module development was based on a needs analysis that identified the need for digital teaching materials that integrate the presentation of chemistry concepts with contextual, interactive, and problem-solving-oriented learning activities.

The e-module was designed in Canva and converted via the Flip Corporation platform, enabling flexible access on computers, laptops, and smartphones. The e-module is structured systematically, encompassing learning outcomes, learning objectives, concept maps, learning materials, learning videos, case-based student worksheets (LKPD), practice questions, evaluations, a glossary, and a bibliography. Each component is designed to support a student-centered learning process while facilitating the connection between theoretical concepts and phenomena encountered in everyday life (Zulhannan et al., 2025).

The case method is applied through the presentation of authentic cases related to the concepts of acids and bases. These cases serve as a starting point for learning, encouraging students to identify problems, analyze information, connect chemical concepts to real-world contexts, and formulate alternative solutions based on the scientific principles they have learned. Thus, the e-module functions not only as a digital learning resource but also as a tool that supports the development of students' critical thinking, scientific reasoning, and problem-solving skills (Gall et al., 2003; Amalia & Kuntjoro, 2026).

Figure 1. Display of the Case Method-Based Interactive E-Module

Figure 1 shows several key features of the developed e-module, including the cover page, main menu, concept map, and learning evaluation. The visual display is designed with a combination of colors, illustrations, navigation icons, and an attractive layout to increase learning motivation and facilitate student navigation through each module section. The structured menu allows students to access learning materials independently according to their individual needs and learning pace. In addition to the visual aspect, the e-module's content structure also considers the integration of materials, learning activities, and evaluation. The concept map is presented to help students understand the relationships among concepts in the acid-base topic. At the same time, the evaluation feature measures the level of concept mastery after the learning process. The intgration of these various components demonstrates that the developed e-module emphasizes not only technological aspects but also incorporates pedagogical principles that support meaningful learning and active student involvement in constructing their knowledge(Asrial et al., 2021; Manggala et al., 2024).

Validity of the Case Method-Based Interactive E-Module

The validity of the case method-based interactive e-module was evaluated by three validators: a media expert, a content expert, and a linguist. The validation process aimed to ensure that the developed product met the eligibility standards for content, media design, and language use before implementation in learning. The validation results showed that the e-module received a highly valid

rating across all assessment aspects, indicating that the product aligns with the learning objectives, student characteristics, and the principles of digital teaching materials development (Fenanlampir et al., 2021; Kelana et al., 2023).

Table 2. Summary of E-Module Validation Results

Aspect	Percentage	Category
Media	88,2%	Very Valid
Material	96,2%	Very Valid
Language	95,0%	Very Valid

Based on Table 2, the material aspect had the highest percentage at 96.2%, followed by the language aspect at 95.0% and the media aspect at 88.2%. The high score in the material aspect indicates that the content presented in the e-module aligns with the learning outcomes, demonstrates good conceptual accuracy, and supports students' understanding of acids and bases. In addition, the presentation of material integrated with contextual cases is considered able to facilitate the connection between chemical concepts and phenomena encountered in everyday life (Nuralita et al., 2025b; Yerizon et al., 2025). The language aspect obtained a very valid category with a percentage of 95.0%. These results indicate that the language used in the e-module follows good linguistic rules, is communicative, and is appropriate to students' cognitive development. The use of clear, easy-to-understand language is an important factor in the effectiveness of digital teaching materials, as it helps students understand information without multiple interpretations.

Meanwhile, the media aspect achieved a score of 88.2% and remained in the very valid category. This assessment indicates that the visual design, layout, navigation, color selection, and integration of various multimedia elements within the e-module support the product's readability and ease of use. Although this score is lower than other aspects, it indicates that the media display meets eligibility standards and can support a more engaging and interactive learning experience. Overall, the validation results indicate that the developed interactive e-module based on the case method has met the eligibility criteria very well in terms of material, language, and media. This finding indicates that the resulting product is suitable for use during implementation and further testing. The high level of validity also indicates that the integration of the acid and base material, the case method approach, and the interactive features in the e-module has been systematically designed to meet the needs of chemistry learning in high schools.

Practicality of the Case Method-Based Interactive E-Module

The practicality of the case-method-based interactive e-module was evaluated through trials with educators and students after the learning process was implemented. This evaluation aimed to determine the e-module's ease of use, efficiency, appeal, and usefulness in supporting the chemistry learning process. The analysis showed that the e-module was rated very practical by both educators and students, indicating that the product can be used effectively in learning activities without significant obstacles.

Table 3. Summary of Practicality Test Results

Respondent	Percentage	Category
Teacher	95,4%	Sangat Praktis
Student	92,24%	Sangat Praktis

Based on Table 3, educators gave a practicality rating of 95.4%, while students gave a rating of 92.24%. The high percentages in both groups of respondents indicate that the developed e-module is highly usable, easily accessible on digital devices, and supports more effective, flexible learning. These results also indicate that the interface design, material presentation structure, and navigation in the e-module have been designed to meet user needs, thereby facilitating both the learning process and educators' learning management. To obtain a more detailed picture of student responses, a practicality analysis was conducted based on several key indicators: ease of use, attractiveness, display efficiency, and the benefits of using the e-module.

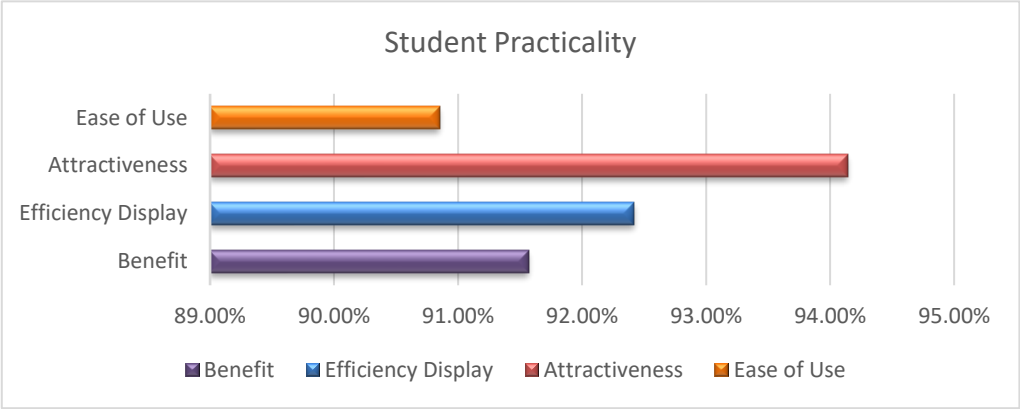

Figure 2. Practicality Based on Student Responses

The analysis results in Figure 2 show that all practicality indicators fall into the very practical category, with a percentage range of 90.85%–94.14%. The attractiveness aspect obtained the highest score of 94.14%, followed by efficiency display at 92.42%, usefulness at 91.57%, and ease of use at 90.85%. Overall, these results indicate that the interactive e-module based on the case method has a very high level of practicality, as indicated by student responses. This finding aligns with previous research indicating that integrating interactive multimedia and case-based learning activities into digital teaching materials can increase user acceptance and support student engagement in the learning process (Staneviciene & Žekienė, 2025; Syawaluddin et al., 2025).

Effectiveness of the Case Method-Based Interactive E-Module

The effectiveness of the case-method-based interactive e-module was evaluated by comparing students' learning outcomes before and after participation. Measurements were conducted using a test instrument that met instrument quality criteria, with a validity rate of 94.9% and a Cronbach's Alpha reliability coefficient of 0.79. Effectiveness testing was conducted at the small-group and classroom implementation stages to provide an overview of the effect of e-module use on student learning outcomes in acids and bases. In the small-group stage, the analysis showed a significant increase in pretest-to-posttest scores. The average student score increased from 42.33 on the pretest to 89.17 on the posttest, as shown in Table 4.

Table 4. Pretest and Posttest Results of Small Group Test

Indicator	Value
Pretest Average	42,33
Posttest Average	89,17

Based on Table 4, the average score increased by 46.84 points after students participated in learning using the interactive e-module based on the case method. These results indicate a positive

change in learning outcomes during the small group trial stage. Furthermore, the product's effectiveness was tested during the classroom implementation stage by analyzing student learning outcomes after using the e-module. The analysis results showed that the average posttest score reached 81.34 with a classical completion rate of 85.71%. Furthermore, the paired-samples t-test showed a significant difference between students' pretest and posttest scores.

Table 5. Summary of E-Module Effectiveness Results

Indicator	Value
Pretest Average	81,34
Classical Completion	85,71%
t Test Results	Significant
Category	Effective

The results in Table 5 indicate that more than 85% of students achieved learning completion after using the developed e-module. This finding is supported by statistical test results, which showed a significant difference between pre- and post-learning scores. Therefore, the interactive, case-based e-module meets the effectiveness criteria and supports student learning outcomes in acids and bases. To provide a clearer picture of improvements in learning outcomes, the average pretest and posttest scores can be presented graphically. This visualization shows a trend of increasing student achievement after the implementation of the e-module in the learning process.

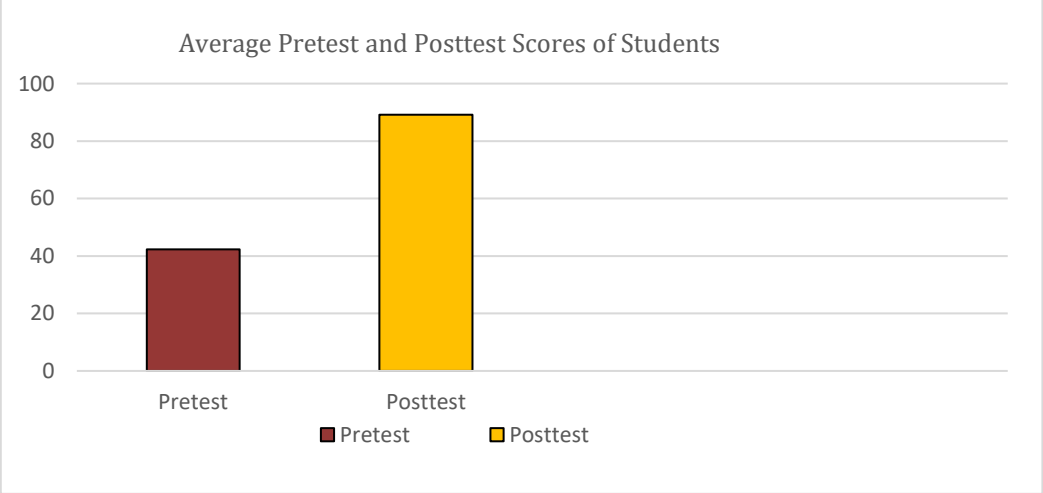

Figure 3. Comparison of Average Pretest and Posttest Scores of Students

Figure 3 presents the results of the effectiveness test of the interactive case-based e-module on acid–based learning. The findings show an increase in students' learning outcomes, with the mean pretest score of 42.33 improving to 89.17 on the posttest. This result indicates a gain of 46.84 points following the implementation of the developed e-module. Furthermore, the paired-samples *t*-test revealed a statistically significant difference between the pretest and posttest scores ($p < 0.05$). These findings indicate that the developed e-module met the effectiveness criteria and was feasible for use in acid–based learning at the senior high school level (Daryanes et al., 2023).

Furthermore, improvements in learning outcomes indicate that integrating interactive e-modules into learning can create a more flexible, independent, and student-centered learning experience (Rahmiati et al., 2023). This finding reinforces the view that interactive e-modules serve not only as learning support media but also as effective digital innovations that improve conceptual

understanding and student learning outcomes. Thus, the developed interactive e-module based on the case method has been shown to meet the criteria of validity, practicality, and effectiveness, making it suitable as an alternative digital teaching material for chemistry learning, particularly on acids and bases (Sofia et al., 2023).

Discussion

The research results show that the developed interactive e-module based on the case method has high validity, practicality, and effectiveness. These findings indicate that integrating digital technology with a case-based learning approach can produce teaching materials that are not only suitable for use but also relevant to the demands of 21st-century learning, which emphasize conceptual mastery, critical thinking, and problem-solving skills. These findings reinforce the view that innovative digital teaching materials should be designed not only as a medium for conveying information but also as a means to foster active, meaningful learning experiences (Pedraja-Rejas et al., 2024; Cong & Ironsi, 2025).

The high validity scores for the material, language, and media aspects indicate that the e-module has been systematically developed in line with students' characteristics and the complexity of the acid-base material (Adriani et al., 2021; Afrianti & Zainul, 2021). The material aspect that received the highest score indicates that the content presented is conceptually accurate, deep, and appropriate to the learning outcomes. Furthermore, the presentation of authentic cases allows students to connect the concepts of acids and bases to real phenomena, so that learning does not stop at theoretical understanding but develops into a deeper conceptual understanding (Asli et al., 2023; Cárdenas et al., 2024). This is important, as the material on acids and bases is one of the topics in chemistry that often gives rise to misconceptions and learning difficulties due to its abstract nature (Panambulo et al., 2022).

From a practical perspective, positive responses from educators and students indicate that e-modules can meet the needs for flexible, user-friendly, and engaging digital learning (Holisoh et al., 2023; Masie et al., 2025). High scores on the appeal indicator indicate that the combination of multimedia, visual design, and interactive activities successfully increased student engagement during the learning process. These findings indicate that display quality and ease of navigation are not merely complementary but also important factors influencing student motivation and learning comfort when using digital learning materials (Matarneh et al., 2025).

Furthermore, the effectiveness of e-modules, as demonstrated by significant improvements in learning outcomes, confirms that integrating the case method significantly contributes to students' conceptual understanding (Agustin et al., 2023). Learning activities, which begin with case presentations, encourage students to identify problems, analyze information, connect chemical concepts to real-world contexts, and formulate solutions based on scientific principles (Bernardi & Pazinato, 2022; Yan et al., 2023). This process aligns with the constructivist approach, which positions students as active subjects in the construction of knowledge. Therefore, improvements in learning outcomes not only reflect students' success in mastering the material but also demonstrate the development of analytical thinking and scientific reasoning skills during the learning process (Sukarmin, 2023; Rochim et al., 2024).

The findings of this study indicate that the developed interactive case-based e-module achieved high levels of validity, practicality, and effectiveness, which is consistent with previous studies reporting the positive impact of digital chemistry modules on student learning and

engagement (Mohd Hamid et al., 2021; Pertiwi et al., 2024). Similar to earlier R&D studies, the integration of multimedia elements such as videos, visual representations, and interactive navigation supported students in accessing and understanding learning content more effectively. However, the present study extends previous work by integrating the *case method* into the e-module design, allowing students not only to receive information but also to analyze authentic problems related to acid–base concepts. This finding is in line with research demonstrating that case-based learning promotes active knowledge construction, contextual understanding, and deeper cognitive engagement through the examination of real-world situations (Dai et al., 2026).

The novelty of this study lies in the integration of an interactive e-module with the case method in acid–base chemistry learning, where digital learning materials are not merely designed as repositories of content but as structured learning environments that guide students through contextual problem identification, conceptual analysis, and solution formulation. Unlike previous studies that have generally focused on the development of digital modules, multimedia learning materials, or case-based instruction separately, this study combines interactivity, authentic cases, multimedia representation, and systematic validation within a single instructional product. This integrated design provides a more comprehensive learning pathway for helping students understand abstract acid–base concepts through concrete and meaningful contexts.

This study contributes to the existing literature by demonstrating that the effectiveness of digital teaching materials depends not only on technological features but also on the pedagogical logic embedded in their design. The findings expand current knowledge in chemistry education by showing that interactive case-based e-modules can simultaneously support content validity, user practicality, learner engagement, conceptual understanding, and problem-solving-oriented learning. Methodologically, this study strengthens research and development studies by combining expert validation, user response analysis, and effectiveness testing, thereby offering a more robust model for evaluating digital instructional products. The findings also challenge the assumption that digital modules are primarily supplementary learning tools by showing that, when designed through a case-based and constructivist framework, e-modules can function as active learning environments that promote deeper scientific reasoning.

Theoretically, the findings support constructivist learning theory, multimedia learning theory, and case-based learning principles by showing that students learn more effectively when abstract scientific concepts are connected to authentic problems and represented through interactive digital media. The improvement in students' learning outcomes indicates that conceptual understanding is strengthened when learners are actively involved in interpreting cases, analyzing information, and constructing meaning rather than passively receiving explanations. These results also extend the theoretical understanding of digital chemistry learning by suggesting that technology becomes pedagogically meaningful only when it is aligned with inquiry, contextualization, and problem-solving processes. Therefore, the developed e-module provides evidence that the combination of multimedia representation and case-based learning can serve as a theoretical bridge between digital learning innovation and meaningful chemistry concept acquisition.

Pedagogically, this study implies that chemistry teachers should design learning experiences that move beyond explanation-based instruction toward interactive, contextual, and student-centered learning. The case-based e-module can help educators facilitate students' engagement, critical thinking, conceptual reasoning, and scientific problem-solving, particularly in abstract topics

such as acids and bases. From a policy perspective, the findings indicate the need for institutional support in developing and implementing digital teaching materials that are pedagogically grounded, curriculum-aligned, and accessible to students. Schools and education authorities should consider providing teacher training in digital module development, strengthening digital infrastructure, and encouraging the use of case-based digital resources in science learning. Such policies are important to ensure that digital transformation in education does not only focus on the availability of technology but also on the quality of learning design, teacher readiness, and students' equitable access to meaningful digital learning experiences.

This study has several limitations that should be considered when interpreting the findings. First, the study was conducted within a specific educational context and focused only on acid–base material, which may limit the generalizability of the results to other chemistry topics, school levels, or geographical settings. Second, although the study measured validity, practicality, and effectiveness, the analysis was primarily focused on short-term learning outcomes and did not examine long-term retention, transfer of learning, or sustained changes in students' critical thinking and problem-solving skills. Third, student responses may contain subjective bias because learners' perceptions of digital media can be influenced by novelty effects, prior digital literacy, and access to learning devices. Future research should involve larger and more diverse samples, compare the interactive case-based e-module with other instructional models through experimental or quasi-experimental designs, and investigate its impact on higher-order thinking skills, scientific literacy, learning motivation, and long-term conceptual retention. Further studies may also explore the integration of adaptive learning features, artificial intelligence-based feedback, or collaborative case analysis to strengthen the effectiveness and scalability of interactive digital modules in chemistry education.

Conclusion

This study aimed to develop and evaluate a case method-based interactive e-module on acid–base materials for Grade XI senior high school students by examining its validity, practicality, and effectiveness. The findings demonstrate that the developed e-module met high-quality criteria across the three dimensions of product evaluation. Expert validation confirmed that the e-module was highly valid in terms of material, language, and media aspects, indicating that its content, presentation, and technical design were appropriate for chemistry learning. Practicality testing also revealed highly positive responses from teachers and students, suggesting that the e-module was accessible, attractive, user-friendly, and relevant to classroom needs. Furthermore, the increase in students' learning outcomes from pretest to posttest, supported by statistical evidence, indicates that the e-module contributed to improved understanding of acid–base concepts. These findings answer the research objectives by showing that the integration of interactive multimedia and contextual case-based learning can produce a feasible and effective digital learning resource for supporting conceptual understanding, engagement, and problem-solving in chemistry education.

Theoretically, this study contributes to the development of digital chemistry learning by reinforcing the relevance of constructivist, multimedia, and case-based learning perspectives in designing instructional materials for abstract scientific concepts. Methodologically, the study offers a structured development and evaluation model that integrates expert validation, practicality assessment, and effectiveness testing within the ADDIE framework. Practically, the findings suggest that chemistry teachers can use interactive case-based e-modules to create more contextual, student-

centered, and problem-solving-oriented learning experiences. However, this study was limited to one chemistry topic, a specific school context, and a one-group pretest–posttest design, which restricts broader generalization and causal interpretation. Future research should involve larger and more diverse samples, apply comparative or experimental designs, examine long-term retention and higher-order thinking skills, and explore the integration of adaptive feedback or collaborative digital learning features. By positioning e-modules as active learning environments rather than supplementary digital materials, this study provides a forward-looking contribution to the advancement of technology-enhanced chemistry education.

References

Adriani, D., Azhar, M., Dj, L., Putra, A., & Yerimadesi. (2021). Validity and practicality level of acid-base electronic module based on structured inquiry containing three levels of chemical representation for senior high school student. *Journal of Physics: Conference Series, 1788*(1), 012038. https://doi.org/10.1088/1742-6596/1788/1/012038

Afrianti, T., & Zainul, R. (2021). E-learning development on basic chemical law materials in senior high school (SMA/MA) to improve high order thinking skill ability. *Journal of Physics: Conference Series, 1783*(1), 012128. https://doi.org/10.1088/1742-6596/1783/1/012128

Agustin, W., Sari, M. S., Suhadi, S., & Juwariyah, S. (2023). Developing a biology e-module based on PjBL-STEAM model to improve students' collaboration skills. *BIOEDUKASI, 21*(2), 117. https://doi.org/10.19184/bioedu.v21i2.39621

Alcantar-Nieblas, C., Glasserman-Morales, L. D., Suárez-Brito, P., Del Rio-Urenda, S., Tramon-Pregnan, C. L., & Vázquez-Parra, J. C. (2025). Developing future-ready competencies: Perceptions of complex thinking among university students in three nations. *Humanities and Social Sciences Communications, 12*(1), 1980. https://doi.org/10.1057/s41599-025-05859-9

Alyusfitri, R., Gistituati, N., & Fauzan, A. (2024). The effectiveness and relationship of student responses toward learning outcomes using interactive multimedia-based e-modules in elementary schools. *International Electronic Journal of Elementary Education, 5*. https://doi.org/10.26822/iejee.2024.354

Amalia, I. R., & Kuntjoro, S. (2026). Validitas e-modul berbasis guided inquiry pada materi perubahan lingkungan untuk melatihkan keterampilan literasi sains siswa. *BIODIK, 12*(1), 1–15. https://doi.org/10.22437/biodik.v12i1.53204

Asli, S., Basheer, A., & Hugerat, M. (2023). Acid-base chemistry and societal, individual, and vocational aspects of students' learning. *Creative Education, 14*(05), 943–960. https://doi.org/10.4236/ce.2023.145060

Asrial, A., Syahrial, S., Kurniawan, D. A., & Saputri, J. (2021). E-module based on local wisdom Ngubat Padi improves students' social care character. *Jurnal Ilmiah Sekolah Dasar, 5*(4), 579–587. https://doi.org/10.23887/jisd.v5i4.36206

Avargil, S., Herscovitz, O., & Dori, Y. J. (2012). Teaching thinking skills in context-based learning: Teachers' challenges and assessment knowledge. *Journal of Science Education and Technology, 21*(2), 207–225. https://doi.org/10.1007/s10956-011-9302-7

Awang, N. E., Zulkifli, H., & Hamzah, M. I. (2025). Factors affecting teachers' implementation of innovative pedagogies: A systematic literature review. *International Journal of Learning, Teaching and Educational Research, 24*(3), 366–382. https://doi.org/10.26803/ijlter.24.3.18

Bernardi, F. M., & Pazinato, M. S. (2022). O estudo de caso no ensino de química: Um panorama das pesquisas na área. *Revista Insignare Scientia, 5*(2), 221–236. https://doi.org/10.36661/2595-4520.2022v5n2.12999

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer US. https://doi.org/10.1007/978-0-387-09506-6

Cárdenas, F. R., Uribe, P., & Sánchez-Roa, V. A. (2024). Aprendizaje de la química a través de ejemplos farmacéuticos contextualizados: Jarabes y tabletas. *Papeles, 16*(32). https://doi.org/10.54104/papeles.v16n32.1861

Çeken, B., & Taşkın, N. (2022). Multimedia learning principles in different learning environments: A systematic review. *Smart Learning Environments, 9*(1), 19. https://doi.org/10.1186/s40561-022-00200-2

Clark, T. M., Dickson-Karn, N. M., & Anderson, E. (2022). Calculating the pH of a strong acid or a strong base before and after instruction in general and analytical chemistry. *Journal of Chemical Education, 99*(4), 1587–1595. https://doi.org/10.1021/acs.jchemed.1c00819

Cong, L., & Ironsi, C. S. (2025). Integrating mobile learning and problem-based learning in improving students' action competence in problem-solving and critical thinking skills. *Humanities and Social Sciences Communications, 12*(1), 1238. https://doi.org/10.1057/s41599-025-05397-4

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications.

Dai, C.-P., Ke, F., Zhang, N., Barrett, A., West, L., Bhowmik, S., Southerland, S. A., & Yuan, X. (2026). Investigating preservice teachers' emotions and dialogic teaching practices in simulation-based learning with artificial intelligence-powered virtual student agents. *Learning and Instruction, 104*, 102381. https://doi.org/10.1016/j.learninstruc.2026.102381

Damanhuri, M. I. M., Treagust, D. F., Won, M., & Chandrasegaran, A. L. (2016). High school students' understanding of acid-base concepts: An ongoing challenge for teachers. *International Journal of Environmental and Science Education, 11*(1), 9–27. https://doi.org/10.12973/IJESE.2015.284A

Daryanes, F., Darmadi, D., Fikri, K., Sayuti, I., Rusandi, M. A., & Situmorang, D. D. B. (2023). The development of articulate storyline interactive learning media based on case methods to train student's problem-solving ability. *Heliyon, 9*(4), e15082. https://doi.org/10.1016/j.heliyon.2023.e15082

Dewi, C. A., & Rahayu, S. (2024). Implementation of case-based learning in science education: A systematic review. *Journal of Turkish Science Education, 20*(4), 729–749. https://doi.org/10.36681/tused.2023.041

Fenanlampir, A., Leasa, M., & Batlolona, J. R. (2021). The development of homogeneity psycho cognition learning strategy in physical education learning. *International Journal of Evaluation and Research in Education (IJERE), 10*(3), 1047. https://doi.org/10.11591/ijere.v10i3.21713

Field, A. (2018). *Discovering statistics using IBM SPSS statistics*. SAGE Publications.

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational research: An introduction*. Allyn and Bacon.

Guerra-Reyes, F., Guerra-Dávila, E., Naranjo-Toro, M., Basantes-Andrade, A., & Guevara-Betancourt, S. (2024). Misconceptions in the learning of natural sciences: A systematic review. *Education Sciences, 14*(5), 497. https://doi.org/10.3390/educsci14050497

Haryaka, U., & Razak, N. K. (2025). Integrating digital literacy, critical thinking, and collaborative learning: Addressing contemporary challenges in 21st century education. *Journal of Hunan University Natural Sciences, 52*(3). https://doi.org/10.55463/issn.1674-2974.52.3.9

Holisoh, A., Nurhalimah, N., & Hamda, N. (2023). Analysis of the benefits of using e-modules as distance learning media: Can it help students improve cognitive and affective aspects of students? *Gema Wiralodra, 14*(2), 592–597. https://doi.org/10.31943/gw.v14i2.313

Ivan Sebastian, R.-A., Steider Benny, W., Santelises Leonor, A., Carlos Alberto, V. P., González Gabriela, A., Vazquez Ramón, S., & María Teresa, C. O. (2025). Case method in the teaching-learning process in higher education: A pedagogical innovation in transition. *Ciencia Latina Revista Científica Multidisciplinar, 9*(4), 7827–7856. https://doi.org/10.37811/cl_rcm.v9i4.19371

Jauza Nareswari, T., Wahyu Wijaya, H., & Candra Eka Setiawan, N. (2024). Development of STEAM-2C: Integrated acid-base digital book based on Malang local wisdom. *E3S Web of Conferences, 481*, 04003. https://doi.org/10.1051/e3sconf/202448104003

Kapici, H. O. (2023). From symbolic representation to submicroscopic one: Preservice science teachers' struggle with chemical representation levels in chemistry. *International Journal of Research in Education and Science, 9*(1), 134–147. https://doi.org/10.46328/ijres.3122

Kelana, A. J., Irfan, D., Maksum, H., Wulansari, R. E., & Efrizon. (2023). Flipbook based e-module with case method in vehicle testing course. *Journal for Lesson and Learning Studies, 5*(3), 480–486. https://doi.org/10.23887/jlls.v5i3.57186

Kibga, E. S., Sentongo, J., & Gakuba, E. (2022). Development of chemistry learners' problem-solving skills through hands-on instructional model. *International Journal of Evaluation and Research in Education (IJERE), 11*(4), 2029. https://doi.org/10.11591/ijere.v11i4.22688

Kumar, S. (2025). Misconceptions in acid-base chemistry: Diagnostic assessment and instructional intervention. *International Journal of Applied and Behavioral Sciences, 2*(2), 137–161. https://doi.org/10.70388/ijabs250145

Liu, J., Liu, Z., Wang, C., Xu, Y., Chen, J., & Cheng, Y. (2024). K-12 students' higher-order thinking skills: Conceptualization, components, and evaluation indicators. *Thinking Skills and Creativity, 52*, 101551. https://doi.org/10.1016/j.tsc.2024.101551

Loftus, S. (2022). Case-based learning. In K. N. Huggett, K. M. Quesnelle, & W. B. Jeffries (Eds.), *An introduction to medical teaching: The foundations of curriculum design, delivery, and assessment* (pp. 99–113). Springer International Publishing. https://doi.org/10.1007/978-3-030-85524-6_8

Manggala, M. A., Nyanasuryanadi, P., & Suherman, H. (2024). Inovatif pembelajaran menggunakan e-modul. *JETISH: Journal of Education Technology Information Social Sciences and Health, 3*(1), 550–557. https://doi.org/10.57235/jetish.v3i1.1983

Mardyah, U., Arif, K., Putri, A. N., Yurnetti, Y., Silvia, D., & Sari, Y. P. (2024). Misconception analysis of junior high school student in Lareh Sago Halaban Distrit on vibration, wave and sound materials using the four tier test instrument. *Jurnal Penelitian Pendidikan IPA, 10*(10), 8197–8208. https://doi.org/10.29303/jppipa.v10i10.7629

Masie, S. R., Malabar, S., Mulyanto, A., & Lantowa, J. (2025). Development of e-module for learning folklore based on local wisdom. *Journal of Ecohumanism, 4*(1). https://doi.org/10.62754/joe.v4i1.5967

Matarneh, S., AlQaraleh, L., Alkhrissat, T., & Abdel-Jaber, M. (2025). An analysis of e-learning system challenges in engineering education: An empirical study. *Cogent Education, 12*(1), 2445967. https://doi.org/10.1080/2331186X.2024.2445967

Mohd Hamid, S. N., Lee, T. T., Taha, H., Rahim, N. A., & Sharif, A. M. (2021). E-content module for chemistry massive open online course (MOOC): Development and students' perceptions. *Journal of Technology and Science Education, 11*(1), 67. https://doi.org/10.3926/jotse.1074

Munif, D. H., & Subali, B. (2025). Trends and mapping of STEAM-based interactive media: A systematic and bibliometric review. *Unnes Science Education Journal, 14*(3), 437–449. https://doi.org/10.15294/usej.v13i1.34411

Mutlu-Bayraktar, D. (2024). A systematic review of emotional design research in multimedia learning. *Education and Information Technologies, 29*(18), 24603–24626. https://doi.org/10.1007/s10639-024-12823-8

Nasution, H., Napitupulu, E., & Sinaga, E. K. (2025). Student engagement and achievement with a digital literacy e-module. *Academia Open, 10*(1), 10.21070/acopen.10.2025.11146. https://doi.org/10.21070/acopen.10.2025.11146

Nur, J. (2025). The impact of digital learning tools on students' critical thinking development. *Asian Journal of Applied Education (AJAE), 4*(4), 635–648. https://doi.org/10.55927/ajae.v4i4.15615

Nuralita, A. D. A., Subali, B., Nugroho, S. E., & Sidiq, M. (2025). Integrated interactive e-module for project-based learning to enhance independence and conceptual understanding of alternative energy. *Unnes Science Education Journal, 14*(3), 427–436. https://doi.org/10.15294/usej.v13i1.29167

Omeh, C. B., Olelewe, C. J., & Ohanu, I. B. (2025). Impact of artificial intelligence technology on students' computational and reflective thinking in a computer programming course. *Computer Applications in Engineering Education, 33*(3), e70052. https://doi.org/10.1002/cae.70052

Panambulo, H. E., Ratman, R., & Nurida, N. (2022). Development of chemistry's learning module oriented local wisdom of Central Sulawesi for high school in basic acid solution materials. *Jurnal Akademika Kimia, 11*(1), 14–18. https://doi.org/10.22487/j24775185.2022.v11.i1.pp14-18

Park, C.-Y., Won, J.-A., Shin, J. Y., Choi, H., & Paik, S.-H. (2020). Lack of sub-microscopic representation ability of 12th grade science students in various acid and base problem solving processes. *Journal of the Korean Chemical Society, 64*(1), 30–37. https://doi.org/10.5012/JKCS.2020.64.1.30

Pedraja-Rejas, L., Muñoz-Fritis, C., Rodríguez-Ponce, E., & Laroze, D. (2024). Mobile learning and its effect on learning outcomes and critical thinking: A systematic review. *Applied Sciences, 14*(19), 9105. https://doi.org/10.3390/app14199105

Pertiwi, N. P., Saputro, S., Yamtinah, S., & Kamari, A. (2024). Enhancing critical thinking skills through STEM problem-based contextual learning: An integrated e-module education website with virtual experiments. *Journal of Baltic Science Education, 23*(4), 739–766. https://doi.org/10.33225/jbse/24.23.739

Plomp, T., & Nieveen, N. (2013). *Educational design research: Part A. An introduction*. SLO.

Prasetia, A. (2023). Kajian literatur sistematis analisa penerapan kurikulum darurat di sekolah dasar dalam konsep dunia pendidikan. *Jurnal Kajian Pembelajaran dan Keilmuan, 7*(2), 205. https://doi.org/10.26418/jurnalkpk.v7i2.69297

Pratomo, H., Fitriyana, N., Wiyarsi, A., & Marfuatun, M. (2025). Mapping chemistry learning difficulties of secondary school students: A cross-grade study. *Journal of Education and Learning (EduLearn), 19*(2), 909–920. https://doi.org/10.11591/edulearn.v19i2.21826

Purwanto, A., Rahmawati, Y., Rahmayanti, N., Mardiah, A., & Amalia, R. (2022). Socio-critical and problem-oriented approach in environmental issues for students' critical thinking skills development in chemistry learning. *Journal of Technology and Science Education, 12*(1), 50. https://doi.org/10.3926/jotse.1341

Putra, Y. I., Fadli, R., & Dahry, S. (2023). Meta analyzing the ease of use of e-modules in learning. *Jurnal Inovasi Teknologi Pendidikan, 10*(4), 338–343. https://doi.org/10.21831/jitp.v10i4.62229

Rahadi, I. W. S., Astawa, I. W. P., & Suweken, G. (2025). Interactive e-module based on PQ4R on e-learning platform to improve conceptual understanding of 12th grade students. *Indonesian Journal of Educational Development (IJED), 6*(1), 41–54. https://doi.org/10.59672/ijed.v6i1.4622

Rahmiati, Saputra, I., & Oktarina, R. (2023). Interactive electronic module: Is it beneficial for learning? *Journal for Lesson and Learning Studies, 6*(2), 209–218. https://doi.org/10.23887/jlls.v6i2.60477

Rochim, R. A., Af'idah, N., Fitriyah, L. A., Wijayadi, A. W., & Falah, F. (2024). Profil keterampilan berpikir analisis calon guru IPA pada perkuliahan fisika dasar berbantuan media virtual laboratory. *JIIP - Jurnal Ilmiah Ilmu Pendidikan, 7*(5), 5007–5012. https://doi.org/10.54371/jiip.v7i5.4466

Salame, I. I., Montero, A., & Eschweiler, D. (2022). Examining some of the students' challenges and alternative conceptions in learning about acid-base titrations. *IJCER (International Journal of Chemistry Education Research), 6*(1), 1–10. https://doi.org/10.20885/ijcer.vol6.iss1.art1

Setiawan, N. C. E., Putri, D. E. K., Marfu'ah, S., Pramesti, I. N., & Rosli, M. S. (2023). 21st century skills: The perspective of chemistry teachers in Indonesia. *Hydrogen: Jurnal Kependidikan Kimia, 11*(4), 354. https://doi.org/10.33394/hjkk.v11i4.8575

Sholeha, M. (2026). Needs analysis of the development of self-directed learning e-module for the scientific writing course. *Educational Journal of Learning Technology, 3*(2), 167–181. https://doi.org/10.58230/edutech.v3i2.83

Sofia, N., Sandi, H. H., Yusra, I., & Ritonga, M. (2023). Efektivitas penggunaan e-modul berbasis case method terhadap kemampuan berpikir kritis. *Jurnal Ecogen, 6*(4), 587. https://doi.org/10.24036/jmpe.v6i4.15400

Soleh, A. R., Purnomo, E., & Pratiwi, D. R. (2021). Kesesuaian isi bahan ajar daring dengan kurikulum pada laman sumber.belajar.kemdikbud.go.id sebagai penunjang dalam proses pembelajaran jarak jauh. *Urecol Journal. Part A: Education and Training, 1*(1), 20–27. https://doi.org/10.53017/ujet.21

Staneviciene, E., & Žekienė, G. (2025). The use of multimedia in the teaching and learning process of higher education: A systematic review. *Sustainability, 17*(19), 8859. https://doi.org/10.3390/su17198859

Sukarmin, S. (2023). Analysis student critical thinking skill on physic learning with e-modules type information search during the Covid-19 pandemic. *Jurnal Penelitian Pendidikan IPA (JPPIPA), 9*(6), 4130–4134. https://doi.org/10.29303/jppipa.v9i6.2652

Suresh, B. S., & Vanmathi, G. (2024). An analysis of higher secondary students challenges with chemistry learning. *International Journal of Advanced Research, 12*(10), 292–297. https://doi.org/10.21474/ijar01/19641

Suryani, E., Bentri, A., Hendri, N., Rayendra, R., & Prasetia, A. (2026). Mapping research trends in game-based ICT learning for interactive educational applications: A bibliometric study. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi, 10*(2), 768–782. https://doi.org/10.22437/jiituj.v10i2.54672

Syawaluddin, A., Aeni, N., & Asri, A. (2025). From past to present: Leveraging digital traditional games in teaching English vocabulary for young learners. *World Journal of English Language, 16*(1), 235. https://doi.org/10.5430/wjel.v16n1p235

Sidauruk, T., Delita, F., Berutu, N., Elfayetti, & Rohani. (2025). E-modules to improve learning independence, motivation and learning outcomes. *Jurnal Penelitian dan Pengembangan Pendidikan, 9*(1), 171–180. https://doi.org/10.23887/jppp.v9i1.74404

Ulandari, M., Situngkir, C., Permatasari, D., Tampubolon, P. N., Simamora, M. D., & Sibagariang, S. A. (2025). Analysis of curriculum development and learning planning. *Jurnal Ilmu Sosial dan Humaniora, 3*(4), 336–347. https://doi.org/10.58540/isihumor.v3i4.1222

Wicaksono, A. G. (2022). Johnstone's levels of representation in science learning. *Spektra: Jurnal Kajian Pendidikan Sains, 8*(1), 19. https://doi.org/10.32699/spektra.v8i1.224

Widarti, H. R., Wiyarsi, A., Yamtinah, S., Siddiq, A. S., Sari, M. E. F., Fauziah, P. N., & Rokhim, D. A. (2025). Analysis of content development in chemical materials related to ethnoscience: A review. *Journal of Education and Learning (EduLearn), 19*(1), 422–430. https://doi.org/10.11591/edulearn.v19i1.21210

Wiyantara, A., Widodo, A., & Prima, E. C. (2021). Identify students' conception and level of representations using five-tier test on wave concepts. *Journal of Physics: Conference Series, 1806*(1), 012137. https://doi.org/10.1088/1742-6596/1806/1/012137

Wong, J. T., Chen, E., Au-Yeung, N., Lerner, B. S., & Richland, L. E. (2024). Fostering engaging online learning experiences: Investigating situational interest and mind-wandering as mediators through learning experience design. *Education and Information Technologies, 29*(14), 18789–18815. https://doi.org/10.1007/s10639-024-12524-2

Yan, Y., Yuehong, W., Kun, L., Hongbo, Z., Hongyu, Z., Yingming, Y., & Zhili, Z. (2023). Implementation of mind mapping with problem-based learning in prosthodontics course for Chinese dental students. *BMC Medical Education, 23*(1), 530. https://doi.org/10.1186/s12909-023-04479-8

Yerizon, Y., Arnellis, A., Suherman, S., Arnawa, I. M., Sa'dijah, C., & Anwar, L. (2025). Does adaptive e-module (Ae-M) effective in enhancing students' numeracy literacy ability? *Salud, Ciencia y Tecnología, 5*, 1480. https://doi.org/10.56294/saludcyt20251480

Yunita Susanti, L., & Hasanah, R. (2025). Development of a basic chemistry e-book enhanced with multiple representations and STEM activities. *Journal of Tropical Chemistry Research and Education, 7*(2), 95–108. https://doi.org/10.14421/jtcre.2025.72-03

Zulhannan, Kesuma, G. C., Musyarrofah, U., & Andriansyah, Y. (2025). Enhancing communicative Arabic teaching: Evaluating the Al-Arabiyah Baina Yadaik model. *Journal of Educational and Social Research, 15*(3), 318. https://doi.org/10.36941/jesr-2025-0100