



The Development of Chemistry E-Module Using STS Approach Based on HOTS on Acid-Base Materials

Salma Syauqi* & Retno Dwi Suyanti

Chemistry Education Study Program, Faculty of Mathematics and Natural Science, Universitas Negeri Medan, Jl. William Iskandar Ps. V, Medan Estate, Deli Serdang, Sumatera Utara 20221, Indonesia

*Corresponding Author e-mail: retnodwisuyanti@unimed.ac.id

Article History

Received: 28-04-2026

Revised: 04-05-2026

Published: 30-06-2026

Keywords: E-module; Science Technology Society; Higher Order Thinking Skills; Acid-Base; 4D Model.

Abstract

This study aims to develop a chemistry e-module based on the Science Technology Society (STS) approach oriented toward Higher Order Thinking Skills (HOTS) on acid-base material for eleventh-grade senior high school students. The development was conducted using the 4D model (Define, Design, Develop, and Disseminate). Validation was carried out by three expert groups: the content expert yielded a score of 3.50 (*Highly Feasible*), the media expert 3.20 (*Feasible*), and the instructional expert 3.30 (*Feasible*). Student responses to the e-module obtained a mean score of 3.60 (*Highly Feasible*). The effectiveness of the e-module was examined with 35 eleventh-grade students at SMA Negeri 2 Medan. Pretest results indicated a mean score of 39.00, which increased to 85.86 on the posttest. The mean N-Gain score of 0.7734 was categorized as *High*. The Paired Sample T-Test yielded $t = 32.3004$ ($p = 0.000$), further supported by the Wilcoxon signed-rank test ($W = 0$, $p = 0.000$). Cohen's d effect size was 5.4598, classified as *Large*. Furthermore, 97.1% of students surpassed the minimum mastery criterion (KKM). These findings demonstrate that the *KelasKimia.ku* e-module, developed within the STS framework and oriented toward HOTS, is valid, practical, and effective in improving student learning outcomes on acid-base material).

How to Cite: Syauqi, S., & Suyanti, R. D. (2026). The Development of Chemistry E-Module Using STS Approach Based on HOTS on Acid-Base Materials. *Hydrogen: Jurnal Kependidikan Kimia*, 14(3), 670-674. <https://doi.org/10.33394/hjkk.v14i3.20430>

 <https://doi.org/10.33394/hjkk.v14i3.20430>

This is an open-access article under the [CC-BY-SA License](#).



INTRODUCTION

Education plays a strategic role in shaping and developing high-quality human resources in a comprehensive and optimal manner (Halean et al., 2021). The challenges of the 21st century demand that the Indonesian education system undergo fundamental adaptation, particularly in fostering students' analytical thinking within the framework of 4C competencies: communication, collaboration, creativity, and critical thinking (Izzania et al., 2024). Higher Order Thinking Skills (HOTS) refer to cognitive abilities at the three highest levels of the revised Bloom's Taxonomy, namely analyzing (C4), evaluating (C5), and creating (C6) (Listiani & Rachmawati, 2022). Mastery of HOTS has become a primary priority in the implementation of the *Kurikulum Merdeka* (Independent Curriculum). However, the 2022

PISA results ranked Indonesia 68th out of 81 countries with a science score of 383, substantially below the OECD average of 485 (OECD, 2023), indicating a persistently low level of higher-order thinking among Indonesian students.

Chemistry, particularly the topic of acid-base, remains one of the most challenging subjects for senior high school students, as it encompasses three levels of representation: macroscopic, submicroscopic, and symbolic (Laohapornchai-phan & Chenprakhon, 2024). Observations and interviews conducted with chemistry teachers at SMA Negeri 2 Medan in October 2025 revealed that lecture-based instruction and exercise-based practice continue to dominate classroom learning, instructional resources are largely limited to textbooks, and laboratory practicals are

conducted only once per academic year. Students encounter considerable difficulty in connecting acid-base concepts to real-world phenomena, such as the acidic properties of rainwater, the mechanism of antacids, and the influence of soil pH on plant growth.

The Science Technology Society (STS) approach offers a relevant solution by integrating scientific content with authentic technological issues and socio-environmental problems (Acut & Antonio, 2023). The integration of the STS approach into a chemistry e-module is believed to create learning experiences that bridge theoretical knowledge with societal realities while simultaneously cultivating HOTS (Santoso et al., 2022). As an evolution of printed modules, electronic modules (e-modules) offer significant advantages, including high accessibility, incorporation of interactive multimedia elements, and flexibility of use across multiple devices (Balazon et al., 2026).

A review of prior studies indicates that, although considerable research has been conducted on chemistry e-modules and the STS approach independently, relatively few studies have specifically integrated both within a HOTS-oriented framework applied to acid-base material. This research gap serves as the foundational rationale for the present study. Accordingly, this study aims to: (1) develop an STS-based chemistry e-module oriented toward HOTS on acid-base material for eleventh-grade students; (2) assess the feasibility of the e-module based on expert validator evaluations and student responses; and (3) determine the effectiveness of the e-module in improving student learning outcomes.

METHOD

This study employed a Research and Development (R&D) methodology utilizing the 4D development model proposed by Thiagarajan et al., which consists of four sequential stages: Define, Design, Develop, and Disseminate. The study was conducted at SMA Negeri 2 Medan during the even semester of the 2025/2026 academic year.

Define Stage

A needs assessment was conducted through interviews with chemistry teachers and direct observation of classroom learning processes. The analysis encompassed four dimensions:

developmental needs, *Kurikulum Merdeka* curriculum analysis, student characteristics, and the conceptual and learning task requirements of acid-base material.

Design Stage

This stage involved the design of the e-module's structure and content, user interface layout, and research instruments. The e-module was designated *KelasKimia.ku* and published via Google Sites

(<https://sites.google.com/view/kelaskimiaku>).

This platform was selected for its accessibility across multiple devices, absence of additional installation requirements, and support for multimedia integration. The e-module structure was designed in accordance with the STS instructional stages: invitation, exploration, explanation and solution, and taking action.

Develop Stage

This stage encompassed the production of the e-module and its validation by three expert groups — content expert, media expert, and instructional expert — using a four-point Likert scale assessment instrument (1 = *Not Feasible* to 4 = *Highly Feasible*). The product was subsequently revised based on validator feedback prior to field testing.

Disseminate Stage

Field testing was conducted with 35 eleventh-grade students of Class XI Borland 2 at SMA Negeri 2 Medan across four instructional meetings (January–February 2026). The learning achievement test instrument comprised 20 multiple-choice items based on HOTS cognitive levels (C4–C6), adapted from a previously validated instrument (Berliana, 2023). Data were analyzed using the following procedures: descriptive statistics, Shapiro-Wilk normality test, Levene's test for homogeneity of variance, normalized N-Gain, Paired Sample T-Test, Wilcoxon Signed-Rank Test, and Cohen's d effect size

RESULTS AND DISCUSSION

Expert Validation Results

The validation results from the three expert groups are presented in Table 1. Content expert validation yielded a mean score of 3.50 (*Very Feasible*), with the majority of assessed aspects receiving a score of 4. The aspects of scientific concept accuracy, relevance of STS examples, and quality of evaluation items received a score of 3,

indicating the need for further refinement. This high overall score suggests that the integration of acid-base concepts within the STS framework was structured with scientific and pedagogical soundness, consistent with Al Idrus's (2025) assertion that science-based e-modules must demonstrate high conceptual accuracy and contextual relevance.

Table 1. Expert Validation Results of the KelasKimia.ku E-Module

Validator	Mean Score	Category
Content Expert	3.50	Very Feasible
Media Expert	3.20	Feasible
Instructional Expert	3.30	Feasible
Overall Mean	3.33	Feasible

Media expert validation yielded a score of 3.20 (*Feasible*), encompassing aspects of visual design, layout, navigation, interactivity, and accessibility. Following revision, the e-module met the standards required for digital instructional media. This finding aligns with the principle outlined by Hasanah et al. (2023) that clear navigation and consistent visual presentation facilitate students' comprehension of instructional content. Instructional expert validation yielded a score of 3.30 (*Feasible*), with recommendations for strengthening the student-centered orientation and clarifying the reflective learning procedure.

Student Responses

A student response questionnaire consisting of 10 items was administered to all 35 students upon completion of the e-module. The mean response score of 3.60 fell within the *Very Feasible* category. Aspects pertaining to the clarity of usage instructions, utility of visual illustrations, quality

Prerequisite Tests

Table 3. Results of the Shapiro-Wilk Normality Test and Levene's Homogeneity Test

Test	Data	Statistic	p-value	Remark
Shapiro-Wilk	Pretest	W = 0.9530	0.1405	Normal
Shapiro-Wilk	Posttest	W = 0.9420	0.0646	Normal
Levene	Pretest-Posttest	F = 2.9628	0.0897	Homogeneous

Both Shapiro-Wilk p-values (0.1405 and 0.0646) exceeded the significance level of $\alpha = 0.05$, confirming that the pretest and posttest data were normally distributed. Levene's test yielded a p-

N-Gain Analysis

Table 4. Distribution of N-Gain Categories

Category	Range	Number of Students	Percentage
High	$g \geq 0.70$	26	74.3%
Moderate	$0.30 \leq g < 0.70$	9	25.7%
Low	$g < 0.30$	0	0.0%
Mean N-Gain	0.7734	35	High

of HOTS items, and relevance to real-world contexts received the highest scores (4). These results reinforce the principle of e-module contextuality articulated by Wahyudi et al. (2022), who demonstrated that instructional materials grounded in real-world phenomena foster meaningful learning experiences.

E-Module Effectiveness: Descriptive Statistics

Table 2 presents the descriptive statistics of pretest and posttest scores for the 35 students of Class XI Borland 2.

Table 2. Descriptive Statistics of Pretest and Posttest

Statistic	Pretest	Posttest
N (Number of Students)	35	35
Minimum Score	20	70
Maximum Score	60	100
Mean	39.00	85.86
Median	40.00	85.00
Standard Deviation	9.84	7.81
Mastery (KKM = 75)	0 students (0%)	34 students (97.1%)

The mean pretest score of 39.00 indicated low baseline student competence, with no student achieving the minimum mastery criterion (KKM). Following instruction using the STS-based e-module, the mean posttest score increased substantially to 85.86, with 34 out of 35 students (97.1%) surpassing the KKM. The mean gain of 46.86 points indicates a high level of e-module effectiveness in improving student learning outcomes, consistent with the findings of Santoso et al. (2022), who demonstrated that the STS approach significantly enhances chemistry learning outcomes and students' analytical thinking skills.

value of 0.0897 > 0.05, indicating homogeneity of variance across groups. The fulfillment of both assumptions validated the application of parametric statistical tests.

The mean N-Gain of 0.7734 fell within the *High* category ($g \geq 0.70$). A total of 74.3% of students achieved a *High* N-Gain and 25.7% achieved a *Moderate* N-Gain, while no student fell within the *Low* category. These results are consistent with Amaliyah et al. (2023), who reported that the implementation of the STS approach supported by e-modules significantly improved student learning outcomes, including among students

Effectiveness Tests

Table 5. Results of the Paired Sample T-Test, Wilcoxon Signed-Rank Test, and Cohen's d

Statistical Test	Statistic	p-value	Remark
Paired T-Test	$t = 32.3004$	0.000	Significant
Wilcoxon Signed-Rank	$W = 0$	0.000	Significant
Cohen's d	$d = 5.4598$	—	Large Effect ($d \geq 0.80$)

The Paired Sample T-Test yielded $t = 32.3004$ with $p = 0.000$ ($p < 0.05$), substantially exceeding the critical value t -table ($df = 34$) = 2.032. H_0 was rejected and H_1 was accepted, confirming a highly significant difference between pre- and post-intervention learning outcomes. The nonparametric Wilcoxon Signed-Rank Test produced $W = 0$ ($p = 0.000$), reinforcing the consistency of this conclusion. Cohen's $d = 5.4598$ far exceeded the threshold for a *Large* effect ($d \geq 0.80$) as defined by Cohen (1988), indicating an exceptionally large practical impact of the e-module on learning improvement.



Figure 1. Mean Pre-test and Post-test Score Comparison

Viewed holistically alongside the N-Gain (0.7734, *High*) and posttest mastery rate (97.1%), it can be firmly established that the *KelasKimia.ku* STS-based HOTS-oriented e-module fulfills all three quality criteria for instructional materials: valid, practical, and effective (Izzania et al., 2024). The exceptionally large effect size reflects a genuine transformation in students' cognitive capacities, rather than a merely statistical difference. These outcomes directly address the research gap identified at the outset of the study, demonstrating that the integration of the STS approach within a HOTS-oriented e-module on

who had previously encountered difficulties in comprehending abstract chemistry concepts. This achievement can be attributed to the characteristics of the STS instructional stages employed: the four phases — invitation, exploration, explanation and solution, and taking action — systematically encouraged students to activate prior knowledge, conduct inquiry, and construct scientific solutions in a sustained manner.

acid-base material is not only academically viable but also empirically effective.

CONCLUSION

The *KelasKimia.ku* chemistry e-module, developed through the Science Technology Society (STS) approach and oriented toward HOTS on acid-base material, was successfully developed using the 4D model. The e-module was established to be: (1) *valid*, with expert validation scores of 3.50 (*Very Feasible*) for content, 3.20 (*Feasible*) for media, and 3.30 (*Feasible*) for instructional aspects; (2) *practical*, with a mean student response score of 3.60 (*Very Feasible*); and (3) *effective*, with a mean N-Gain of 0.7734 (*High*), a mastery rate improvement from 0% to 97.1%, $t = 32.3004$ ($p = 0.000$), and Cohen's $d = 5.4598$ (*Large*). This e-module has been proven to significantly enhance the learning outcomes and HOTS of eleventh-grade senior high school students on acid-base material.

RECOMMENDATION

Based on the research findings, it is recommended that chemistry teachers adopt the *KelasKimia.ku* e-module as a digital instructional supplement in the classroom. Future research may extend the implementation to other chemistry topics and larger student populations, as well as explore the integration of richer instructional video elements to enhance student engagement, particularly under conditions of limited internet access.

BIBLIOGRAPHY

Acut, D., & Antonio, R. (2023). Effectiveness of Science-Technology-Society (STS) approach on students' learning outcomes in science education: Evidence

- from a meta-analysis. *Journal of Technology and Science Education*, 13(3), 718–739. <https://doi.org/10.3926/jotse.2151>
- Al Idrus, S. W. (2025). Practicality analysis of an ethnoscience-based environmental chemistry e-module integrated with STEM in higher education. *Jurnal DIDIKA: Wahana Ilmiah Pendidikan Dasar*, 11(1), 177–187.
- Alifa, N. K., Bakti, I., Sholahuddin, A., & Iriani, R. (2025). Development of an e-module using an ethnoscience approach assisted by Heyzine Flipbook to improve science literacy on acid-base material. *JCAE (Journal of Chemistry and Education)*, 9(1), 27–38.
- Amaliyah, N., Rohaeti, E., & Wiyarsi, A. (2023). Development of a Science Technology Society (STS)-based chemistry module on buffer solution material to improve critical thinking skills of senior high school students. *Jurnal Pendidikan Sains Indonesia*, 11(2), 221–233.
- Amaliyah, T., Supardi, K. I., & Sumarti, S. S. (2023). Implementation of the Science Technology Society (STS) approach assisted by e-module to improve student learning outcomes and critical thinking skills. *Jurnal Inovasi Pendidikan Kimia*, 17(1), 30–40.
- Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.
- Balazon, F. G., Rosales, J., Alimoren, D. O., & Malaluan, N. E. (2026). Tech-based interactive e-module (TBIEM): A flexible learning material in biochemistry. *Frontiers in Education*, 11. <https://doi.org/10.3389/feduc.2026.1810422>
- Berliana, B. (2023). *The effect of guided inquiry learning model assisted by Lectora Inspire media on students' HOTS literacy in acid-base material* [Undergraduate thesis]. Universitas Negeri Medan.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
- Gultom, E. H., & Amdayani, S. (2023). Development of a STEM-based chemistry e-module on reaction rate material. *Jurnal Teknologi Pendidikan*, 8(2), 425–434.
- Halean, S., Kandowangko, N., & Goni, S. Y. (2021). The role of education in improving human resources at SMA Negeri 1 Tampan Amma in Talaud. *HOLISTIK: Journal of Social and Culture*, 14(2).
- Hasanah, M., Supeno, S., & Wahyuni, D. (2023). Development of a Flip PDF Professional-based e-module to improve students' creative thinking skills in science learning. *Tarbiyah Wa Ta'lim: Jurnal Penelitian Pendidikan dan Pembelajaran*, 10(1), 44–58.
- Izzania, F., Hamidah, I., & Setiawan, W. (2024). Application of the 4D model in the development of technology-based instructional materials in secondary education: A systematic literature review. *Jurnal Riset Pendidikan IPA*, 10(2), 118–133.
- Laohapornchaiphan, J., & Chenprakhon, P. (2024). A review of research on learning activities addressing the submicroscopic level in chemistry. *Journal of Chemical Education*, 101(11), 4552–4565.
- Listiani, W., & Rachmawati, R. (2022). Transformation of Bloom's taxonomy in HOTS-based learning evaluation. *Jurnal Jendela Pendidikan*, 2(03), 397–402.
- OECD. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. <https://doi.org/10.1787/53f23881-en>
- Santoso, B., Sumarti, S. S., & Wardani, S. (2022). The effect of the Science Technology Society (STS) approach on chemistry learning outcomes and students' analytical thinking skills on chemical equilibrium material. *Jurnal Inovasi Pendidikan Kimia*, 16(2), 88–98.
- Wahyudi, P., Hidayat, S., & Andayani, S. (2022). Development of a contextual chemistry e-module to improve conceptual understanding and learning motivation of senior high school students. *Jurnal Pendidikan Sains Indonesia*, 10(4), 678–689.
- Widiana, I. W., & Rosy, B. (2021). Development of a feasibility assessment instrument for digital-based instructional materials in chemistry learning. *Jurnal Penelitian dan Pengembangan Pendidikan*, 5(3), 381–391.