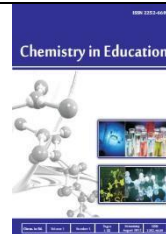




Chemined 15 (1) (2026)

Chemistry in Education

<https://journal.unnes.ac.id/journals/chemined>



Development of a Guided Inquiry-Based E-Module to Optimize Student's Conceptual Understanding of Buffer Solution Material

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ARTICLE INFO

Article history:

Received: September 2025

Approved: July 2026

Published: July 2026

Kata Kunci:

E-modul, Inkuiri terbimbing, Larutan penyangga, Pemahaman Konsep, Google Sites

Keywords:

E-Module, Guided Inquiry, Buffer Solution, Conceptual Understanding, Google Sites

DOI:

<https://doi.org/10.15294/chemined.v15i1.33206>

ABSTRAK

Penelitian ini bertujuan untuk mengembangkan e-modul berbasis pembelajaran inkuiri terbimbing guna mengoptimalkan pemahaman konsep siswa pada materi larutan penyangga. Penelitian menggunakan model pengembangan 4D yang dibatasi hingga tahap develop (3D). E-modul dirancang menggunakan platform Google Sites dan dilengkapi fitur interaktif seperti video pembelajaran, laboratorium virtual, dan permainan edukatif dari Wordwall. Subjek uji coba terdiri dari siswa SMA Muhammadiyah 1 Temanggung (skala kecil) dan SMA Negeri 1 Temanggung (skala besar). Hasil validasi ahli menunjukkan bahwa e-modul tergolong sangat layak dari segi materi dan media. Validasi e-modul oleh ahli materi mendapatkan skor 88,37% yang tergolong "sangat valid", dan validasi oleh ahli media mendapatkan skor 95,16% yang juga tergolong "sangat tinggi". Efektivitas e-modul ditunjukkan oleh peningkatan skor pemahaman konsep siswa yang signifikan berdasarkan uji pretest dan posttest ($n\text{-gain}$ 0,8260), serta respon positif dari siswa terhadap e-modul. Dengan demikian, e-modul yang dikembangkan dinilai layak, efektif, dan menarik untuk digunakan dalam pembelajaran kimia materi larutan penyangga.

ABSTRACT

This study aims to develop a guided inquiry-based e-module to optimize student's conceptual understanding of buffer solution material. The research employed the 4D development model, limited to the development stage (3D). The e-module was designed using the Google Sites platform and equipped with interactive features such as instructional videos, virtual laboratories, and Wordwall educational games. The trial subjects included students from SMA Muhammadiyah 1 Temanggung (small scale) and SMA Negeri 1 Temanggung (large scale). Expert validation indicated that the e-module was highly feasible in terms of content and media. Validation by subject matter experts yielded a score of 88.37%, categorized as "very valid", while media experts gave a score of 95.16%, also categorized as "very high". The effectiveness of the e-module was evidenced by a significant increase in student's conceptual understanding scores, with an $n\text{-gain}$ of 0.8260, as well as positive student responses to the learning media. Therefore, the develop e-module is considered feasible, effective, and engaging for teaching buffer solution material in chemistry learning.

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p-ISSN 2252-6609

e-ISSN 2502-6852

INTRODUCTION

Chemistry is a branch of science characterized by an interconnected and hierarchical structure of concepts. Consequently, an incomplete understanding of fundamental concepts may lead to difficulties in comprehending more complex and abstract advanced concepts (Wahdini, 2023). One of the chemistry topics considered complex is buffer solutions, which not only require an understanding of equilibrium, acids and bases, and stoichiometry, but also involve students' critical thinking skills and analytical abilities (Aliyah et al., 2023; Yudha et al., 2023). However, classroom instruction remains dominated by conventional methods that emphasize mere information transfer and provide limited opportunities for students to engage in concept discovery (Rizkayanti et al., 2023).

This situation is also observed at SMA Negeri 1 Temanggung, where the teaching of buffer solutions still relies on PowerPoint presentations without the support of interactive media, and the limited availability of digital learning resources results in a lack of active student participation and deep conceptual understanding. This is reflected in the average daily test score of only 79.38, indicating the need to improve the quality of learning through innovative, contextually relevant, and interactive learning media.

The development of information technology has created significant opportunities for the implementation of digital learning media, one of which is through e-modules. Compared to printed media, e-modules are capable of presenting dynamic and interactive content, as well as providing flexible access anytime and anywhere (Ardiansyah & Oktariani, 2024; Febriyanti & Muna, 2023). Platforms such as Google Sites enable multimedia integration and easy accessibility, which strongly supports students' independent learning (Hidayat et al., 2025; Lativa et al., 2024). In addition, integration with educational games such as Wordwall can significantly enhance students' engagement and learning motivation (Christianto et al., 2023; Putri & Kurniawati, 2025).

Furthermore, the implementation of the guided inquiry learning model aligns with the characteristics of chemistry topics that require conceptual understanding and scientific processes. This model has been proven effective in improving students' conceptual understanding through active engagement in problem formulation, hypothesis development, investigation, and conclusion drawing (Nurmaulita et al., 2022; Rahmadhani et al., 2023). Previous studies have also indicated that the development of guided inquiry-based e-module equipped with videos and interactive media can significantly enhance learning outcomes (Cahyani et al., 2021; Dewita & Andromeda, 2023; Simanjuntak et al., 2022).

Based on the aforementioned background the development of an interactive e-module based on guided inquiry learning, supported by Google Sites and Wordwall, for the topic of buffer solutions becomes highly relevant in addressing current learning challenges. This medium is expected to promote

more active, engaging, and meaningful learning experiences, as well as encourage students to construct a deeper conceptual understanding.

METHODS

This study employed a Research and Development (R&D) approach aimed at developing an interactive e-module based on guided inquiry learning for the topic of buffer solutions. The development model adopted was the 4D model (Define, Design, Develop, Disseminate) proposed by Thiagarajan, Semmel, and Semmel (Slamet, 2022). However, in this study, the process was limited to the this stage (Develop) due to time and cost constraints.

The define stage was carried out through a literature review and field study to identify the needs of teachers and students regarding chemistry learning media. Interviews with a chemistry teacher at SMA Negeri 1 Temanggung revealed the necessity of additional learning resources that are interactive and technology-based.

The develop stage consisted of validation by subject matter and media experts, as well as limited (small-scale) and large-scale trials to measure the e-module's effectiveness. Validation was conducted by lecturers and chemistry teachers using expert validation sheets. The small-scale trial was carried out with 15 students of Grade XII MIPA at SMA Muhammadiyah 1 Temanggung, while the large-scale trial involved 30 students of Grade XI MIPA at SMA Negeri 1 Temanggung.

Data collection was conducted through interview, expert validation sheets for content and media, readability questionnaires, test instruments (pretest and posttest), student response questionnaires, and documentation. Effectiveness analysis was performed by calculating the n-gain score to determine the improvement in conceptual understanding before and after using the e-module.

RESULT AND DISCUSSION

Result

Feasibility of the Guided Inquiry-Based E-Module on Buffer Solution Material

Table 1. Product Validation Results by Media Experts

No	Validator	Total Score	Maximum Score	Criteria
1	Validator 1	113	124	Very Valid
2	Validator 2	122	124	Very Valid
3	Validator 3	119	124	Very Valid
Average		118		Very Valid
Score Percentage			95,16%	Very Valid

The percentage score from the three media expert validators for the developed e-module achieved an average of 118 out of a maximum score of 124, corresponding to a percentage score of 95.16%, categorized as “very valid”.

Table 2. Product Validation Results by Subject Matter Experts

No	Validator	Total Score	Maximum Score	Criteria
1	Validator 1	141	152	Very Valid
2	Validator 2	143	152	Very Valid
3	Validator 3	119	152	Valid
Average		134,34		Very Valid
Score Percentage			88,37%	Very Valid

The evaluation from subject matter experts indicated an average score of 134.34 out of a maximum score of 152, with a percentage score of 88.37%, falling under the category of “very valid”.

Table 3. Readability Questionnaire Results

No.	Assessment Aspect	Percentage (%)	Category
1	Content	80	High
2	Display	82	High
3	Language	78	High
4	Student Engagement	75	High
5	Concept Understanding	78	High
Average		79	High

Based on the recap of media readability questionnaire administered to students, the results indicated an average percentage score of 79%, which falls into the “High” category.

Effectiveness of the Guided Inquiry-Based E-Module on Buffer Solution Material

Table 4. Pretest, Posttest, and N-Gain Results

Data	Pretest	Posttest
Number of Students	34	34
Highest Score	63.89	100
Lowest Score	19.45	65.28
Average Score	34.64	84.96
N-Gain	0.8260	
Category	High	

Based on these results, it was found that 34 students participated in the pretest and posttest to measure their performance before and after the learning process. The highest pretest score of 63.89 increased to 100 in the posttest, while the lowest score rose from 19.45 to 65.28. The average score also demonstrated a significant improvement, increasing from 34.64 during the pretest to 84.96 in the posttest. The N-Gain analysis revealed a score of 0.8260, which falls under the “high” category.

Table 5. Grouping of Students' Conceptual Understanding Ability

Score Range	Level of Understanding	Number of Students		Percentage (%)	
		Pretest	Posttest	Pretest	Posttest
$85 \leq X \leq 100$	Very High	0	14	0	41
$70 \leq X < 85$	High	0	14	0	41
$55 \leq X < 70$	Moderate	0	4	0	12
$40 \leq X < 55$	Low	1	2	3	6
$0 \leq X < 40$	Very Low	33	0	97	0
Total		34	34	100	100

The distribution of students' conceptual understanding levels indicated a highly positive change. During the pretest, the majority of students (97%) were in the very low category, with only one student (3%) in the low category. However, after the posttest, there was a substantial shift: 14 students (41%) were in the very high category, another 14 students (41%) in the high category, 4 students (12%) in the moderate category, and only 2 students (6%) remained in the low category.

Table 6. Students' Conceptual Understanding Based on Indicators

No.	Indikator	Number of Students Understanding Concept		Percentage Pretest (%)	Percentage Posttest (%)
		Pretest	Posttest		
1	Providing examples and non-examples	13	32	38	94
2	Restating the concept	8	31	24	91
3	Classifying objects based on certain properties	28	34	82	100
4	Presenting the concept in mathematical form	1	18	3	53
5	Applying, utilizing, and selecting procedures for specific tasks	4	22	12	65
6	Applying the concept	0	26	0	76
7	Developing necessary or sufficient conditions	5	29	15	85
Average		8	27	25	81

Table 6 details the results of students' conceptual understanding ability per indicator, showing that all aspects of conceptual understanding experienced a significant improvement from pretest to posttest. Overall, the average pretest score was only 25%, whereas the posttest average increased to 81%.

Students' Response to the E-Module Based on Guided Inquiry Learning on Buffer Solution Material

Students' responses were obtained from a questionnaire consisting of 15 items using a 4-point Likert scale. A score of 1 indicated a very low response, while a score of 4 indicated a very high response. The results are presented in Figure 1 and Figure 2.

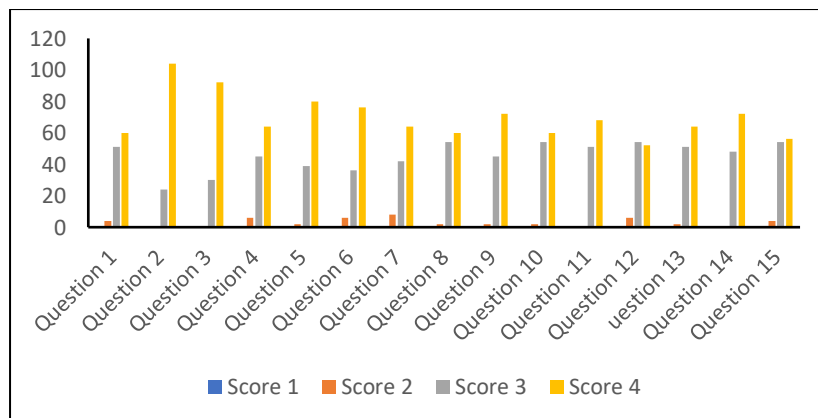


Figure 1. Recapitulation of Students' Responses to the Use of the E-Module

The majority of students responded with scores of 3 and 4, indicating that they gave a positive response toward the e-module used. Almost all statement items were dominated by score 4 (yellow), followed by score 3 (gray). Only a small number of student responses were at scores 1 and 2.

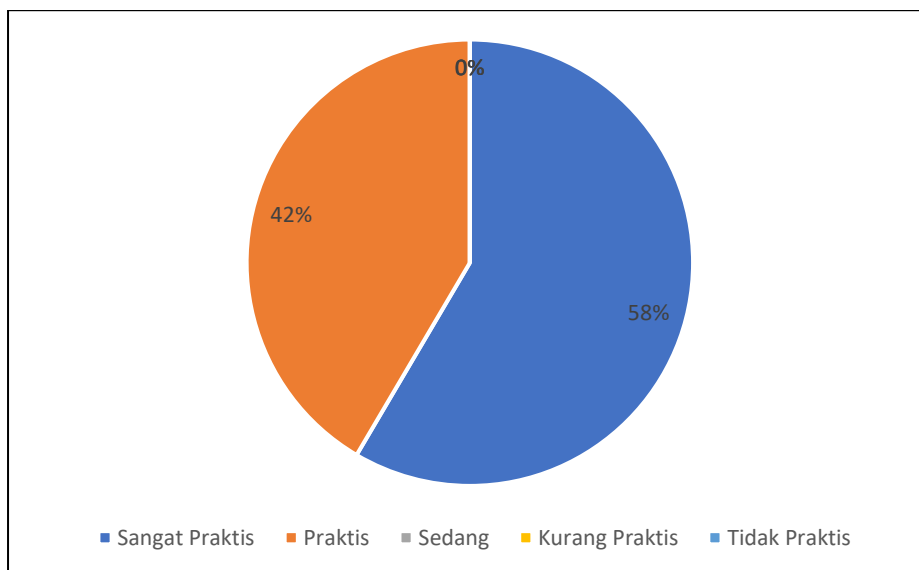


Figure 2. The Practicality of the Learning Media According to Respondents

Figure 2 shows the overall percentage of students' responses in a pie chart. As many as 58% of students stated that the developed e-module was categorized as very practical, while 42% stated it was practical. No student rated the media as moderate, less practical, or not practical at all (each 0%).

Discussion

Feasibility of the E-Module Based on Guided Inquiry Learning on Buffer Solution Material

The feasibility of the e-module was evaluated through validation by subject matter experts and media experts using validation sheets developed by the researchers. The validation covered aspects such as content, presentation, language, layout, interactivity, and alignment with the guided inquiry learning syntax. Based on the validation results, the average feasibility score from material experts reached 92.5% and from media experts 91.25%, both of which fall into the category of highly feasible. This indicates that the developed e-module meets quality standards and can be effectively implemented in learning.

These findings are consistent with previous research by Cahyani et al. (2021), who stated that guided inquiry-based e-modules have high validity in terms of both material and media aspects. The high feasibility scores indicate that the e-module is suitable for use as a learning resource in chemistry education, particularly for buffer solution material.

These results are also consistent with the findings of Tony et al. (2025), who developed an interactive e-module based on Google Sites for IPAS learning, obtaining scores of 92% for the language

aspect and 91.67% for the material aspect. These relatively high results demonstrate that media in the form of an e-module based on Google Sites is valid for use.

Effectiveness of the E-Module on Students' Conceptual Understanding

Learning effectiveness refers to the success of the learning process in terms of the level of achievement of learning objectives after instructional activities have been completed. A learning activity is considered effective if the previously formulated objectives are achieved. Effectiveness testing involves an evaluation process of the learning media developed by involving students as direct users of the media (Milala et al., 2021).

The number of students in the large-scale test of this study was 34. The highest pretest score was 63.89, which increased to 100 in the posttest, while the lowest score increased from 19.45 to 62.28/ The average pretest score of 34.45 experienced a significant increase to 84.96 in the posttest. Based on the calculations, the N-Gain value obtained was 0.8260, categorized as high. This indicates that the e-module developed is effective in improving students' conceptual understanding of buffer solution material.

This improvement shows that guided inquiry-based e-modules are effective in helping students understand buffer solution concepts. The learning activities emphasize observation, data collection, and hypothesis testing, allowing students to be more active and critical in building concepts.

These findings are consistent with research by Dewita and Andromeda (2023), who also found that the use of guided inquiry-based e-modules on titration material significantly improved learning outcomes. Thus, integrating guided inquiry learning into e-modules becomes an effective strategy to improve chemistry conceptual understanding. Similarly, Puspitasari et al. (2019) in their research stated that using the guided inquiry model influences students' conceptual understanding. This model effectively improves students' understanding, even optimally compared to direct learning models. The average score of students using the guided inquiry model was 80.00, which is higher compared to those using conventional model (69.96). This is due to the guided inquiry approach being rooted in constructivist theory, which views knowledge as being constructed by students through their learning experiences.

Students' Responses to the E-Module

The practicality of a learning medium can be assessed by the extent to which the medium can be effectively applied in learning activities, as well as by the feedback provided by teachers and students regarding its use. Evaluation of this practicality aspect is generally conducted through the administration of questionnaires to students after participating in the learning process using the medium (Milala et al., 2021).

Students' responses to the e-module were measured using a questionnaire covering aspects such as appearance, ease of access, interactivity, learning motivation, and usefulness. Students provided feedback on the e-module used during the learning of buffer solution material by completing a questionnaire consisting of 15 statement items. Students were also given the opportunity to provide additional comments to the researcher at the end of the questionnaire. Based on the results, the average score obtained was 92.6, which falls under the very positive category.

Most students stated that the e-module was easy to use, attractive, and helped them learn independently. The inclusion of video features, Wordwall games, and a responsive layout on both mobile phones and laptops provided a pleasant and engaging learning experience without monotony.

These results are supported by previous research by Lestari et al. (2024), which found that interactive learning platforms such as Google Sites can increase student engagement and motivation. The addition of educational game elements has also been proven effective in fostering interest in learning and conceptual understanding (Christianto et al., 2023; Paulus et al., 2023). Research by Ramadanti et al. (2021) showed that mathematics e-modules based on Problem-Based Learning (PBL) obtained highly positive responses from students when presenting data material. Based on data from the student response questionnaire covering design, content, and language aspect, an average practicality score of 87.2% was achieved, categorized as very high. All evaluation indicators, such as student interest in the e-module, material clarity, relevance to everyday life, and appropriate language usage in accordance with Indonesian Language General Guidelines (PUEBI), received high ratings from students. These findings indicate that the e-module developed is not only practical and easy to understand but also engaging and aligned with junior high school students' learning needs. Therefore, these findings reinforce the conclusion that the use of e-modules as digital learning media is well accepted by students.

CONCLUSION

Based on the research findings, it can be concluded that the guided inquiry-based e-module on buffer solution material developed through the Google Sites platform and integrated with the educational game Wordwall is considered highly feasible, effective, and received highly positive responses from students. The feasibility of the e-module was validated by both the material and media, which were categorized as highly feasible. The effectiveness of the e-module was reflected in the improvement of students' conceptual understanding, indicated by a high N-Gain score, demonstrating that this medium significantly supports the achievement of learning objectives. Furthermore, students' responses to the use of the e-module were highly positive, as they felt assisted in understanding the material, became more motivated, and were more actively engaged in the learning process. Thus, the e-module developed can serve as an alternative to innovative digital learning media that supports more meaningful, interactive chemistry learning tailored to the need of students in the digital era.

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