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# Enhancing Students' Achievement in Chemical Equilibrium Through a Scientific Literacy-Integrated 7E Learning Cycle E-Module

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**Abstract:** Scientific literacy is crucial in chemistry education, yet PISA results indicate that Indonesian students still struggle with abstract concepts like chemical equilibrium. To address this issue, this study developed a scientific literacy-integrated e-module based on the Learning Cycle 7E model to improve student learning outcomes. Using an educational design research approach with the Plomp model, the e-module's validity, practicality, and effectiveness were evaluated. Validation by subject matter and media experts yielded high validity scores of 0.89 and 0.91, respectively. Practicality testing involving teachers and students resulted in high scores of 91.27% and 89.70%. Effectiveness analysis, measured using the N-Gain formula, showed a significant improvement in students' learning outcomes. These results indicate that the developed e-module is valid, practical, and effective in supporting the understanding of chemical equilibrium among senior high school students.

**Keywords:** e-Module; Learning Cycle 7E; Chemical Equilibrium; Sscientific Literacy; Educational Design

## Introduction

Chemistry is a scientific discipline characterized by a multitude of abstract and interconnected concepts, many of which are closely related to other fields of science (Cebrián-Lacasa et al., 2024). With its wide-ranging descriptive and theoretical scope, chemistry education demands that students not only memorize facts but also develop scientific literacy skills (Trencher et al., 2023). Scientific literacy refers to the ability to explain scientific phenomena, interpret scientific data, evaluate information critically, and apply scientific knowledge to solve real-world problems (Romanova et al., 2024). In the context of 21st-century education, scientific literacy is considered a crucial competency and a key indicator of a nation's scientific achievement (Vlachopoulos & Makri, 2024).

Despite its importance, scientific literacy among Indonesian students remains a significant challenge (Yetti, 2024). The Programme for International Student Assessment (PISA), conducted by the Organisation for Economic Co-operation and Development (OECD), evaluates educational systems worldwide by measuring 15-year-old students' competencies in reading, mathematics, and science (Furnham & Cheng, 2024). The 2018 PISA results showed that Indonesian students scored an average of 396 points in scientific literacy, a decline from 403 points in 2015, and considerably lower than the OECD average of 480 points (Marini et al., 2025). These findings indicate that science education in Indonesia has not sufficiently equipped students with the skills necessary to understand and apply scientific concepts effectively (Hsu et al., 2025).

One contributing factor to this issue is the tendency for science education to focus heavily on memorization

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rather than fostering inquiry, critical thinking, and problem-solving skills (Motlagh et al., 2024). Students often perceive science learning as the process of memorizing concepts, theories, formulas, and laws without understanding their underlying principles or practical applications (Biedermann et al., 2025). This superficial approach to science education hampers students' ability to meaningfully connect scientific ideas to real-world phenomena, leading to difficulties in mastering complex topics such as chemical equilibrium (Azimi et al., 2023).

Chemical equilibrium, a fundamental concept in chemistry, is known for its abstract nature and its reliance on understanding dynamic systems at the macroscopic, submicroscopic, and symbolic levels. Preliminary observations conducted in several Indonesian schools, including MAN Insan Cendekia Padang Pariaman, SMAN 12 Padang, and SMAN 14 Padang, revealed that a significant proportion of students perceive chemical equilibrium as a difficult topic. Specifically, 53% of students rated the topic as difficult, while 47% considered it moderately difficult. Additionally, 67% of teachers indicated that students' academic performance in chemical equilibrium was still lacking. These findings highlight the urgent need for improvements in science teaching methods to better support students' conceptual understanding.

Addressing this challenge requires the adoption of innovative instructional models that align with the goals of 21st-century education. One promising approach is the Learning Cycle 7E model, a constructivist-based instructional design that emphasizes active student engagement in the learning process (Truc, 2024). The 7E model guides students through seven interconnected phases: elicit, engage, explore, explain, elaborate, evaluate, and extend. This model promotes inquiry-based learning, encourages students to construct their own understanding through exploration and reflection, and fosters the development of scientific attitudes and skills (Luan et al., 1925).

However, despite its potential, the implementation of the Learning Cycle 7E model remains limited in many schools (Xu et al., 2025). Teachers often lack familiarity with the model's structure, syntax, and the benefits it offers in enhancing student learning outcomes (Hastert et al., 2022). Therefore, there is a pressing need to introduce and integrate this model more effectively into science education, particularly in challenging topics like chemical equilibrium.

In addition to adopting an effective learning model, it is essential to consider the unique characteristics of chemistry as a discipline (Weeks & Sullivan, 2024). Chemistry knowledge is structured across three levels of representation: macroscopic (observable phenomena), submicroscopic (particle-level processes), and symbolic (mathematical and chemical notation) (Regalia et al., 2023). Integrating these representations seamlessly in instruction is critical for fostering a deep understanding of chemical concepts (Duan et al., 2024). Traditional teaching methods often struggle to make these connections explicit, leading to fragmented student understanding (Warshauer et al., 2023). Visual aids such as animations, simulations, and digital visualizations have been recommended to address this gap, providing dynamic and tangible representations of submicroscopic processes and linking them to macroscopic observations and symbolic expressions (Eswaran et al., 2025).

The integration of digital technology into science education is also aligned with the competencies required for 21st-century learners, particularly in using information and communication technology (ICT) effectively (Demissie et al., 2022). Schools with advanced technological facilities, such as MAN Insan Cendekia Padang Pariaman, present significant opportunities to implement technology-enhanced learning approaches. Despite the availability of devices such as Smart TVs and One Screen tools, the integration of technology into chemistry instruction remains limited, primarily due to the lack of suitable digital learning resources. Existing teaching materials are often in printed form, missing opportunities to utilize technology for more interactive and engaging learning experiences.

E-modules, as digital instructional materials, offer a practical solution to this challenge (Hustad et al., 2025). Designed for flexible and independent learning, e-modules present content in an organized, interactive, and media-rich format accessible across a range of electronic devices (Novitra et al., 2025). The development of e-modules should align with the 2013 Curriculum in Indonesia, which emphasizes the importance of mastering ICT skills as part of preparing students for global competition (Lemana II et al., 2024).

Based on these considerations, this study aims to develop a Learning Cycle 7E-based e-module integrated with scientific literacy for the topic of chemical equilibrium. The objectives are to design a valid, practical, and effective instructional material that can enhance students' understanding of chemical equilibrium and support the improvement of scientific literacy skills among senior high school students.

## Method

This study employs a Research and Development (R&D) approach with the aim of producing a 7E Learning Cycle-based e-module integrated with scientific literacy on the topic of chemical equilibrium, as well as testing its validity, practicality, and effectiveness in improving the learning outcomes of Grade XI senior high school students. The development model used in this study is the Plomp model, developed by Tjeerd Plomp, which consists of three main stages: Preliminary Research; Development or Prototyping Phase; and Assessment Phase (Merrouche et al., 2025).

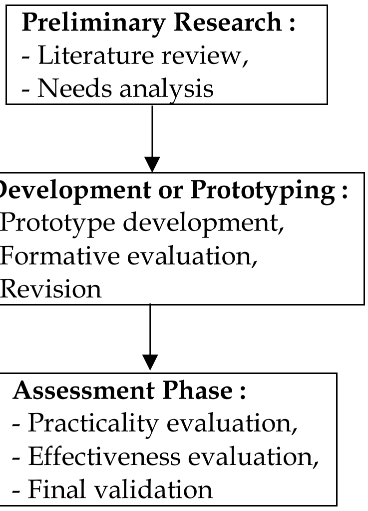


**Figure 1.** Plomp Development Model

During the Preliminary Research phase, the research primarily focuses on content validity, with minor emphasis on consistency and practicality. Activities conducted at this stage include literature reviews and analysis of previous research relevant to the topic under study. Subsequently, in the Development or Prototyping Phase, the initial emphasis is placed on consistency (construct validity) and practicality. A prototype of the e-module is developed and iteratively revised based on formative evaluations. The final stage, Assessment Phase, focuses on evaluating the actual practicality, relevance, sustainability, and the effectiveness of the e-module in enhancing student learning outcomes.

To test the practicality and effectiveness of the e-module, field trials were conducted using a Nonequivalent Control Group Design (Sugiyono, 2019). This design involved two groups: an experimental group and a control group, each receiving different treatments. The experimental group used the developed e-module, while the control group underwent conventional instruction without the e-module.

The research population consisted of Grade XI students from public senior high schools (SMA/MA) in Padang City and its surrounding areas during the 2022/2023 academic year. Samples were selected through purposive sampling technique, considering specific criteria relevant to the study. Two classes were chosen as samples, one serving as the experimental class and the other as the control class. The sample comprised Grade XI students from MAN Insan Cendekia Padang Pariaman.

The research procedure involved several steps, starting with the design of the field trial and sample selection. Both classes underwent a pre-test to assess their initial knowledge. The learning process then took place: the experimental class used the 7E Learning Cycle-based e-module integrated with scientific literacy, while the control class followed conventional learning methods. During the learning process, students' learning activities were also evaluated. After the instructional period, a post-test was administered to measure learning outcomes. Additionally, teachers and students from the experimental class were asked to complete a practicality questionnaire to assess the ease of use and relevance of the e-module.

The data collection instruments used in this study included: teacher interview forms and student questionnaires to gather preliminary information and perceptions; instrument validation sheets to ensure measurement tool validity; self-evaluation sheets for formative evaluation; e-module validation instruments assessed by experts; one-to-one evaluation instruments for direct interaction-based assessment; practicality questionnaires for evaluating usability from teachers' and students' perspectives; and effectiveness instruments for measuring student learning outcomes improvement.

The data analysis techniques applied included: literature review analysis to build the theoretical foundation and identify development needs; validity analysis based on expert validation results; practicality analysis through calculating mean scores from practicality questionnaires; and effectiveness analysis by comparing pre-test and post-test results using appropriate statistical techniques to evaluate the impact of the e-module on students' learning outcomes.

## Result and Discussion

This study aimed to develop an e-module grounded in the learning cycle 7E integrated with scientific literacy for equilibrium chemistry, validated for its validity, practicality, and effectiveness in enhancing student learning outcomes in Grade XI of Senior High School. The study followed the Plomp development model, which includes three stages: preliminary research, prototyping, and assessment.

*Preliminary Research*

The initial phase involved several analyses: needs analysis, curriculum analysis, and concept analysis. Through interviews with chemistry teachers and questionnaires administered to Grade XII students, it was revealed that existing instructional materials were predominantly print-based and did not leverage technology despite the supportive infrastructure. Students expressed a preference for digital resources enriched with visuals and interactive elements. Notably, 68% of students found equilibrium chemistry challenging, highlighting the need for enhanced instructional materials.

This step ensured alignment with the 2013 Curriculum's Competency Standards (KD) and translated these into Indicators of Competency Achievement (IPK), ensuring comprehensive coverage of essential concepts.

Systematic identification and organization of key concepts such as dynamic equilibrium, homogeneous and heterogeneous equilibria, equilibrium constants, Le Chatelier's principle, and equilibrium shifts were conducted to structure the e-module effectively.

*Prototyping Phase*

Four prototypes were developed and refined through formative evaluations: Prototype I: Basic structure including cover, table of contents, instructions, competency standards, learning activities, evaluations, and references. Activities were designed around the 7E stages; Prototype II: Enhanced based on self-evaluation feedback, improving components like cover design, usage instructions, concept maps, and glossaries; Prototype III: Validated by subject matter and media experts. Adjustments addressed font sizes, image captions, exercise corrections, video translations, and overall layout refinements. Validator ratings across content, construction, language, and graphic components averaged Aiken's V = 0.89–0.91; and Prototype IV: Finalized after small group trials, focusing on eliminating blank pages and fixing audio issues in videos.

*Assessment Phase*

*Validity*

Validators rated the e-module highly across all evaluated components (average Aiken's V = 0.89–0.90).

**Table 1.** Overall E-module Validity Assessment

| Aspect | Value | Validity Category |
|---|---|---|
| Content Component | 0.90 | Very Valid |
| Construct Component | 0.89 | Very Valid |
| Language Component | 0.88 | Very Valid |
| Graphic Component | 0.99 | Very Valid |
| Average | 0.89 | Very Valid |

*Practicality*

Small group and field tests confirmed high usability (average practicality ratings > 89%).

**Table 2.** E-module Practicality Assessment in Small Group Trials

| Aspect | Score | Validity Category |
|---|---|---|
| Attractiveness | 95.00 | Very Practical |
| Ease of Use | 92.86 | Very Practical |
| Learning Time Efficiency | 93.33 | Very Practical |
| Benefit | 93.33 | Very Practical |
| Average | 93.63 | Very Practical |

*Effectiveness*

Experimental class (using the e-module) showed significantly higher post-test scores (N-Gain = 0.712) compared to the control class (N-Gain = 0.571), supported by a t-test (t-calculated = 2.352 > t-table = 2.015).

**Table 3.** N-Gain for Experimental and Control Classes

| Class | N | Pretest | Posttest | N-Gain | Criteria |
|---|---|---|---|---|---|
| Experimental | 23 | 17.91 | 76.35 | 0.712 | High |
| Control | 23 | 23.30 | 67.13 | 0.571 | Medium |

The comprehensive approach integrating the learning cycle 7E with multimedia elements substantiated the e-module's effectiveness. This method not only aligned with curriculum standards but also engaged students actively, fostering better conceptual understanding and critical thinking. Literature supports these findings; previous studies indicate substantial effect sizes for both the learning cycle 7E (3.15) and e-modules (3.53). This underscores the robust impact of structured, interactive learning tools on educational outcomes (Irwan & Aznam, 2021).

By addressing identified instructional gaps and leveraging technology, the developed e-module provided an effective solution enhancing accessibility and engagement. Its design facilitated flexible, self-paced learning, accommodating diverse academic abilities. This is particularly important in complex subjects like equilibrium chemistry, where visual aids and interactive elements can significantly enhance comprehension.

The significant improvement in learning outcomes, evidenced by higher N-Gain scores and positive practicality ratings, highlights the module's efficacy. These results suggest potential adaptability across various educational settings, reinforcing the value of innovative, well-structured digital learning resources in contemporary education (Alberto et al., 2024).

Future implementations could further explore its scalability and long-term impacts on student performance and engagement. Additionally, continuous updates and enhancements based on user feedback can ensure the module remains relevant and effective. This ongoing process of refinement aligns with the principles of iterative development, ensuring that educational tools evolve alongside advancements in technology and pedagogy (Hagos & Andargie, 2024).

**Table 4.** Hypothesis Test Results

| Class | N | X | $S^2$ | T-Calculated | T-Table |
|---|---|---|---|---|---|
| Experimental | 23 | 76.35 | 155.51 | 2.352 | 2.015 |
| Control | 23 | 67.13 | 197.75 | | |

Based on the table, the calculated t-value (t-count) is greater than the table t-value (t-table), indicating that the learning outcomes of the experimental class using the e-module were significantly higher than those of the control class.

## Conclusion

This study demonstrates that the integration of the learning cycle 7E with scientifically literate e-modules offers a transformative approach to teaching equilibrium chemistry. By addressing existing instructional challenges and leveraging multimedia technology, the developed e-module proves to be a valid, practical, and effective tool for enhancing student learning outcomes. Future research should focus on broader applications across different educational contexts and continuous improvement based on evolving educational needs and technological advancements.

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