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Integrating Flipped Classroom with Guided Inquiry Based on Digital Literacy Using Discord on Atomic Structure for First Year Chemistry Students

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Abstract: This study aims to develop an integrated flipped classroom learning system based on guided inquiry using the Discord platform for teaching atomic structure to first-year chemistry students. The research employed the Plomp development model. Research instruments included a validation form completed by five chemistry lecturers from UNP, an interview guide for one-on-one evaluations with three students, and a practicality questionnaire answered by nine students and two lecturers. Content and construct validity were analyzed using Aiken's V coefficient, while practicality was evaluated through a percentage-based analysis. The findings showed that the developed product met the validity standards, achieving Aiken's V values of 0.90 and 0.91, and demonstrated high practicality levels, with scores of 92% from students and 91% from lecturers. These results indicate that the integrated flipped classroom system incorporating guided inquiry through Discord is valid and practical for use in chemistry learning, particularly on the topic of atomic structure.

Keywords: Atomic structure; Digital literacy; Discord application; Flipped classroom; Guided inquiry

Introduction

The progress of industry in the fourth industrial revolution era is unavoidable. This era is marked by the rapid growth of knowledge and technology, resulting in swift and highly competitive transformations. A nation's success, particularly in the field of education, largely depends on the quality of its educators. In this context, technology can be leveraged as an educational tool to enhance learning processes (Nuryana, 2019). Consequently, educational institutions in Indonesia are expected to possess digital literacy to adapt and thrive in this changing landscape (Nurhayati et al., 2020). Furthermore, as cited in Putriani et al. (2021), it is essential that the integration of information and communication technologies encourages a transformation in teaching practices from a teacher-centered learning approach to a more student-centered learning model. One of the government's strategies to respond to the challenges of the 4.0 era is the implementation of the Merdeka Curriculum, also known as Kampus Merdeka. With the effective execution of the *Merdeka Belajar* program, students are expected to develop strong competencies in both hard and soft skills (Kemendikbudristek, 2022). Educators are also encouraged to create enjoyable and interactive learning environments by applying appropriate instructional models such as blended learning (Indarta et al., 2022).

Blended learning is an instructional model that integrates conventional in-person teaching with online learning elements, creating a collaborative and cohesive learning environment (Sari et al., 2025; Sofyan et al., 2025). It integrates both in-person and computer-assisted activities, whether offline or online to maximize the advantages of each method (Setyanto et al., 2023).

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This model is considered effective because it balances the limitations of both formats, enabling students to benefit from direct interaction and technological support (Khusna & Febrianto, 2023). One instructional model applied in this research is the flipped classroom approach (Ismail et al., 2023; Novitri et al., 2022).

The flipped classroom approach is one method to implement blended learning (Mawardi & Nur, 2022). This model enhances student participation by encouraging them to engage more actively during the teaching and learning process. The flipped approach operates under two modes: synchronous and asynchronous learning. Synchronous learning takes place simultaneously, even if participants are not physically in the same place, while asynchronous learning allows students to study at their own pace and time, supported by tools such as Google Classroom, WhatsApp, or various learning management systems like Moodle and Discord (Siregar & Mawardi, 2022). To make lessons more engaging and interactive, educators must design creative and effective learning (Indarta et al., 2022). One such model is guided inquiry learning. In this approach, instructors provide a sequence of guiding questions referred to as key questions that lead students to discover core concepts. This model often involves group work and the use of structured learning materials like Student Worksheets (LKM), with instructional steps including introduction, investigation, concept development, implementation, and summary (Hanson, 2006).

Guided inquiry learning has been shown to enhance students' engagement, motivation, and academic performance (Sitanggang et al., 2022; Susilawati et al., 2022). In chemistry, this model is particularly applicable to topics such as atomic structure. This topic is essential in introductory chemistry courses for first-year university students, encompassing subjects like the historical development of atomic models (from Thomson to Rutherford), the hydrogen atomic spectrum, and Bohr's model of the atom. However, students often face difficulties with this topic, such as understanding different atomic theories, identifying electron configurations and valence electrons, as well as differentiating between isotopes, isobars, and isotones (Marsella et al., 2024).

Learning chemistry at the university level requires students to understand complex and abstract concepts such as atomic structure, which are often difficult to grasp through traditional lecture-based instruction. To address these challenges, innovative learning approaches such as blended learning and the flipped classroom have been increasingly adopted to strengthen conceptual understanding and promote learner autonomy (Harahap et al., 2025; Putri et al., 2022). However, previous studies have revealed that these models still present several limitations, particularly in promoting interactivity, supporting guided inquiry, and integrating with effective digital media. Commonly used platforms such as Google Classroom and Moodle are often teacher-centered and do not adequately support real-time engagement or inquiry-oriented learning (Santosa et al. 2023).

Although the guided inquiry approach has been shown to enhance students' critical thinking skills and conceptual understanding in chemistry (Siregar et al., 2024), instructional tools that effectively combine guided inquiry with digital technology remain limited. This lack of integration restricts students' opportunities for collaborative and exploratory learning, especially when dealing with abstract materials such as atomic structure.

Discord, a communication platform widely used among students, has strong potential to overcome these limitations through its interactive features such as voice channels, text discussions, and customizable roles that facilitate both synchronous and asynchronous learning (Ananda et al., 2023; Tuti et al., 2023). Originally designed for gamers, Discord offers a variety of features that support communication and interaction, making it a promising platform for educational purposes (Kusumah et al., 2024). It can also be integrated with other digital learning tools, making it a versatile and user-friendly option with the potential to enhance the learning environment (Almazova et al., 2020).

Previous research has demonstrated that the use of Discord in flipped guided inquiry settings can increase student engagement and promote more interactive discussions (Santia et al., 2025; Tuti et al., 2023). Nevertheless, these studies have primarily focused on topics such as reaction rate and chemical equilibrium, leaving limited exploration of its use for the atomic structure topic among first-year students. Although it shows great potential, the application of Discord in Indonesia's educational context is still relatively limited (Tjahjadi et al., 2021).

The novelty of this research lies in developing an integrated flipped classroom learning system grounded in guided inquiry using the Discord platform, specifically designed for first-year chemistry students studying atomic structure. This system is expected to address the limitations of existing models and media by providing a more interactive, guided, and technology-enhanced learning experience.

Method

This study employs educational design research. Educational design research is a type of research with steps or processes to develop and produce a new product or improve and perfect an existing product. Development research is a type of study aimed at creating a product and evaluating its effectiveness once developed (Nieveen & Folmer, 2013). In this case, the development carried out by the researcher is the development of a flipped classroom learning system with digital literacy based on guided inquiry using the Discord application on atomic structure material for firs t-year students and also tested for validity, practicality, and effectiveness.

The model used in this study is the Plomp model (Nieveen & Folmer, 2013). Based on Figure 1, this model consists of three main phases, namely the preliminary research, prototyping, and assessment stages. The development research procedure to be implemented is designed with the Plomp model. The Plomp model research design includes three phases: the initial investigation, the development or prototype construction, and the evaluation stage. Formative evaluation is categorized into several phases, as shown in Figure 1.

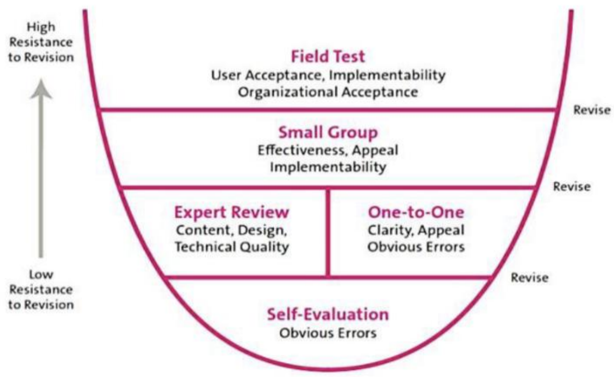

Figure 1. Formative evaluation layers (Plomp et al., 2013)

The initial investigation stage aims to identify and define the necessary requirements for developing a flipped classroom learning system that integrates guided inquiry and digital literacy through the Discord application, focusing on atomic structure material for first-year students. At this stage, there are several activities, namely needs analysis, context analysis, and the conceptual framework.

The needs analysis was conducted through a structured interview approach. Prior to interviewing the resource persons, the interviewer prepared a set of guiding questions.

The structured interviews were conducted with four chemistry lecturers from Universitas Negeri Padang (UNP) to analyze learning challenges and instructional needs related to the atomic structure topic. In addition, an analysis was performed on the 2023 Undergraduate Chemistry Curriculum (S1) and the General Chemistry Course Syllabus (RPS), which is a compulsory three-credit course offered in the first semester. The RPS document (SOP.01.001.00; issue date: January 10, 2019; revision number: 06; pages 1–20; preparation date: May 2, 2025) was examined to identify the scope of content and learning outcomes covered in the topic. The conceptual framework was formulated based on the findings from the needs and context analysis stages, and further reinforced through a literature review. This framework illustrates the overall thought process and rationale underlying the conduct of the research.

The validity of the developed learning system is measured by a validation questionnaire. This process involved five General Chemistry lecturers from UNP, selected based on their expertise and teaching experience in the field of atomic structure. The validators consisted of two subject matter experts, two media experts, and one instructional design expert. Each validator assigned values to the questionnaire categories and the level of validity is determined using the Aiken's V formula, as presented in equations (1) and (2) (Aiken, 1985).

$$V = \frac{\sum s}{[n\,(c-1)]} \quad (1)$$

$$s = r - lo \quad (2)$$

Description:
s : r - Io
r : the value given by the validator
Io : lowest value
n : number of expert validators
c : highest validity score

Where V is the value of Aiken validity coefficient, n is the number of validators, r is the score of a category, I0 is the lowest score in the scoring category, S represents the difference between the validator's score and the minimum possible score. The range and corresponding categories are presented in Table 1.

Table 1. Classification Level of Validity

Interval	Category
$V \geq 0.8$	Valid
$V < 0.8$	Not valid

Meanwhile, practicality is measured by students' response through a questionnaire in small group test. The practicality testing aimed to determine the usability and effectiveness of the validated learning system in an actual learning environment. This stage involved nine Chemistry students of UNP from the 2020 class students, purposively selected based on their achievement in the Basic Chemistry course. The participants were divided into three ability categories: three high-ability, three moderate-ability, and three low-ability students. Equation (3) is used to calculate the percentage of practicality, where NP is the expected percentage, R denotes the student's actual (raw) score, while SM refers to the highest possible score (Ngalim Purwanto, 2014).

$$p = \frac{f}{N} \times 100 \quad (3)$$

Description:
p = final score
f = score acquisition
N = maximum score

Table 2. Category of Practicality Level (Purwanto, 2014).

Interval	Category
80 - 100	Very high
60 - 80	High
40 - 60	Moderately high
20 - 40	Low
0 - 20	Very low

Results and Discussion

Structured interviews were held with three chemistry lecturers at Universitas Negeri Padang (UNP). The lecturers confirmed that the undergraduate chemistry curriculum follows the Kurikulum Merdeka Kampus Merdeka (MBKM), which promotes learner independence and encourages active, collaborative participation. They explained that classroom instruction generally incorporates learner-centered strategies, including group collaboration, case-based learning, problem-based learning (PBL), and project-based learning (PJBL). Despite these approaches, the lecturers observed that students still show limited inquiry ability and remain largely dependent on lecturer guidance during discussions.

In addition, the lecturers reported the regular use of social media tools—particularly WhatsApp—for learning communication. However, its features were considered insufficient for facilitating structured dialogue and managing instructional materials effectively. Although some lecturers were familiar with the Discord platform, it had not yet been applied in teaching practice. According to Tjahjadi et al. (2021), the utilization of Discord in Indonesia is still relatively rare and restricted. This condition underscores the need for a digital learning environment capable of supporting guided questioning and both asynchronous and synchronous learning interactions, which are fundamental to the Guided Inquiry model.

Based on these findings, the development of a Guided Inquiry learning system through Discord is well justified. The Guided Inquiry approach provides support for students through sequenced questions, hypothesis testing, and reflection activities—precisely addressing the lecturers' concerns about students' lack of questioning and conceptual reasoning skills. This finding aligns with international studies reporting that inquiry-based instruction helps students build deeper conceptual understanding and stay more engaged in chemistry learning (Berhanu & Sheferaw, 2022; Dmoshinskaia et al., 2021) When incorporated into a flipped classroom approach, guided inquiry learning has been demonstrated in numerous studies to improve students' cognitive skills and teacher-student interaction. High degrees of validity and applicability were shown by earlier research by Siregar et al. (2022), Delfianza et al. (2023), Kartini et al. (2019), Ismail et al. (2021), Tuti et al. (2023), and Handri et al. (2023).

The early version of guided inquiry learning through digital literacy using Discord on atomic structure content was created during the Prototype I stage. The prototype was made to include a model that aligns with the learning objectives, important questions that can help students, practice questions on the application syntax, and other Discord application components. The syntaxes or leaning cycle of flipped guided inquiry from (Aumi & Mawardi, 2021) can be seen in Figure 2. The developed prototype takes the form of a worksheet that can be moved and modified within the Discord app.

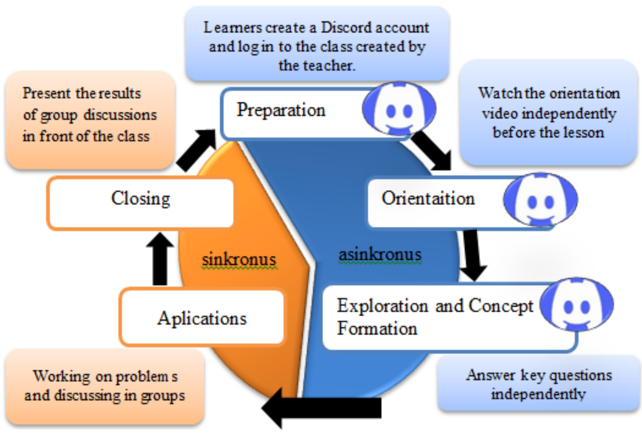

Figure 2. Stages of learning using the guided inquiry model integrated with the flipped classroom through the Discord application (Aumi & Mawardi, 2021)

After obtaining Prototype I, the prototype was formatively evaluated using a check questionnaire sheet. The researcher examined and verified that the necessary elements were appropriate, accessible, and usable. The researcher discovered that every element of the guided inquiry learning through using discord on atomic structure content was complete and operational according to the evaluation results.

At the orientation stage, students will be presented with a video containing the introduction to atomic structure (Figure 3). The video is designed to ignite students' motivation before entering the next syntax (Khairunnisak et al., 2023). Subsequently, during the exploration and concept formation stages, students are presented with a model relevant to the learning topic (Figure 4) (Amanda et al., 2023). The model is accompanied by key questions arranged accordingly to their level of difficulty from the simplest to the most difficult. By answering and following thesekey questions, students form concepts within their own understanding (Hanson, 2006). This syntax is worked on by students asynchronously and is provided in the Discord channel. At the application stage, students are given questions that are useful as exercises to strengthen the concepts obtained in the previous syntax (Figure 5) (Siregar & Mawardi, 2022). This syntax is implemented synchronously, either face-to-face on campus or in the Discord channel. Students work on the questions given through group discussions. Finally, in the closing phase, students present the outcomes of their group discussions related to the application stage in front of the class. Similar to the application, this syntax is implemented in class or Discord synchronously.

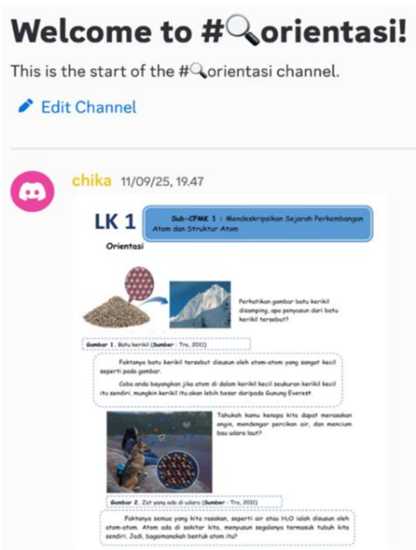

Figure 3. Orientation stage in discord

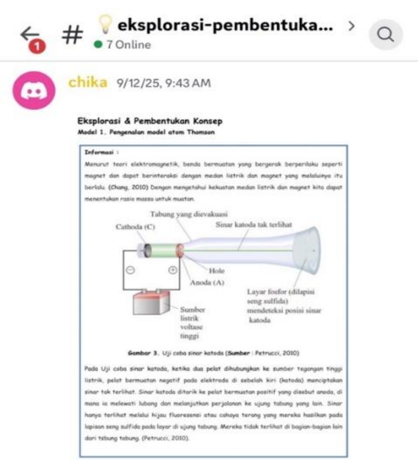

Figure 4. Exploration and concept development phase conducted via discord

Figure 5. Application on discord

At this stage, Prototype II underwent a series of formative evaluations, which included expert reviews and individual (one-on-one evaluation) assessments. Expert review assesses the learning system developed in terms of its content and construct. The results of content validation show that all aspects of the components assessed have achieved a good level of validity with V > 0.80. The same thing applies to construct validation where all components have achieved high validity.

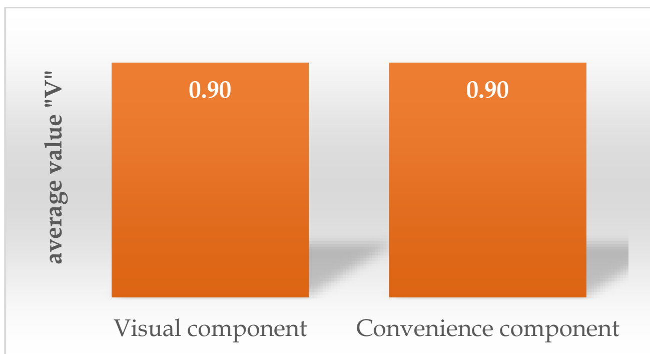

Figure 6. Results of content validity

Subsequently, during the one-to-one evaluation phase, three chemistry students who had previously studied atomic structure were interviewed regarding the guided inquiry approach implemented through the Discord platform in the topic of atomic structure. The Interviews revealed that the orientation video on Discord was clear and well-explained., featuring good visuals, relevant images, accurate information, and clear audio. Students also stated that the video effectively introduced the learning topic and guided them through the initial stages of the activity. In addition, the language is easy to used, the guiding questions presented, the instructions provided, and the models displayed were all clear and easy to comprehend.

As for content validity based on Figure 6, it resulted to an average value of 0.90, with each aspect exceed 0.90. Aspect 1 pertains to the alignment between the flipped classroom model and the guided inquiry learning phases; this means the system has designed inline between the used approach and model. Meanwhile, Aspect 2 relate to the suitability of the usage of Discord and its integration with guided inquiry syntaxes. In regard of the scores, it can be interpreted that the usage and integration are done logically so it is meet the intended purpose. Again, the measured validity indicates the presented materials in stages like exploration and concept formation and application are properly aligned and include chemistry multiple representations (Kalmar Nizar & Mawardi, 2018).

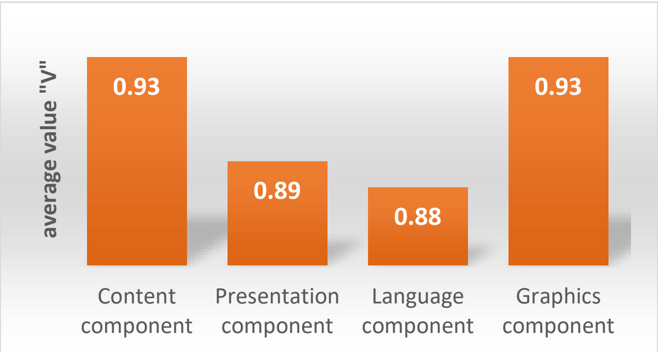

Figure 7. Results of construct validity

According to Figure 7, the content component of the Discord-based learning system showed an average validity score of 0.93, which falls within the valid category. This reflects the alignment of the included material with the objectives, supported by references, and visual resources derived from credible and relevant sources. Likewise, the presentation component obtained an average validity score of 0.89, indicating a systematic, well-structured design without any unnecessary content. Engaging illustrations enhance the material's appeal and help clarify complex concepts, highlighting the importance of visual elements in stimulating student interest. The language component achieved an average validity score of 0.88, indicating to use of easily comprehensible language use. This ensures that students encounter minimal confusion in understanding chemical concepts. In addition, the graphic component of the Discord-based learning system achieved a validity score of 0.93, categorized as valid. The selection of fonts, colors, and contrasts paired with high-contrast text and background combinations enhances enhances readability and visual comfort (Winata & Mawardi, 2021). The results show that the learning system developed in this study is well-aligned in terms of theory, instructional flow, and media design. All Aiken's V scores were higher than the standard cutoff of 0.80, which indicates strong agreement among the expert validators and supports the overall validity of the system (Kania et al., 2024; Tajuddin et al., 2025)

During the validation process, experts particularly appreciated the logical sequencing of the material, the clear instructional directions, and the effective use of Discord channels to represent the different inquiry stages—orientation, exploration, concept formation, and application. Only a few technical suggestions were made, mainly related to improving the visual layout and enhancing image quality, and these revisions were applied in the next prototype version.

Following revisions to Prototype III based on formative assessments conducted through small group evaluations, Prototype IV was subsequently developed. The practicality phase involved nine undergraduate chemistry students from the 2020 class students, categorized into three achievement levels based on their General Chemistry grades: high, medium, and low achievers (three students per group). Three chemistry lecturers participated as evaluators in this stage. All of the evaluated aspects fall into the practical or very practical category, according to Figure 8 and 9. In terms of easibility, 92% of users and 90% of lecturers find it practical. This means the Discord learning system is easy to use for both students as the users, and teachers or lecturers as the administrators (Mawardi & Fitriza, 2019). It also means the learning system has been developed logically and thematically so it can be navigated without any necessay hindrance for the users.

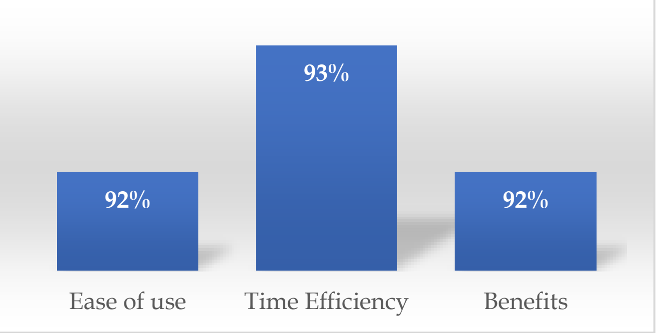

Figure 8. Results of students practicality

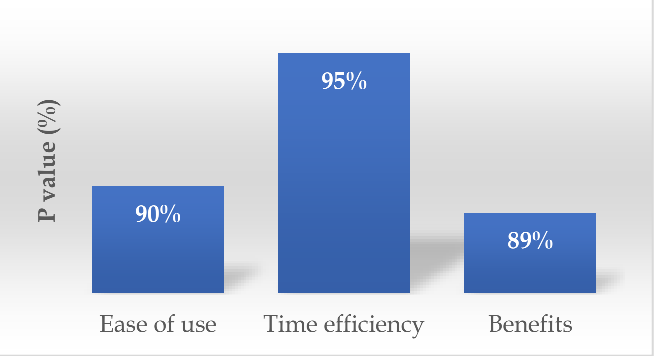

Figure 9. Results of lecturer's practicality

In terms of time efficiency, 93% of users and 95% of lecturers rated the system as practical. This score relates to the time required for sharing the information either from students to lecturers. Furthermore, 92% of lecturers and 89% of students, respectively, rate the benefits aspect as practical. Benefits can be interpreted as how the students could gain knowledge from the learning system (Syafei & Mawardi, 2022).

Considering how high the score is, it is safe to say that the Discord learning system is beneficial as a learning resource or material. These findings correspond with previous research on the practicality of digital learning environments that reported similar levels of usability and instructional efficiency (Jaaffar & Adnan, 2025; Mokmin et al., 2024; Sher Baz Ali et al., 2024). All things considered, the developed learning system can be considered useful for educational purposes.

Figure 10. Synchronous discussion during the application phase

According to Figure 10, a real-time discussion was conducted with undergraduate chemistry students to evaluate the practicality of the Discord-based guided inquiry system. Students collaboratively solved problems using concepts developed in earlier stages, while the lecturer and researcher provided direct feedback. The session demonstrated effective interaction, peer collaboration, and instructional support, highlighting the system's practical implementation in actual learning conditions.

Conclusion

The Discord learning system integrated with the flipped classroom and guided inquiry model on atomic structure was successfully developed and evaluated. The results showed that the system achieved strong validity, with average content and construct validity scores of 0.90 and 0.91, respectively, both categorized as very valid. The practicality assessment obtained average scores of 92% from students and 91% from lecturers, classified as very practical. Therefore, the developed learning system meets the criteria of validity and practicality, indicating its feasibility for educational implementation and future research applications.

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Author Contributions

All authors contributed to the research article according to their respective roles and responsibilities. M.M. was responsible for conceptualization, methodology, validation, supervision, review, and editing. M.M. also contributed to formal analysis and validation. F.A. oversaw investigation, data curation, original draft writing, editing, and project administration.

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Conflicts of Interest

The authors declare no conflict of interest.

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