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Atomic Structure Learning System With Flipped Guided Inquiry On Discord: A Development Study

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Abstract

This study aims to develop a Flipped Classroom learning system based on Guided Inquiry using the Discord application on the Atomic Structure material to improve the understanding of high school students, tested up to the validity and practicality stages. The product is considered valid if the validity score (V) is above 0.8 and highly practical if the practicality percentage score exceeds 86%. The method used in this study is Educational Design Research (EDR) with the Plomp model. In the development stage, formative evaluation was conducted through four prototypes. The first prototype was developed based on needs analysis, context analysis, and literature study. The second and third prototypes were refined through expert review and one-to-one evaluation, with results showing excellent content and construct validity. The research subjects consisted of 3 chemistry lecturers from UNP. Meanwhile, the practicality test on the fourth prototype, which involved teachers and students, showed that this learning system was highly practical, with 2 chemistry teachers and 9 students from SMAN 8 Padang. The data collection instruments used in this study were validity and practicality test questionnaires. Based on the results, a validity score of 0.86 and a practicality score of 92% were obtained, indicating that the system is valid and highly practical.

Keywords: *Learning System, Flipped Classroom, Guided Inquiry, Discord Application, Atomic Structure*

I. INTRODUCTION

Chemistry is one of the branches of science that has unique characteristics that distinguish it from other sciences. This field studies matter comprehensively, including its composition, properties, and the changes in matter and the energy associated with them (Barat, 2023). The distinctive characteristics of chemistry as a science make most of its concepts abstract, such as the topic of atomic structure, which presents its own challenges for students to understand. Several studies indicate that chemistry is often considered a difficult subject, primarily because its concepts cannot be directly observed (Agustin & Sunarto, 2018).

One of the essential topics in the chemistry subject for Grade X of senior high school is atomic structure. This topic includes an understanding of the development of atomic theory, the fundamental particles that make up atoms, and electron configuration (Sari et al., 2018; Susanti et al., 2023). Nevertheless, learning about atomic structure often presents various obstacles in the students' learning process. Students find it difficult to understand the atomic models developed by scientists, determine electron configurations, identify valence electrons, and distinguish between the concepts of isotopes, isobars, and isotones. These difficulties are further aggravated by the high level of misconceptions among students (Harahap, 2016).

A'yun & Nuswowati, (2018) research shows that students' misconceptions regarding the subtopics of Dalton's, Thomson's, Rutherford's, Bohr's atomic theories, and quantum mechanical theory reached significant levels, namely 24.85%, 27.27%, 45.45%, 39.39%, and 33.33%, respectively. Data from distributed questionnaires also indicate that 68% of students find it difficult to understand atomic structure material, primarily due to its complex and theoretical nature. This condition calls for instructional strategies that can bridge abstract concepts into more concrete and meaningful understanding for students.

One approach that can be used to address this challenge is the use of multiple representations in chemistry learning. Johnstone, (2000) stated that chemical concepts can be better understood through three levels of representation: macroscopic (observable phenomena), submicroscopic (particles and their interactions), and symbolic (chemical

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symbols and notations). Research by Guci et al., (2017) also shows that the interconnection among these three representational levels significantly enhances students' conceptual understanding. However, based on interviews with chemistry teachers (Appendix 3), the application of multiple representations is still limited and tends to rely mainly on the macroscopic and symbolic aspects. The submicroscopic representation, which is crucial for understanding atomic structure, is still rarely applied to its full potential.

To support the implementation of multiple representations in learning, various educational media and technologies have been developed. Currently, Learning Management Systems (LMS) such as Moodle, Edmodo, and Google Classroom are widely used. However, each of these platforms has its drawbacks. For example, Edmodo and Moodle require paid subscriptions and stable internet connections. Meanwhile, Google Classroom has yet to provide interactive video discussion features (Octasyavira & Nurlizawati, 2022). Teachers have also tried using social media platforms like WhatsApp and Telegram in learning. However, these applications are not specifically designed for educational purposes, leading to several limitations such as slow material downloads, communication disruptions due to excessive group messages, and the potential for cheating in assessments (Ardiani & Pujiriyanto, 2022).

One alternative medium that is more flexible and supports the needs of interactive learning is the Discord application. Initially used within gaming communities, Discord has now been widely adopted in education due to its features such as text, voice, and video channels, as well as organized server-based discussion rooms (Setyawati et al., 2019). Discord enables teachers and students to access and share materials in various formats (text, audio, video, images) in a structured manner. These features make Discord highly potential as a supportive tool in fostering a more collaborative and interactive learning process(Salim & Si, 2021). Unfortunately, despite its great potential, the use of Discord in education in Indonesia remains very limited (Tjahjadi et al., 2021). However, the use of Discord has been found to be effective in educational contexts. This is supported by previous research indicating that Discord can be effectively utilized in the learning process (Akmar et al., 2024; Amien et al., 2024; Violin et al., 2024).

In the context of 21st-century educational development and the implementation of the Kurikulum Merdeka, the learning paradigm has shifted from teacher-centered to student-centered. This shift requires teachers to be more innovative in selecting learning approaches and strategies. One learning model that aligns with the principles of student-centered learning is the blended learning model, particularly the rotation model with the flipped classroom submodel (Syafei & Mawardi, 2022; Tuerah & Tuerah, 2023). The flipped classroom is an approach in which students study the material beforehand outside the classroom (usually through instructional videos), and classroom time is used for discussion, practice, and problem-solving (Guswita & Mawardi, 2021). The flipped classroom model offers many advantages, including providing students with opportunities for independent learning, enhancing curiosity, and allowing learning to occur anytime and anywhere (Herpika & Mawardi, 2021). In flipped classroom learning, interaction can take place both synchronously and asynchronously (Handri et al., 2023; Insani et al., 2022). However, for distance learning, direct synchronous interaction cannot always be carried out optimally, thus requiring the support of media such as Discord, which enables effective online learning (Bergmann, 2022).

To optimize the flipped classroom model, it can be combined with the guided inquiry learning model. Guided inquiry is a learning model in which the teacher provides guidance through key questions that lead students in constructing concepts (Asra et al., 2016; Khairunnisak et al., 2023). This model involves learning syntax consisting of orientation, exploration, concept formation, application, and closure (Hanson, 2015). The characteristics of guided inquiry, which emphasize exploratory and collaborative activities, strongly support the implementation of the flipped classroom, especially when integrated through interactive learning media such as Discord (Ananda et al., 2023). This study aims to develop a Guided Inquiry-Based Flipped Classroom learning system using the Discord application for teaching the topic of Atomic Structure in Phase E of Senior High School.

II. METHODS

The study employs the Educational Design Research (EDR) method using the Plomp development model, which consists of three phases: preliminary research, prototyping phase, and assessment phase. This study is limited to the development and prototyping phase.

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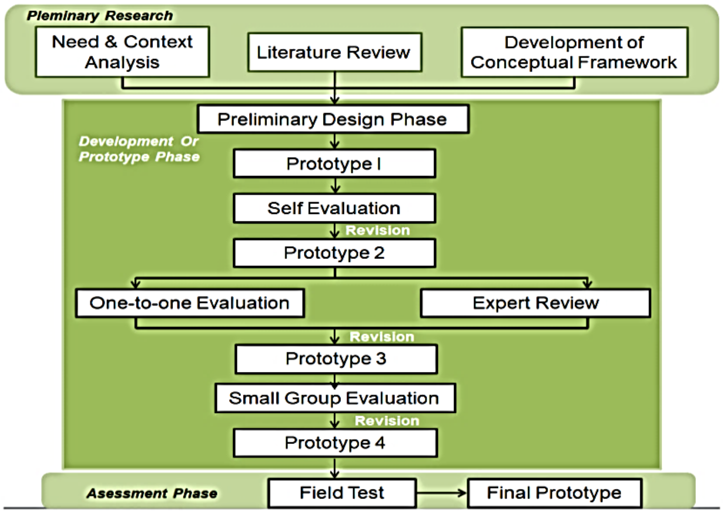

Fig. 1 Stages of EDR

The first stage of this research begins with the preliminary research phase, also known as the initial investigation stage, starting with a needs analysis and context analysis, followed by a literature review and the development of a conceptual framework. The needs analysis aims to identify the fundamental problems occurring in senior high schools. The method used for the needs analysis was interviews with three chemistry teachers from three different senior high schools in Padang City, namely SMAN 10 Padang, SMAN 8 Padang, and SMA Pertiwi 1 Padang. Meanwhile, the context analysis involved an analysis of the curriculum and learning outcomes.

Next, the literature review stage is carried out by collecting sources relevant to the research to be conducted. Then, the literature review involves analyzing articles from several journals, examining the methods used, and identifying solutions to the problems faced by teachers and students in the learning process. The second stage is development or prototyping, which involves analysis, design, evaluation, and revision of the developed product. Four prototypes will be produced, namely prototype I, prototype II, prototype III, and prototype IV, through a series of formative evaluations including: self-evaluation, expert review, one-on-one evaluation, and small group testing.

Four prototypes will be developed through a series of formative evaluations: Prototype I is the initial product design; Prototype II is the result of a self-evaluation revision of Prototype I; Prototype III is developed by revising Prototype II based on expert review and one-to-one evaluation; and Prototype III will then be tested on a small group, in this case, Grade X students of SMAN 8 Padang, to produce Prototype IV. The data collection instruments employed in this study consist of an interview observation sheet, a self-assessment questionnaire, a one-to-one evaluation questionnaire, a content and construct validity questionnaire to assess the validity of the instruments, and teacher and student practicality questionnaires to evaluate the practicality of the instruments. The validators' assessments of each statement are analyzed using Aiken's V formula, as shown in the equations below.

$$V = \frac{S}{n(c-1)}$$

$$S = r - lo$$

Explanation:
V : Aiken's V scale
S : Score assigned by the validator minus the lowest score in the category
lo : The lowest evaluation score
c : The highest validity evaluation score
r : The score chosen by the validator
n : Number of validators

Since the items used involve five validators and five selection categories, the scale used for Aiken's validity index is as shown in the following table:

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Table 1. Aiken's Validity Index Categories for Five Validators

Aiken's V scale	Validity Category
V ≥ 0.80	Valid
V < 0.80	Invalid

The assessment of the practicality sheet was obtained from the students' response questionnaire, which was analyzed using the following formula.

$$P = \frac{R}{SM} x100\%$$

Explanation:
P : Percentage value to be calculated
R : Raw score obtained
MS : Maximum score

Table 2. Category of Practicality Level

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

III. RESULTS AND DISCUSSION

1. *Preliminary Research*

At this stage, product design is carried out based on the plans developed during the initial investigation phase (preliminary research), which includes initial observations, needs and context analysis, literature review, and the development of a conceptual framework. The initial investigation phase is conducted to identify and analyze the fundamental problems encountered in the field and to find solutions to those problems.

The needs analysis stage was carried out by interviewing chemistry teachers at several schools, namely SMAN 10 Padang, SMAN 8 Padang, and SMA 1 Pertiwi Padang. The interview results showed that all three schools in Padang have implemented the *Kurikulum Merdeka* in their teaching processes, in accordance with the curriculum's demand for student-centered learning. However, two out of the three schools have not yet fully implemented student-centered learning effectively, as some students still struggle to grasp certain chemistry concepts.

In addition, the use of social media in the learning process, such as WhatsApp, has proven to be less effective due to several limitations. These include difficulties in downloading learning materials when the internet connection is poor, phone performance slowing down due to an overload of group messages, and the potential for academic dishonesty when individual assessments are shared via group (Ardiani & Pujiriyanto, 2022).

Furthermore, teachers have also used Learning Management Systems (LMS) such as Edmodo in the learning process. However, Edmodo is no longer in use due to the company's bankruptcy. A potential solution that could address the shortcomings of both LMS platforms and social media is to utilize more advanced technology, such as the Discord application.

After the needs analysis, the next step is context analysis related to the topic of Atomic Structure. The topic of Atomic Structure has an adequate level of complexity, combining abstract and concrete concepts, making it highly suitable for the development of innovative and contextual learning approaches. Based on interview results, it was stated that some students experience difficulties in understanding the topic of atomic structure due to its abstract nature. Subsequently, an analysis of the learning outcomes for Phase E of senior high school was conducted. After the analysis, learning objectives were formulated in accordance with the operational verbs found in the atomic structure material. The formulation of learning objectives was carried out using the revised Bloom's taxonomy, which consists of six levels of cognitive processes, one of which involves the cognitive process level with the verb 'understand'.

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Next, a literature study analysis was conducted by reviewing journals to find solutions to the problems faced by teachers and students in carrying out teaching and learning activities. The following is the conceptual framework developed after obtaining information from the needs and context analysis. Subsequently, a literature review was conducted by analyzing relevant journals to identify solutions to the problems faced by teachers and students in the teaching and learning process. The following is the resulting conceptual framework:

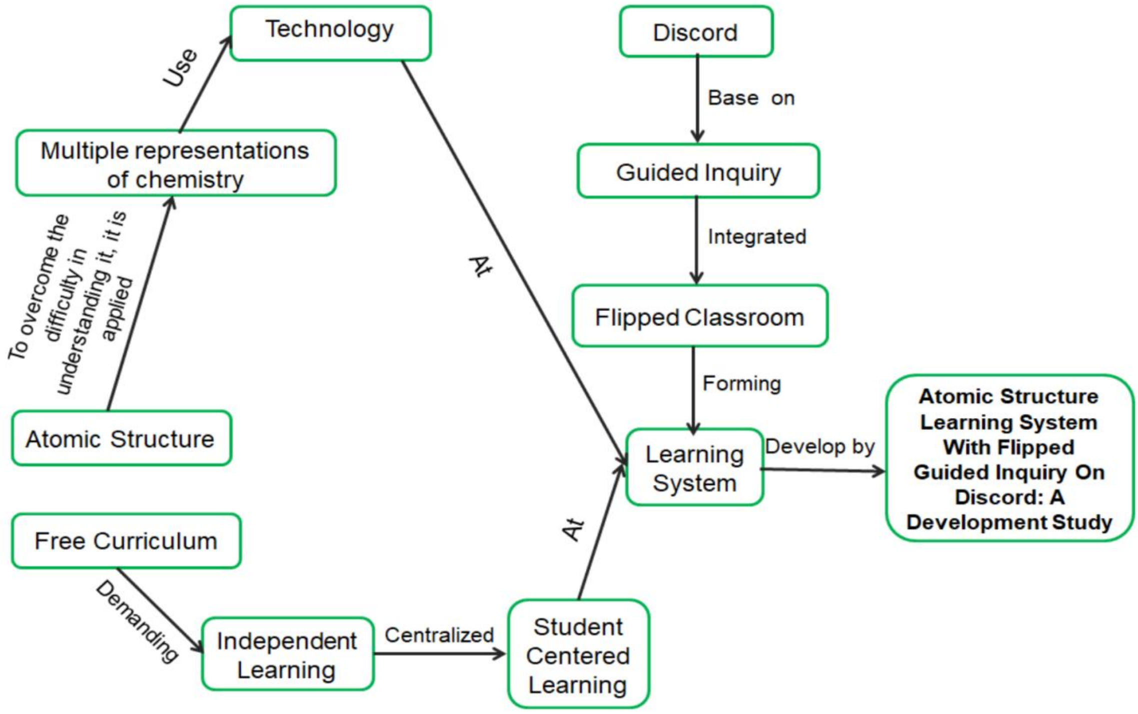

Fig. 2 Conceptual Framework (Delfianza et al., 2023; Tuti et al., 2023)

The initial step in implementing the learning system begins with designing the product. The teacher creates a lesson plan on atomic structure using the guided inquiry learning model. This design is also integrated with the flipped classroom approach, which includes two conditions: asynchronous activities occurring during the orientation, exploration, and concept formation phases, and synchronous activities taking place during the application and closing phases. Subsequently, the learning system design is uploaded to Discord according to the pre-arranged channels.

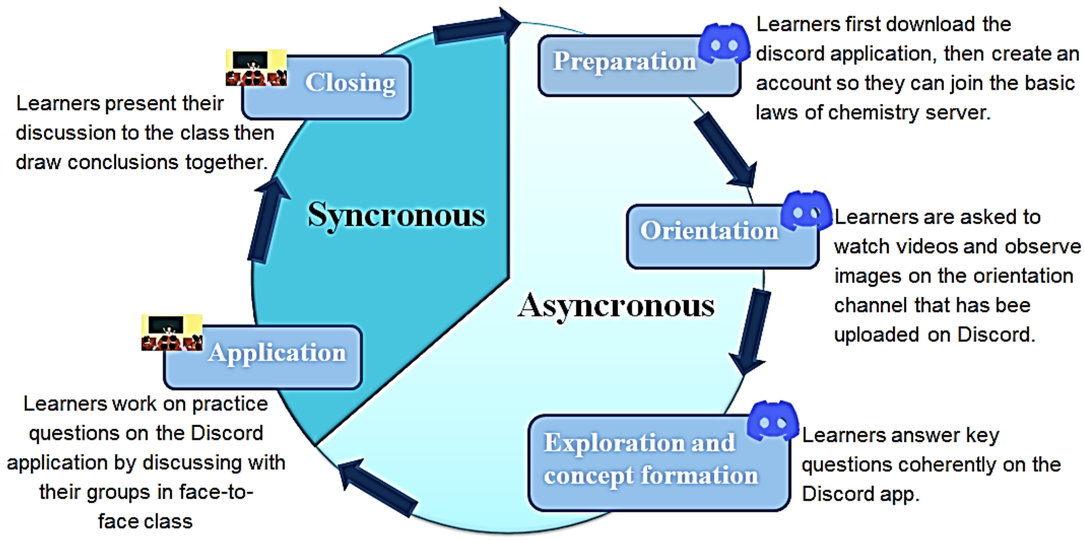

Fig. 3 The Cycle of a Flipped Classroom System Based on Guided Inquiry Learning Model Using Discord (Aumi & Mawardi, 2021; Irvan & Mawardi, 2022)

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2. Development or Prototyping Phase

Prototype I

At this stage, the product design is developed based on the plans created during the preliminary research phase, which includes initial observations, needs and context analysis, literature review, and the development of a conceptual framework. The outcome of Prototype I is a guided inquiry-based flipped classroom learning system utilizing the Discord application for the topic of atomic structure. This initial product will then proceed to the first stage of formative evaluation, which is self-evaluation, where the developer conducts an assessment of the developed product by completing a questionnaire.

PrototypeII

After conducting a self-evaluation on Prototype I, Prototype II was created. Based on the results from the self-evaluation sheet, it was concluded that the design that had been developed met the criteria outlined in the self-evaluation sheet, such as clear instructions, the presence of videos and images shared on Discord, and the use of video conferences for meetings. The product that has passed the self-evaluation stage is called Prototype II.

Prototype III

1. **Expert Review**

The expert review was conducted by 3 chemistry lecturers from UNP and 2 teachers from SMAN 8 Padang. The instrument used for data collection was a validity questionnaire. The purpose of the expert review was to obtain a scientifically valid prototype. The aspects assessed in content validity included content, presentation, language, and graphics, while the aspects assessed in construct validity were appearance and ease of use.

The average content validity obtained was 0.86. The following is the breakdown of the validated components along with their scores. Meanwhile, the average obtained for construct validity was 0.86. From Tables 1 and 2, the average V value for the 5 validators was 0.87. The result obtained was ÿ 0.8, indicating validity based on the Aiken V scale.

Table 3. Based Content Validity Analisys Results

Assesment Aspects	V	Criteria
Content components	0.85	Valid
Presentation components	0.86	Valid
Lingustic components	0.86	Valid
Graphic components	0.87	Valid
Average content validity	**0.86**	**Valid**

Table 4. Based Content Validity Analisys Results

Assesment Aspects	V	Criteria
appearance components	0.86	Valid
Ease components	0.86	Valid
Average construct validity	**0.86**	**Valid**

The validators also provided suggestions regarding the developed product, necessitating revisions to the product. Below is an example of a revised product that had been commented on by the validators.

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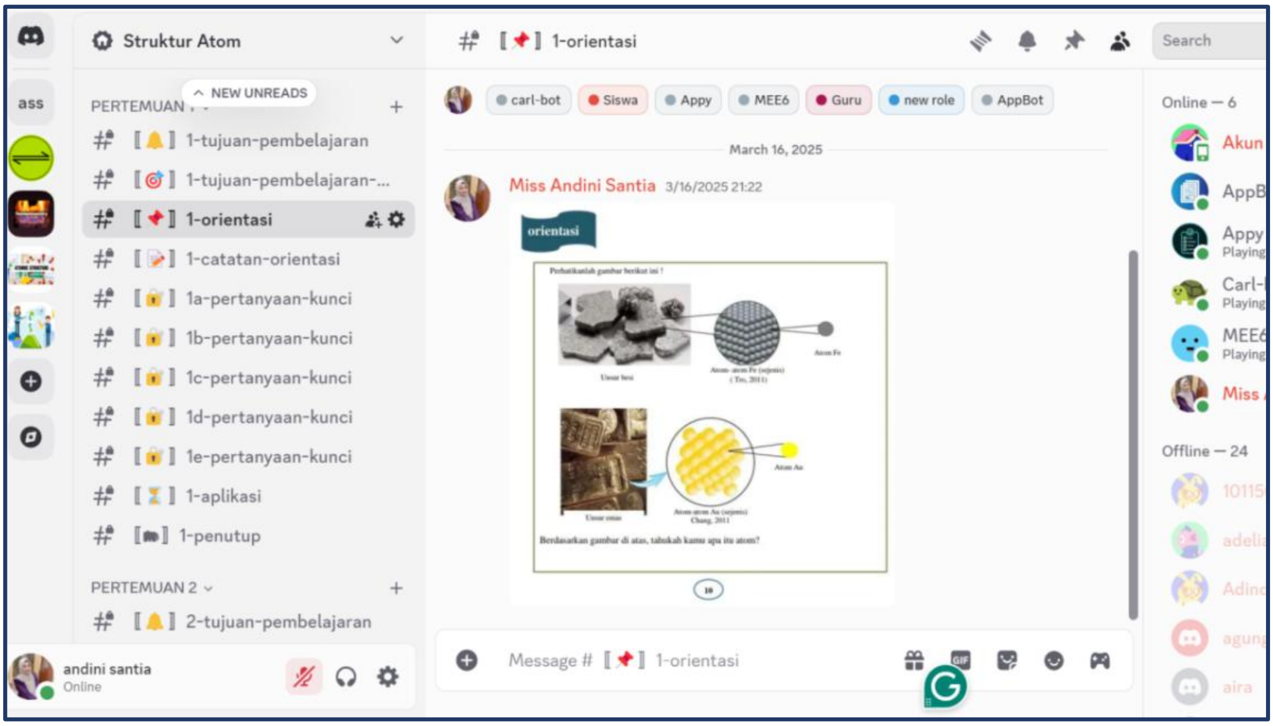

Fig. 4 Discord appearance after revision

2. One-to-one

Next, a One-to-One Evaluation was conducted by interviewing three 11th-grade students from SMAN 8 Padang who had studied the atomic structure material. This stage aimed to observe the students' responses to the second prototype that had been produced. Based on the interview results, the display, images, information, and orientation video on Discord were clear. The language used in the orientation video was also easy to understand and clear. The instructions provided were clear and easy to follow due to their structured format. Initially, one student was confused about using Discord. However, with the help of a guidebook and assistance from the researcher, the student no longer experienced difficulties in using Discord.

Prototype IV

Based on the validation results, the developed product can proceed to the next stage, namely the practicality stage through a small group trial. The small group trial was conducted with 9 students and 2 chemistry teachers from SMAN 8 Padang. In terms of ease of use, the average practicality test score was 90% for students and 92% for teachers, both falling under the "very practical" category. In terms of time efficiency, the average practicality test score was 91% for students and 95% for teachers, also categorized as "very practical." In terms of usefulness, the average practicality test score was 88% for students and 94% for teachers, again falling under the "very practical" category. After averaging the scores, the overall practicality percentage of the system was 93%, which is categorized as "very practical".

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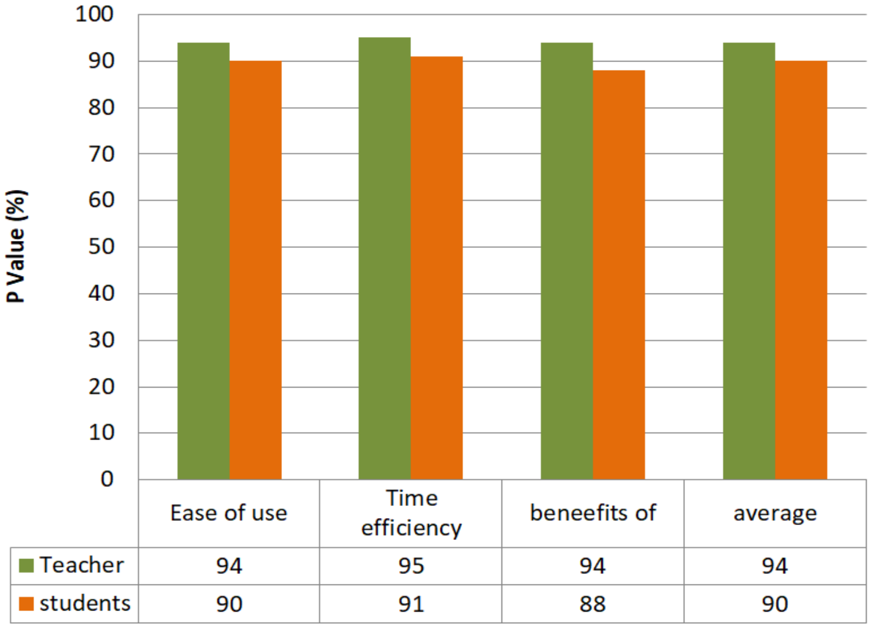

Fig. 5 Analysis of Practicality Result

As previously mentioned, the given model must represent the three components of chemical representation that help students grasp concepts in the macroscopic, submicroscopic, and symbolic worlds. Without these three aspects, students may develop misconceptions, whereas with the aid of chemical representations, learning becomes more meaningful. Below is an example of a model that has been designed:

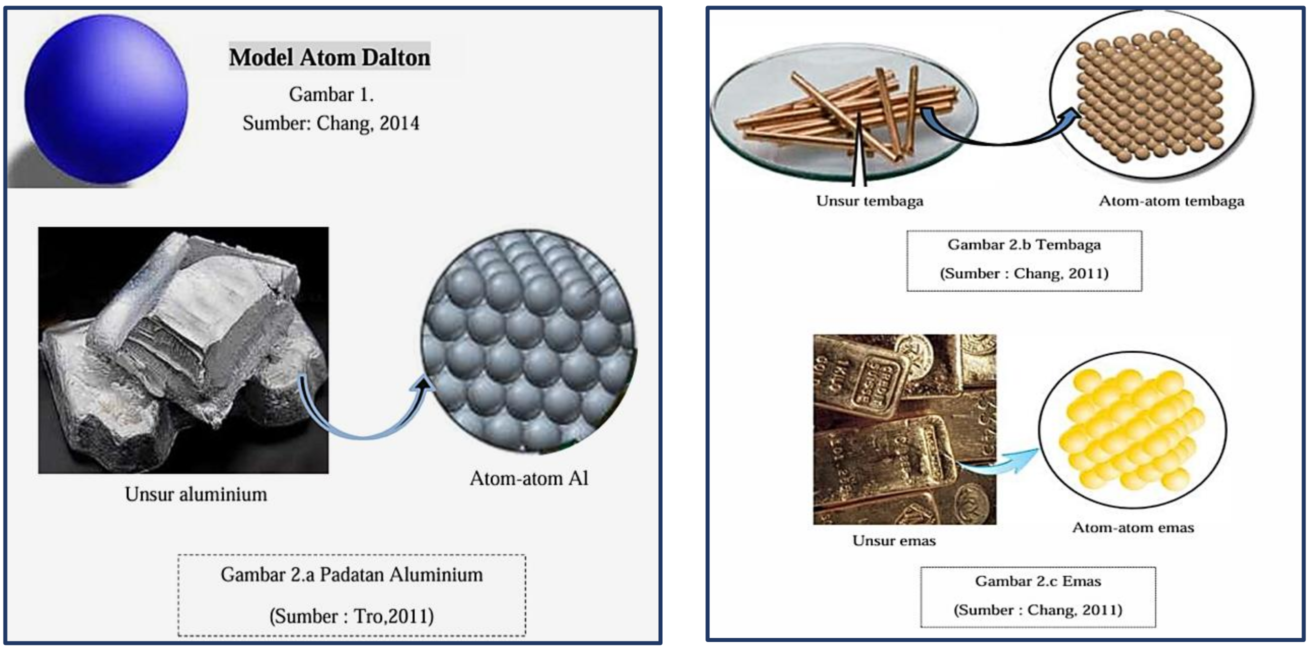

Fig 6. Model Representation in the Exploration and Concept Formation Stage

The responses of three students were analyzed to determine their level of understanding of the given model. The students' understanding is presented in the following table.

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Table 5. Description of Students' Responses to the Model in Figure 6

Student	Response
1	Figure 2a: composed of aluminum atoms, spherical in shape (overall forming a cube) Figure 2b: composed of copper atoms, spherical and small in size Figure 2c: composed of gold atoms, shaped like balls and small in size
2	Figures 2a, 2b, and 2c are composed of atoms and are small in size
3	Figures 2a, 2b, and 2c consist of atoms

Figure 6 is one of the models provided to help answer the key questions during students' exploration and concept formation. Students are expected to answer these key questions in order to gain an understanding of the concept of atomic structure itself. Based on the analysis of student responses, it is evident that Student 1 demonstrates a higher level of thinking compared to the other students, as their answer is clear and aligns with the textbook. Meanwhile, Student 2 shows a moderate ability in identifying the concept of atomic structure, as their answer is not entirely accurate but is close to the textbook content. In contrast, Student 3 shows a low level of understanding.

Students' abilities are limited because their answers fail to clearly describe the observed phenomena, particularly in the submicroscopic aspect (Siregar & Mawardi, 2022). In answering key questions, students must be provided with a clear model that represents the three levels of chemical multirepresentation (Mawardi & Fitriza, 2019). The model should include macroscopic, submicroscopic, and symbolic representations to ensure that students' understanding aligns with the intended concepts. Furthermore, the key questions presented should be coherent and progressively structured from easy to difficult levels, enabling students to construct their conceptual understanding independently. Students are expected to answer key questions accurately, not only by relying on observable images (macroscopic level), but also by interpreting molecular representations (submicroscopic level). This is important because when only macroscopic images are provided, some students still describe them merely as dots and solids, indicating that macroscopic information alone is insufficient for deep conceptual understanding. Submicroscopic information is equally essential, as observing copper atoms can help determine the concept of atoms. In addition, symbolic representations, such as chemical symbols or compound descriptions, also play an important role. Symbols serve to preserve the integrity of the concepts discovered by students, allowing them to reach accurate conclusions. It is the combination of these three types of chemical representations—macroscopic, submicroscopic, and symbolic—that facilitates students' holistic understanding of chemical concepts. Without these three components, students are likely to develop misconceptions. Therefore, the use of chemical representations makes learning more meaningful (Sitanggang et al., 2022; Waer & Mawardi, 2021).

IV. CONCLUSIONS

This study was conducted using the Educational Design Research (EDR) method, following the Plomp model which consists of three main phases: the preliminary phase, the development or prototyping phase, and the assessment phase. In its implementation, the study was limited to the small group trial stage to evaluate the initial effectiveness of the developed learning system. The flipped classroom learning system based on the guided inquiry learning model using Discord for the topic of atomic structure has proven to be feasible for development and valid in terms of content, presentation, language, graphics, layout, and ease of use, with a high average validity score of 0.86. These validation results indicate that the developed learning system meets the required feasibility standards. From the practicality aspect, the learning system demonstrated excellent performance with an average score of 92%. This level of practicality was assessed based on several key indicators, including the ease of using Discord as a learning platform, time efficiency in the learning process, and the perceived benefits in facilitating chemistry learning, especially in the topic of atomic structure. This high practicality score indicates that the developed flipped classroom learning system is not only theoretically valid but also practically applicable in real learning contexts.

The combination of the guided inquiry learning model and the flipped classroom method using the Discord application has been proven to be both valid and practical for use in teaching atomic structure. This learning system allows students to independently explore atomic structure materials beforehand, followed by discussions and deeper understanding with teacher guidance. The use of Discord as a learning platform also provides students with flexibility to access the materials anytime and anywhere, thereby supporting more personalized and adaptive learning. Thus, it can be concluded that the flipped classroom learning system based on the guided inquiry model using Discord for atomic structure content is not only valid and practical, but also ready to be implemented as an innovative learning alternative in chemistry education, particularly on the topic of atomic structure.

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