

Flipped Classroom with Guided Inquiry on Buffer Solutions via Discord: A Study of Learning System Development

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Abstract: This research aims to design a flipped classroom learning system incorporating guided inquiry, using the Discord platform for buffer solution materials in Phase F. The study employed Plomp Educational Design Research framework, which comprises initial investigation, design, construction, testing, evaluation, and refinement. The product underwent validation through expert evaluation and was assessed for practicality and effectiveness. The content validity achieved a score of 0.89, while the media validity scored 0.90, meaning both belong to the valid category. Evaluation of practicality showed that the system was highly practical, with teachers and students giving it an overall score of 90% and 92% respectively. Effectiveness was measured by analyzing pretest and posttest results using the N-Gain formula, yielding a score of 0.75, which is classified as high gain. The overall findings suggest that the developed learning system is valid, practical, and effective in enhancing students' understanding of buffer solutions. Moreover, the integration of Discord provides an accessible and interactive digital environment, aligning with the needs of 21st-century education and the Merdeka Curriculum. Therefore, this model can be recommended as an innovative solution for digital chemistry instruction in senior high schools.

Keywords: Buffer solution; Digital learning; Discord; Flipped classroom; Guided inquiry

Introduction

The rapid advancement of technology has brought significant changes across various aspects of life, including the education sector. As a part of the global community, Indonesia is inevitably influenced by this transformation. The nation has entered the phase of the Fourth Industrial Revolution (Industry 4.0), marking a significant shift towards digitalization and advanced technologies across various sectors, characterized by increased connectivity, digital system integration, and the emergence of technologies such as artificial intelligence (AI), big data, and the Internet of Things (IoT). According to Novsimapera (2021), in this era, human activities are becoming less dependent on

geographical location due to the shift from manual processes to digital-based operations. As a result, the education sector is expected to adapt by integrating digital technologies into the teaching and learning process. In this context, technology is not only seen as a complementary tool but also as a transformative force in education. Teaching strategies are evolving from traditional teacher-centered learning to student-centered learning. Delfianza (2023), emphasizes that the utilization of digital technologies enables more active, independent, and engaged student participation. Consequently, adjustments in the educational curriculum are crucial to support this transformation. (Nengsih, 2024), emphasizes that the curriculum is a key instrument in enabling a country to effectively address

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the challenges posed by the Fourth Industrial Revolution.

In response, the Indonesian Ministry of Education, Culture, Research, and Technology (Kemendikbudristek) launched the Merdeka Curriculum as a strategic initiative aimed at fostering learners who are adaptive, innovative, collaborative, and capable of critical thinking. (Jasmine et al., 2024); highlights that the Merdeka Curriculum promotes flexibility, it emphasizes competence-based learning and grants schools and teachers the autonomy to develop instructional strategies that are responsive to students' individual needs. Furthermore, Ismail (2023), explains that the Merdeka Curriculum requires not only a change in content but also a paradigm shift in teaching and learning methods. Technology is no longer viewed as a mere teaching aid but as an integral part of the learning process that enhances creativity, collaboration, and problem-solving skills (Nurwiati, 2022). Therefore, it is essential for educational institutions to equip teachers with strong digital skills and support them in creating learning environments that address the demands of 21st-century education (Nerantzi, 2020; Levin et al., 2025).

Despite these expectations, the actual implementation of technology in classrooms remains limited. Interviews conducted with chemistry teachers at SMA Negeri 2, SMA Negeri 3, and SMA Negeri 8 Mandau revealed that, although the Merdeka Curriculum has been adopted, the technological tools used in teaching remain unchanged. These include educational videos from YouTube, PowerPoint presentations, and Quizizz for post-tests. Teachers expressed their openness to adopt new technology-based learning strategies but also reported difficulty in finding innovative and engaging methods suited for chemistry instruction. One effective approach to overcoming these challenges is adopting the Flipped Classroom model (Sun et al., 2023; Ruslan et al., 2022; Zhang et al., 2024). This approach enables students to engage with learning materials, such as videos or readings – outside the classroom, reserving in-class time for collaborative discussions, active problem-solving, and other interactive learning experiences. (Fadilah, 2024), states that the Flipped Classroom offers more flexible learning opportunities and prepares students for deeper understanding. To further deepen student understanding, the flipped model can be integrated with the Guided Inquiry method, which encourages students to explore, question, investigate, and draw conclusions under the guidance of the teacher (Sari et al., 2023; Rohali & Hamimi, 2024).

According to Arifin et al. (2025), Nouri (2016), guided inquiry effectively fosters critical thinking,

problem-solving, and learner independence. The integration of flipped classroom and guided inquiry can foster a dynamic and meaningful learning environment. To support this instructional approach in a digital format, a robust and interactive platform is needed. One such platform is Discord, a communication application initially popular in gaming communities. Despite its growing popularity among teenagers, its use in educational contexts remains rare in Indonesia. Kardena & Mawardi, (2020), further emphasizes that its features—such as voice channels, chat rooms, role management, media integration, and asynchronous discussion—make it suitable for interactive and collaborative learning, especially in remote or hybrid settings.

Based on these gaps, this research aims to develop an innovative system titled: "Flipped Classroom with Guided Inquiry on Buffer Solutions via Discord: A Study of Learning System Development." This study is expected to contribute to the field of educational innovation by offering a relevant, effective, and technology-driven learning model. It also serves as a practical reference for educators in designing digital chemistry lessons that align with the objectives of the Merdeka Curriculum and the demands of the digital era.

Method

This research uses an Educational Design Research (EDR) approach, specifically the Plomp development model. This model has three phases:

Preliminary Research Phase:

This phase focused on needs analysis and literature review. The research was conducted through interviews with chemistry teachers at three schools and student questionnaires. The results indicate that: The Independent Curriculum has been implemented: Teachers need more creative, student-centered learning strategies integrated with technology. Students are familiar with Discord and interested in using it for learning.

Prototyping Phase:

To address the identified issues, the research proposes implementing a flipped classroom system utilizing Discord. In this system, students learn material outside of class through videos, while in-class time is used for discussion and application of concepts with teacher guidance. The prototype development was conducted through formative evaluation, consisting of: Prototype I: Initial design that includes guided inquiry syntax, Discord-based modules, key questions, and visual/media aids; Prototype II: Revisions based on self-

evaluation; Prototype III: Improvements after expert review (using a rubric) and one-on-one evaluation with students; Prototype IV: Tried in a small group (9 students) to gauge its practicality. This phase aims to develop learning innovations that meet the needs of teachers and students.

Table 1. Category of N-Gain Level

Score (%)	Level of Practicality
86 - 100	Very Practical
76 - 85	Practical
60 - 75	Practical Enough
55 - 59	Not Practical Enough
≤ 54	Not Practical

At the expert review stage, a validity test was conducted. In the validity test, the validator is presented with several statements and then evaluates them. The validator's assessment of each statement is analyzed using Aiken's V formula.

$$V = \frac{\sum s}{n(c-1)} \tag{1}$$

Information:

s: the score assigned by the validator minus the lowest score in the category used ($s = r - I_o$), where r is the validator's chosen category score and I_o is the lowest score in the scoring category.

n: the number of validators.

c: the number of categories selected by the validator

The level of validity of the developed learning system will be visible after being converted into categories as in the table below.

Table 2. Aiken's Validity Index Categories

Aiken's V Scale	Validity Category
$V < 0.80$	Invalid
$V \geq 0.80$	Valid

Then, at the small group stage, a practicality test was conducted. The practicality sheet assessment was obtained from giving the students a response questionnaire which was analyzed using a modified formula from (Purwanto, 2010) as follows:

$$NP = \frac{R}{SM} \times 100 \tag{2}$$

Information :

NP: The desired or expected percentage value

R: The raw score obtained by the student

SM: The ideal maximum score for the test in question

The categorization of practicality levels is presented in the table 3. After completing the prototyping phase and confirming the validity and practicality of the

developed learning system, the research continued with the assessment phase. In The assessment phase involves field testing. The field test serves to draw conclusions about the product's practical application. This stage also improves the quality of the resulting product, thereby achieving the practicality of prototype IV. If prototype IV requires revision, revisions are made based on input from teachers, students, and discussions with supervisors. The effectiveness of the learning system was tested using a quasi-experimental research design with a one-group pretest-posttest design, where a group was measured before and after the treatment, involving students. The sampling technique used was purposive sampling, a deliberate sampling technique based on specific considerations tailored to the research objectives. The final prototype was evaluated using a quasi-experimental one-group pretest-posttest design:

Table 3. one group pretest-posttest design

Pretest	Experiment	Posttest
O_1	X	O_2

The next stage of the study involved testing the normality of the pre-test and post-test scores. The normality test aims to determine whether the pretest and posttest data are normally distributed. This test is conducted as a prerequisite for performing parametric statistical analysis, in this case, the Paired Sample t-Test. The normality test was carried out using the SPSS software. The significance level used in this study is 5% ($\alpha = 0.05$), with the following criteria: if the significance value (Sig.) is greater than 0.05, the data are considered to be normally distributed; whereas if the significance value (Sig.) is less than or equal to 0.05, the data are not normally distributed. The hypothesis testing was carried out using the Paired Samples t-Test, provided that the data are normally distributed.

The significance level used in this study is 5% ($\alpha = 0.05$), with the following criteria: if the significance value (Sig. 2-tailed) is less than 0.05, then H_0 is rejected and H_1 is accepted, indicating that there is a significant improvement between the pretest and posttest scores. On the other hand, if the significance value (Sig. 2-tailed) is equal to or greater than 0.05, then H_0 is accepted and H_1 is rejected, which means that there is no significant improvement. Lastly, the N-Gain was used to measure the improvement in students' learning outcomes before and after the treatment. The N-Gain indicates the extent to which the learning process is effective in enhancing students' performance. The formula for calculating the N-Gain is as follows:

$$N - Gain = \frac{Posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \tag{3}$$

By incorporating Discord into learning activities, students can begin to shift their perception of the platform—from a gaming tool to a valuable educational space. It also allows teachers to manage learning flexibly, promote student engagement, and offer real-time or asynchronous feedback.

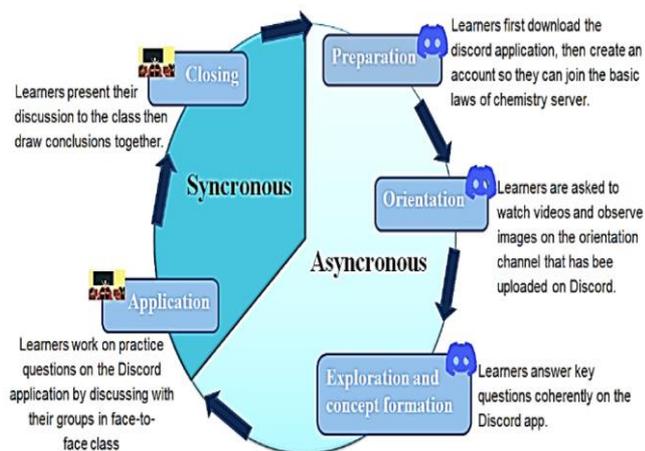


Figure 1. Flipped classroom Guided Inquiry Syntax integrated with Discord

This study focuses specifically on the topic of buffer solutions in high school chemistry. Buffer solutions are often considered difficult due to their abstract nature and the necessity for a strong conceptual understanding of acid-base equilibria, pH stability, and practical applications. Many students struggle with this topic due to its complexity and interrelation with other chemical concepts. Therefore, innovative instructional strategies that support deeper exploration and comprehension are essential. While numerous studies have investigated the effectiveness of the Flipped Classroom approach or Guided Inquiry learning individually, few have attempted to integrate both approaches using Discord as the primary learning platform, particularly in the context of chemistry education.

Result and Discussion

This research, utilizing the Educational Design Research (EDR) methodology and the Plomp development model, resulted in the successful development of a learning system entitled “Flipped Classroom Based on Guided Inquiry Using Discord for the Buffer Solution Topic.” The study was carried out through several phases, as described below:

Preliminary Research

At this stage, product design is carried out based on the plans developed during the initial investigation

phase. The initial investigation phase is conducted to identify and analyze the fundamental problems encountered in the field and to find solutions to those problems. Interviews revealed that the three schools have implemented the Independent Curriculum in their learning processes. Therefore, teachers must be able to integrate technology, innovation, and creativity into their learning, as well as the primary requirement to center learning on students. Overall, the interviews revealed that this is a challenge for teachers today. Teachers recognize that the use of technology in learning is still not optimal, as they have not yet found more creative and innovative learning strategies. Based on this needs analysis, a solution was proposed through a literature review, which involved searching for and understanding relevant sources to address the aforementioned needs. The literature review identified a solution or alternative: the development of a guided inquiry-based Flipped Classroom learning system using the Discord application. The Discord application was used because it is considered an ideal platform with great potential as a learning medium. This application offers several advantages, such as being free of charge, flexible, and data-efficient. Moreover, the use of Discord can support the integration of technology into the learning process.

Prototyping Phase

Self-Evaluation (Prototype I → II). Initial evaluation checked the completeness of flipped inquiry components such as instructional videos, key questions, and attendance tools embedded in Discord. All components were found to be available and well-organized. Expert Review and One-to-One Evaluation (Prototype II → III). The Expert Review is a validation activity for prototype II to determine the level of validity of the resulting prototype. This validation stage involves asking a team of experts in their respective fields to assess the designed product, resulting in a scientifically valid prototype. The expert evaluation was conducted by 5 content validators and 5 media validators.

Table 4. Expert Validation Results (Content)

Aspect	V	Validity
Content Composition	0.90	Valid
Presentation	0.85	Valid
Language	0.91	Valid
Graphics	0.90	Valid
Overall Score	0.89	Valid

Table 5. Media Validation Results

Aspect	V	Validity
Visual Quality	0.89	Valid
Ease of Use	0.90	Valid
Overall Score	0.90	Valid

After the expert review, a one-to-one evaluation is carried out. In PLOMP, the expert review and one-to-one evaluation are carried out simultaneously after completing both stages. Therefore, before revision, a one-to-one evaluation is carried out. One-to-One Evaluation was conducted by interviewing three 11th-grade students from SMAN 2 Mandau who had studied the buffer solution. Three students representing different ability levels high, average, and low shared positive feedback regarding their learning experience. They reported that the audio-visual materials were clear and contributed to better understanding of the content. Instructions and questions provided during the learning sessions were considered easy to follow, making the learning process more accessible for all students. Additionally, they found the use of Discord as a learning platform to be convenient and user-friendly, which helped minimize technical difficulties and improved engagement. The orientation models presented during the sessions were also regarded as helpful tools, as they supported the students in grasping key concepts more effectively. Overall, the learning system that utilized Discord was considered effective in supporting the learning process. After several revisions were made according to the responses from experts and validators at the expert review and one-to-one evaluation stages, the general appearance of the Discord application can be seen in the figure 2.

based flipped classroom learning system. This small group trial involved 9 students and 3 teachers.

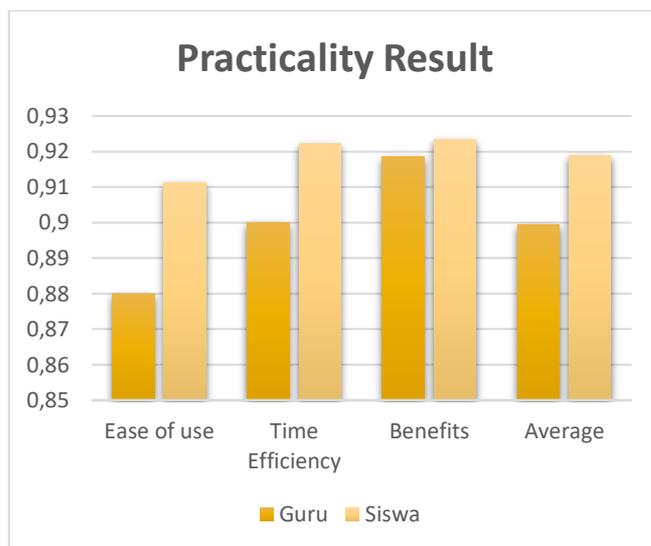


Figure 3. Analysis of Practicality Result

Assessment Phase

The field test continued with an experimental activity on a sample of 30 students. The sample was given a pre-test, followed by treatment using a guided inquiry-based flipped classroom learning system using the Discord application. The results of the normality test show that the pretest and posttest have a significance value greater than 0.05, namely pretest 0.83 and posttest 0.67, which means that the pretest and posttest data are declared normally distributed. Then continued with hypothesis testing of pre-test and post-test research data that had been normally distributed. The results of the hypothesis test showed that the Paired Samples test obtained a significance value of 0.000, which was less than 0.05, indicating a significant change between the students' pre-test and post-test scores. So, it can be stated that H1 is accepted and H0 is rejected. Next, the N-gain test aims to reveal the product's effectiveness. The N-Gain score reflects how effective the instructional method. the improvement from pretest to posttest. The results of the N-gain test can be seen in the table below:

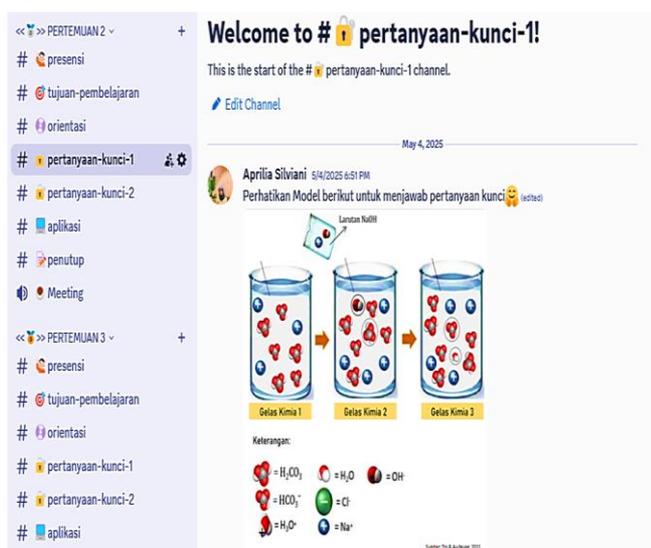


Figure 2. Guided Inquiry Looks Inside Discord System

Based on the results of the one-to-one evaluation and expert validation, the developed product is ready to advance to the next phase, namely the small group evaluation. Small Group Evaluation (Prototype III → IV). Prototype IV was conducted through a small group trial to determine the practicality of the guided inquiry-

Table 6. Result of N-Gain

Gain Score	0.75
Category	High

Discussion

This research followed all the stages of the Plomp development model systematically and thoroughly. In the preliminary research phase, data were gathered through interviews with chemistry teachers from three senior high schools. The findings confirmed the urgency for instructional innovation, especially in integrating

digital tools that align with the Merdeka Curriculum, which emphasizes student-centered learning and the use of technology in the classroom (Harahap, 2022); (Rizal, 2024). Further analysis involving students revealed that they belong to the category of digital natives—highly familiar with and proficient in using mobile technologies such as smartphones, laptops, and internet applications (Iqbal & Bhatti, 2020). This readiness provided a solid foundation for integrating Discord as a learning platform. The learning model developed combined the flipped classroom approach and the guided inquiry model, aiming to actively engage students in constructing their own knowledge (Syafei, 2022); (Tuti, 2023). The flipped classroom method allowed students to access learning materials independently prior to classroom sessions, enabling more effective discussions and active learning when class convened (Fani., 2022); (Herpika., 2021; Akmar, 2024). This approach is supported by the research of (Sarabi Asl et al., 2024; Kruiper et al., 2022), who emphasized the positive impact of flipped inquiry learning on critical thinking and independent exploration.

In practice, the guided inquiry model facilitated structured exploration, where students developed conceptual understanding through problem-solving with teacher support (Hamsil., 2023). The integration of Discord played a crucial role in managing this learning process. Its features enabled asynchronous activities—such as watching orientation videos and answering key questions—and synchronous sessions, including collaborative discussions and teacher feedback. Because many students were already familiar with Discord, the learning curve was minimal, allowing them to participate comfortably and confidently. The instructional flow was structured into four main stages and was implemented directly through Discord. The first was the Orientation Phase (asynchronous), where students watched videos containing apperception, motivation, prerequisite material, and learning objectives. These materials were accessed before class hours. The second stage, Exploration and Concept Formation (asynchronous), involved analyzing models and answering key conceptual questions that led students to formulate their own understanding. Presented below is an example of a key question model related to the topic of buffer solution.

An analysis of three students' answers was conducted to assess their level of understanding of the presented model. The level of understanding of each student is summarized in the table 7. Based on the analysis of student responses, it appears that Student 1 demonstrated a higher level of thinking than the other students, as their answers were clear and aligned with

the textbook. Meanwhile, Student 2 demonstrated moderate ability in identifying the buffer solution concept, as their answers were not entirely accurate but close to the textbook content. Conversely, Student 3 demonstrated a low level of understanding. In the third stage, Application (synchronous), students applied the concepts they had learned by solving exercises during class, reinforcing their understanding. Finally, in the Conclusion Phase (synchronous), students presented their findings and reflections, and the teacher provided feedback and clarification, ensuring conceptual reinforcement (Mansour, 2024); (Van Hoe et al., 2024). The product then underwent a series of evaluations to ensure its validity and practicality. Based on expert reviews, the learning system was found to be highly valid, with Aiken's V values ranging from 0.89 to 0.90, covering aspects such as content, presentation, language, and visual design. Improvements were made during this stage, including rearranging question levels based on Bloom's revised taxonomy and standardizing navigation symbols in the Discord interface to enhance consistency and user experience (Aumi & Mawardi, 2021; Almutairi et al., 2025).

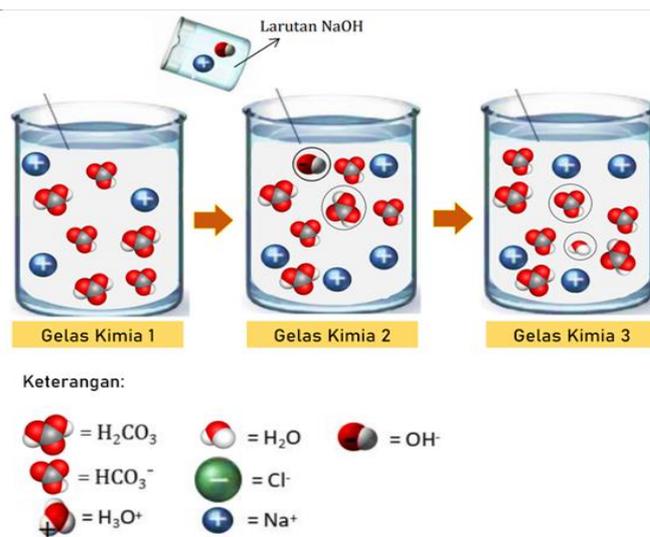


Figure 4. Model of buffer solution

Table 7. Description of Students responses to the model

Student	Response
1	The OH ⁻ from NaOH reacts with H ₂ CO ₃ to form HCO ₃ ⁻ and water. The pH remains stable because the buffer system works
2	After adding NaOH, the OH ⁻ is no longer visible because it reacts. The amount of HCO ₃ ⁻ increases, and the pH doesn't change
3	There is a difference in the number of components in each beaker

Following the development phase, a field trial was conducted to evaluate the effectiveness of the learning

model. A group of 30 students participated in both pre-test and post-test assessments administered before and after the instructional intervention (Oyinloye & Imenda, 2019; Baig & Yadegaridehkordi, 2023). The results of the paired samples t-test showed a statistically significant improvement in student performance, with a p-value of 0.000, which is well below the 0.05 significance level. This finding indicates a meaningful difference in student achievement before and after the implementation of the developed learning system. Additionally, the normalized gain score (N-Gain) analysis yielded a value of 0.75, categorized as "high" according to (Baihaqie et al., 2024; Faros et al., 2025). These results confirm that the flipped classroom model based on guided inquiry and facilitated through Discord proved to be highly effective in enhancing student learning outcomes, particularly on the buffer solution topic in high school chemistry.

Conclusion

Based on the findings of this study, it can be concluded that the flipped classroom learning system, grounded in guided inquiry and supported by the Discord platform, is a viable alternative instructional strategy for teaching buffer solutions in the digital era. This system offers a solution that aligns with the demands of modern education by integrating technology in a meaningful and pedagogically sound way. The combination of flipped learning and guided inquiry encourages students to learn independently, think critically, and actively engage in the classroom, while Discord serves as an effective digital platform that supports communication, collaboration, and flexible access to learning materials. The development process demonstrated that the learning system fulfilled the criteria of validity, practicality, and effectiveness. The content validity achieved a score of 0.89, while the media validity was recorded at 0.90, both falling under the "valid" category. Furthermore, practicality testing yielded very promising results, with an average score of 90% from teachers and 92% from students, both classified as "very practical." Regarding its effectiveness, the learning system exhibited a strong impact, as reflected by an N-Gain score of 0.75, which is classified in the "high" category. These findings affirm that the developed learning model is not only feasible but also has significant potential to enhance students' learning outcomes, particularly in science education and chemistry learning involving abstract concepts like buffer solutions.

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Author Contributions

Aprilia Silviani Harahap was instrumental in conducting a thorough review of the existing literature, collecting data, analyzing data, writing the findings and manuscript, and managing the entire project. Mawardi was instrumental in the conceptualization, initiating, and developing the primary concept and scope of the research. He also designed the research methods and approved the final manuscript. Okta Suryani and Umar Kalmar Nizar contributed significantly to the development and validating content and media to ensure product validity. Reza Akmar was involved in the drafting and revision of the manuscript, particularly in sections related to data analysis and interpretation.

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Conflicts of Interest

The authors declare no conflict of interest.

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