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Flipped Guided Inquiry Learning System Design on Discord for Acid-Base Solutions: A Development Study

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Abstract
The Society 5.0 era introduces substantial transformations in education, prompting Indonesia to embrace the learner-centered Merdeka Curriculum and the incorporation of technology in instruction. The purpose of this study is to design and evaluate the validity and practicality of a flipped guided inquiry learning (FGIL) model, integrated with the Discord application, for acid-base subject matter. This study employs the Educational Design Research (EDR) methodology utilizing Plomp's development framework. The research participants included chemistry lecturers and teachers serving as validators, along with nine students from the phase F class at SMAN 8 Padang. Content and construct validity were evaluated using Aiken's V, whilst practicality was examined by questionnaires administered to teachers and learners. The investigation revealed an average V value of 0.89 for both content validity and construct validity, which is classified as valid. Meanwhile, the practicality analysis results showed a percentage of 93%, based on the assessments of students and teachers, which is classified as very practical. The findings of this study showed that the proposed learning system possesses considerable potential to enhance the quality of chemistry education, thereby serving as a creative solution that aligns with the requirements of the Society 5.0 era and the actual implementation of the Merdeka Curriculum.

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Keywords: Acid-base solutions, discord application, flipped guided inquiry learning, learning system

1. Introduction

The progress of the times towards the Society 5.0 era encourages rapid changes in civilization, including in the world of education. Merdeka Curriculum is presented as a solution to face the challenges of the Society 5.0 era, an era in which technology and educators integrate and collaborate to improve the quality of education (Manalu *et al*., 2022) [20]. This curriculum emphasizes learner-oriented learning while still integrating technology as an important part of the learning process (Tuti *et al*., 2023) [35]. This has led to the emergence of communities in the education sector that utilize media that are better known in certain circles but still less familiar to the general public, such as Discord (Setyawan *et al*., 2024) [35].

Discord is a communication platform that facilitates direct interaction between users through text and voice, video conferencing, screen sharing, and the creation of discussion forums (Ridho *et al*., 2021) [29]. Discord possesses multiple components that could improve the learning experience (Jiang *et al*., 2019). One of them is the video conference feature that facilitates the delivery of material, learner interaction through video, and screen sharing, just like other video conferencing applications. In this case, Discord can also evaluate students' knowledge, provide feedback, and communicate between all learners and teachers without face-to-face meetings (Dewantara *et al*., 2020) [9]. Thus, Discord has the potential to be a beneficial online learning application, both as a medium for conversation and video conferencing (Arifianto & Izzudin, 2021) [5].

Research conducted by Lucho *et al*. (2023) shows that the Discord platform functions as an effective learning medium, thus bringing out the activeness of students through the flipped classroom approach.

The flipped classroom combines two learning treatments: synchronous and asynchronous learning (Yulianis & Mawardi, 2021) [40]. The flipped classroom is an educational methodology wherein students participate in activities typically conducted in the classroom at home (asynchronous), while actions usually performed at home are executed in the classroom (synchronous) (Bergman & Sams, 2012) [6]. This methodology aligns closely with the standards of the Merdeka Curriculum, which emphasizes learner-oriented learning. One of the learner-oriented learning models is guided inquiry (Nengsih & Mawardi, 2021) [24].

Guided inquiry requires the teacher to ask a series of key questions so that learners gain conceptual discovery. The questions are organized hierarchically, from low to high difficulty (Kardena & Mawardi, 2020) [17]. The beneficial effect of guided inquiry learning on learners is that it fosters active engagement in the learning process by enabling them to discover concepts autonomously (Mawardi *et al*., 2020) [22]. By integrating these two methodologies, teachers may use the flipped classroom model to apply the guided inquiry learning strategy both synchronously and asynchronously (Siregar & Mawardi, 2022) [33].

The guided inquiry methodology can be utilized for several chemical topics, including acid-base content. Acid-base concepts are categorized as abstract, resulting in significant challenges for many pupils in comprehending the subject matter (Utami *et al*., 2020) [36]. Challenges in learning acid-base topics can arise due to the failure of students to apply understanding from one level of representation to another (Talanquer, 2011) [34]. Research by Nurjanah *et al*. (2022) [26] supports this statement by finding that students' ability to visualize acid-base topics at the sub-microscopic level reaches 50%, which is relatively lower than other levels. Each of the three stages is interconnected and this approach synergistically fosters the development of students' mental models, leading to improved meaning construction and conceptual understanding. The cultivation of precise mental models can influence students' comprehension of abstract and intricate chemical concepts and their proficiency in problem-solving (Mardatilla *et al*., 2023) [21]. Gabel and Krajik propose that employing technology enables the simultaneous comprehension of chemistry through three levels of representation (Wu dkk., 2000) [39].

Various studies have developed and implemented Discord-assisted chemistry learning platforms with flipped classrooms and guided inquiry models, such as those conducted by (Delfianza *et al*., 2023) [7] for thermochemistry, Ananda *et al*. (2023) [4] for chemical equilibrium, and Tuti *et al*. (2023) [35] for reaction rates. Subsequent research by Amien *et al*. (2024) [3] on thermochemistry, Violin *et al*. (2024) [37] on chemical equilibrium, and Akmar *et al*. (2024) [2] on reaction rates demonstrates that this educational system substantially enhances student learning outcomes. The researcher developed a study to create a learning system utilizing flipped guided inquiry learning (FGIL) through the Discord application, which emphasizes acid-base solutions, and to analyze its validity and practicality. This research is anticipated to positively influence students and teachers in implementing technology-based learning in schools, fostering diverse student competencies that align with the Merdeka Curriculum and Society 5.0 era requirements.

2. Method

The research methodology employed is development research, notably educational design research (EDR). The research focuses on designing and developing a flipped guided inquiry learning (FGIL) system product, leveraging the Discord application as a key component for acid-base material in phase F of senior high school. This development uses the Plomp model, which includes three stages as the basis for this research: (1) preliminary research, (2) development or prototyping stage, and (3) assessment stage (Plomp & Nieveen, 2007) [28]. This study is confined to small-scale practical testing, specifically up to the making of Prototype 4.

The initial phase includes preliminary research, encompassing tasks such as needs analysis, context analysis, literature study, and conceptual framework development. The requirements analysis seeks to examine the fundamental issues encountered by educators and learners with the acid-base learning process. The needs analysis employed interviews with three chemistry educators and the distribution of questionnaires to phase F students across three distinct schools in Padang City: SMAN 1 Padang, SMAN 8 Padang, and SMAN 13 Padang. Simultaneously, a curriculum and learning outcomes analysis was conducted within the context analysis. Subsequently, a literature study by examining publications across many journals, evaluating the methodologies employed, and identifying solutions to the challenges encountered by educators and learners during the educational process (Syafei & Mawardi, 2022) [33].

The next phase involves the development of a conceptual framework informed by a comprehensive analysis of the needs and contextual analysis results. The analysis results are corroborated by the literature study, yielding a statement or summary of the rationale for undertaking this learning system development research (Delfianza *et al*., 2023) [7].

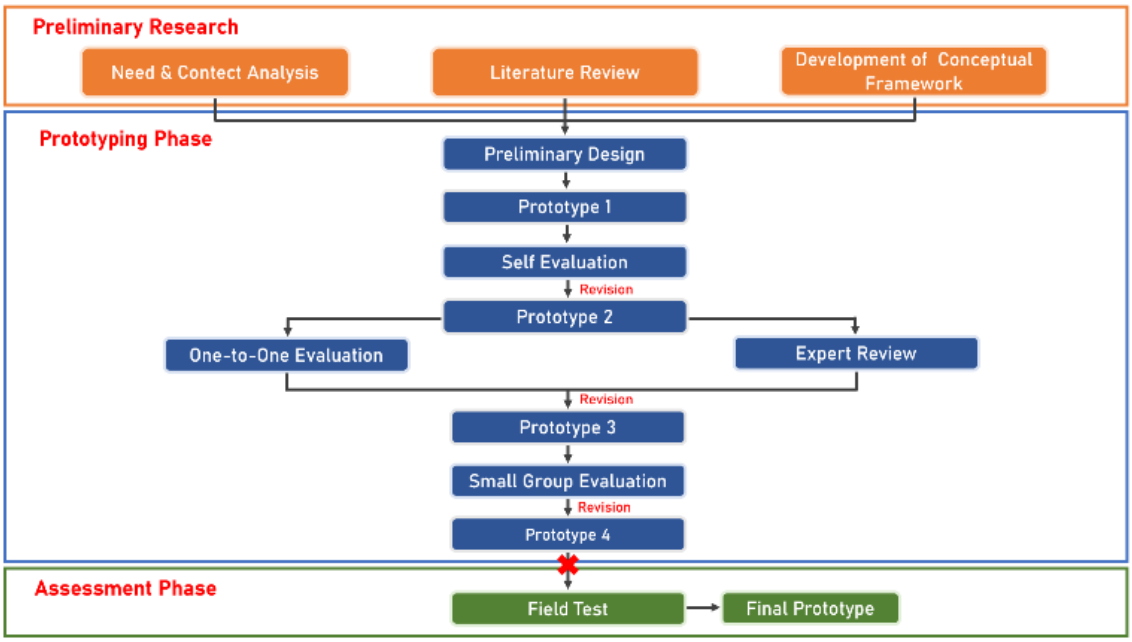


Fig 1: Stages of EDR Research (Fauzan *et al*., 2023)

The next phase is the development or prototype creation phase. The prototype development phase will result in Prototype I, II, III, and IV. The four prototypes result from formative evaluation. This assessment consists of four parts as depicted in Figure 1: self-evaluation, expert review, one-to-one evaluation, and small group assessment. The prototype development phase initiates with the creation of a detailed design for a flipped guided inquiry learning system product, which utilizes the Discord application as Prototype 1. During the second stage, the product under development is subjected to self-assessment by completing a self-evaluation questionnaire presented as a checklist. Subsequently, the product will be refined and revised to produce an updated version, designated as Prototype II (Ismail *et al*., 2023) [15].

The third stage involves an expert review and one-to-one evaluation of the Prototype. Three chemistry lecturers from the chemistry department of Padang State University and two chemistry teachers of SMAN 8 Padang carried out the expert review. The experts review as validators who evaluate Prototype II with a content and construct validity questionnaire. A one-to-one evaluation will be performed by interviewing three eleventh-grade students from phase F of SMAN 8 Padang utilizing an interview sheet instrument. Prototype II will be amended according to all feedback to generate a viable Prototype III.

The last step is a small group trial conducted with nine students from phase F of SMAN 8 Padang. At this stage, the learning system under development is evaluated with multiple small groups of students within a single learning cycle. Prototype III will be amended to yield a viable and functional Prototype IV.

This study uses two instruments: validation instruments and practicality instruments. The data obtained from this study will be analyzed using descriptive statistics to produce percentages and averages, using validity analysis techniques using Aiken's V scale.

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

$$s = r - lo$$

Explanation:
V = Aiken's V scale
Σs = the sum of all s values from all validators
n = number of validators
c = highest validity score (= 5)
lo = lowest validity score (= 1)
r = the number chosen by the validator

Table 1: Aiken's Criteria (Aiken, 1985)

Aiken's V Scale	Description
V ≥ 0.80	Valid
V < 0.80	Invalid

The practicality of processing is derived from the implementation of student and teacher answer questionnaires, which are evaluated using the formula:

$$P = \frac{R}{MS} \times 100\%$$

Explanation:
P = percentage value sought
R = raw score obtained by students
MS = ideal maximum score of the test concerned

Table 2: Practicality Level Criteria (Purwanto, 2010)

Percentage	Description
86%-100%	Very Practical
76%-85%	Practical
60%-75%	Practical Enough
55%-59%	Not Practical Enough
≤ 54%	Not Practical

3. Results and Discussion

Preliminary Research

Needs analysis

The research commenced with a comprehensive needs analysis, which included conducting interviews with chemistry teachers and administering questionnaires to students across three schools: SMAN 1 Padang, SMAN 8 Padang, and SMAN 13 Padang. The results of the interviews

showed that although the Merdeka Curriculum had been implemented and emphasized student-centered learning, its implementation was not optimal. Teachers still predominantly provided direct instructions, so that students were not fully active in finding concepts independently. Thus, the implementation of student-centered learning was considered not optimal. The learning media used were also limited to the macroscopic and symbolic levels, making it difficult to understand abstract concepts in acid-base material. Also, the use of technology in education remains minimal, and the use of social media such as WhatsApp often creates obstacles, such as information that is easily buried.

A needs analysis was performed by implementing questionnaires to 97 students from SMAN 1, 8, and 13 Padang. The results showed that 54 students considered the acid-base material difficult to understand because of its abstract nature and the many theories and calculations. In addition, 54 students felt unfulfilled with the learning media used, such as printed books, worksheets, printed modules, PowerPoint presentations, E-Modules, and E-worksheets. Thus, the characteristics of the learning media needed by students include 50 students choosing easy to obtain and use, 47 students choosing that can be used anywhere and anytime, and 31 students choosing that does not require expensive costs.

Thus, implementing a guided inquiry paradigm inside a flipped classroom context with the Discord application is anticipated to provide an alternate solution for education designed to meet the specifications of the Merdeka Curriculum and the evolving needs of the Society 5.0 era.

Context Analysis

The context analysis phase involves a thorough evaluation of the curriculum and learning outcomes, with the primary goal of discovering, articulating, and systematically organizing learning objectives and materials by applying multiple chemical representations and strategies chosen systematically to develop a learning system. These learning outcomes are then derived into learning objectives and learning objective flows in acid-base material. The curriculum used at SMAN 8 Padang is the Merdeka Curriculum. Acid-base solutions are part of the curriculum in phase F, specifically during the second semester of the Merdeka Curriculum.

Predicated upon the analysis of learning outcomes and learning objectives, some of the items needed were discovered that facilitate comprehension of the subject of acids and bases, encompassing the principles of chemical reactions, molar calculations, electrolyte and nonelectrolyte solutions, as well as chemical equilibrium (Devi & Azra, 2023) [8]. Before studying the topic of acid-base material, students have studied chemical equilibrium material previously. The first concept that must be studied in acid-base material is acid-base theory. Next is the topic of acid-base strength. Students must first understand the topic of acid strength and base strength as a prerequisite for studying the concept of calculating acid and base pH. After studying this concept, students will study the next concept, namely acid-base indicators.

Literature Study

Subsequent to the completion of the field interview phase, the researchers proceeded with a literature study of several scholarly journals pertinent to the highlighted difficulties and tried to formulate solutions for the challenges encountered by students and educators in the educational setting. Therefore, a system development based on guided inquiry learning on the Discord application was designed for acid-base material.

Development of a conceptual framework

Furthermore, the research progressed to the conceptual framework development stage by evaluating the outcomes of the needs analysis and contextual analysis. The analysis results are corroborated by the literature study, leading to a summary of the rationale for doing the development research, namely a flipped guided enquiry learning-based educational system utilising the Discord application for acid-base content. Figure 2 illustrates the results of the development of the conceptual framework.

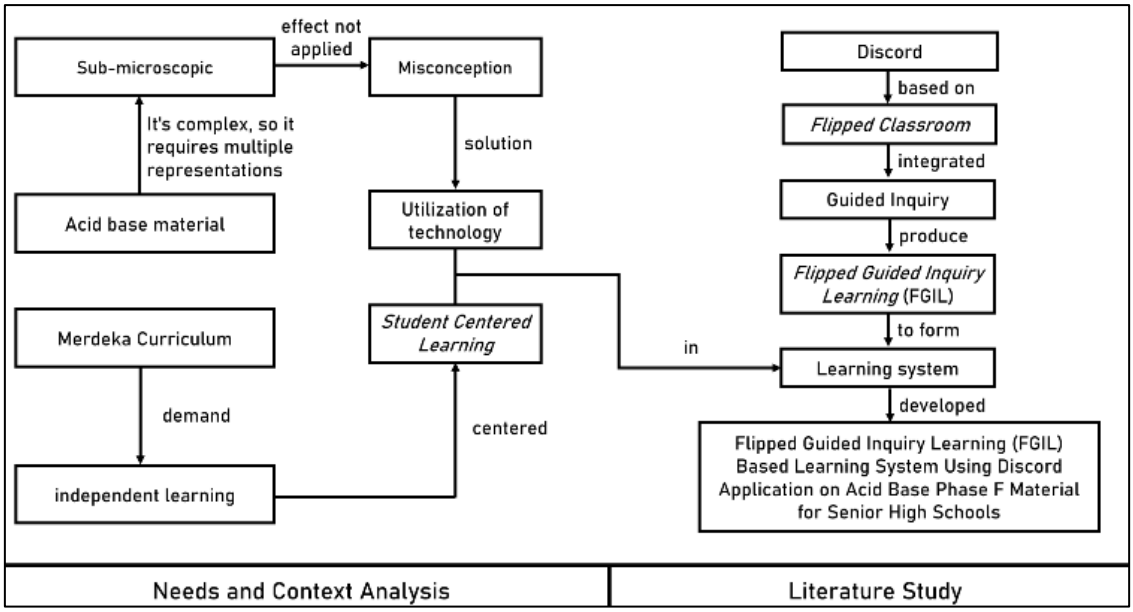


Fig 2: Development of Conceptual Framework

Development or prototyping stage

Prototype I

In the initial stage of development, namely Prototype 1, a flipped guided inquiry learning (FGIL) system was developed based on the following learning stages: orientation, exploration and concept formation, application, and conclusion. This learning system integrates two forms of implementation, namely, asynchronous and synchronous learning. The orientation, exploration, and concept formation stages are facilitated through asynchronous learning. In contrast, the application and conclusion stages are conducted synchronously, either through face-to-face meetings in the classroom or through online platforms such as Discord (Handri *et al*., 2023) [11]. A visual representation of the FGIL learning stages based on Discord is shown in Figure 3.

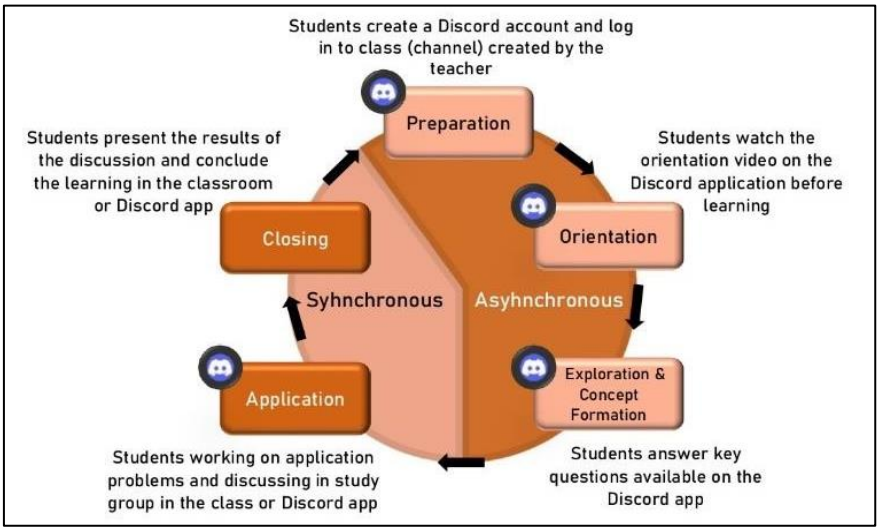


Fig 3: The Cycle of a Flipped Guided Inquiry Learning Based System Using the Discord Application

Once all components are properly organized, the next step is to integrate the learning design into the Discord application. The learning stages begin with students self-verifying as a form of participation in the class. Subsequently, they engage in asynchronous learning using the Discord application. Figures 4 and 5 show illustrations of self-verification and attendance capture in the Discord app.

Fig 4: View of the Self-verification on Discord Application

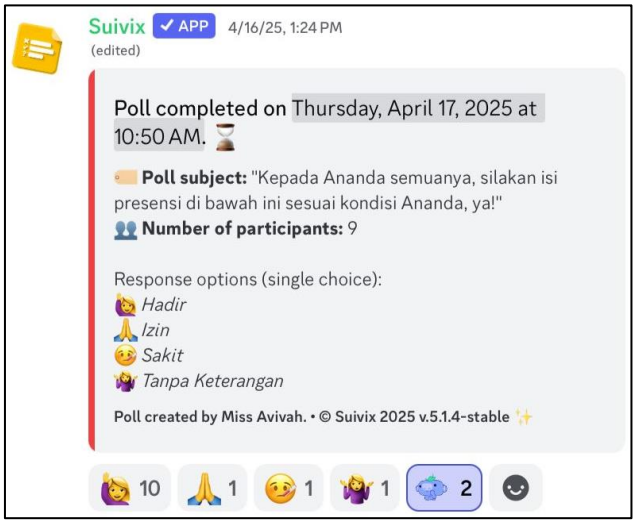


Fig 5: View of the Presence on Discord Application

The initial phase of guided inquiry is orientation. Students will access a teacher-created video disseminated via the Discord channel, which clearly articulates the learning objectives, motivation, and requisite knowledge necessary to link prior content with the upcoming topic. Figure 6 is an instance of the orientation video presentation on the Discord application.

Fig 6: View of the Orientation video on Discord Application

Exploration and concept generation are elements of the subsequent syntax. At this juncture, students are typically provided with a model or data for examination, which prompts them to address key questions. The use of models plays a very important role in chemistry learning, especially in conveying abstract and complex concepts. Thus, the selection of models must be done appropriately to prevent misconceptions from emerging in students. In order to reduce the potential for misconceptions, abstract chemical concepts can be presented through a three-level representation approach (Suparwati, 2022) [32]. Supplying questions from the offered model can facilitate students' independent comprehension of the studied content (Lenggogeni & Mawardi, 2022) [33]. The key questions are interconnected, progressing from basic to more advanced cognitive levels (Iqbal & Mawardi, 2022) [33]. Concept formation emerges from the preceding exploration stage, with these two stages unfolding in a sequential and interconnected manner. The concept formation phase commences as students examine the given model, generate predictions, and make deductions to answer key questions.

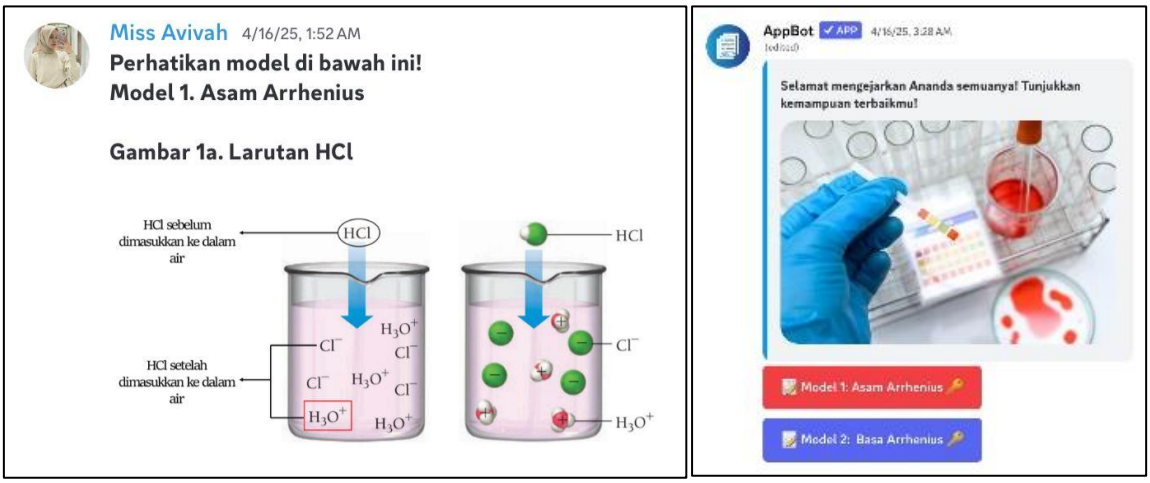


Fig 7: View of the Key Question on Discord Application

The next phase of syntax is application. To reinforce comprehension of the acquired concerns, students will be provided with practice questions at this juncture. Students will additionally respond to the practice questions through discussions within their pre-established groups. Suppose students evaluate the model by employing the key inquiries and comprehend the fundamental concepts identified during the exploration and concept formation phases. As a result,

students will be successful in replying to inquiries at the application phase (Khairunnisak *et al*., 2023) [18]. This activity is flexible and can be facilitated in either offline classroom settings or online sessions, utilizing the video conferencing functionality provided by the Discord platform.

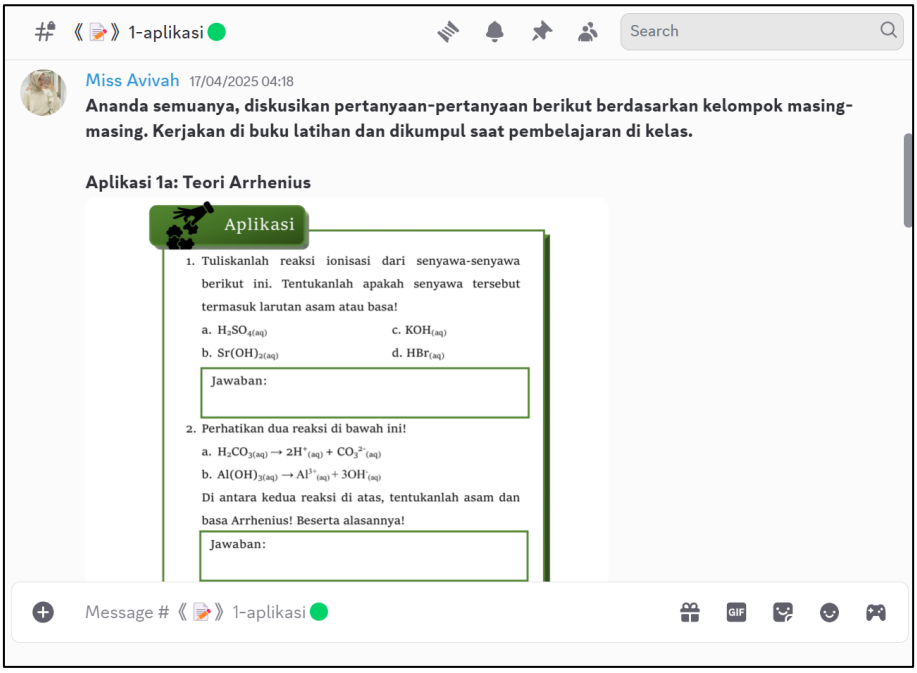


Fig 8: View of the Application Stage on Discord Application

The concluding phase of guided inquiry learning is the closure. At this stage, students present the results of their group discussions in front of the class, thereby facilitating a process of knowledge and experience sharing among groups. Additionally, students and teachers collaboratively draw conclusions related to the learning that has been done. The teacher validates and strengthens the concepts obtained by students directly, both in online and face-to-face class conditions. Upon the completion of the learning design, Prototype I is established.

Prototype II

The outcomes of Prototype I will advance to the self-evaluation phase to generate Prototype II. At this juncture, evaluative instruments in the format of a checklist are supplied. This self-evaluation evaluates the comprehensiveness of the learning system grounded in flipped-guided inquiry learning. Upon finishing the self-evaluation form, the subsequent stage is to refine and finalize the elements of the flipped guided inquiry learning system and upload them to the Discord application. Upon completion of the adjustments and enhancements to the components as per the self-evaluation form, Prototype II is finalized.

Prototype III

After Prototype II is developed, the validation process will comprise expert reviews and one-to-one evaluations conducted by a panel consisting of three lecturers from the Department of Chemistry at the State University of Padang and two chemistry teachers from SMAN 8 Padang participated in the expert review stage. The evaluation by these experts reviews the established product's validity level. The validation procedure employed two distinct evaluation instruments: content validity assessment forms and construct validity assessment forms. The content validity assessment encompassed an examination of several key aspects, including content relevance, presentation quality, linguistic clarity, and the utilization of graphics to facilitate comprehension. In contrast, construct validity assesses the appearance and ease of use of the product. The questionnaire is also equipped with a column for validators to provide suggestions, input, and comments related to the product. Feedback from the experts will be used as the basis for improving the product. If necessary, improvements will be made so that the resulting product is of higher quality and in accordance with its development objectives.

The average content validity obtained is 0.88 from 24 question items tested, while the average construct validity obtained is 0.89 from 15 question items tested. From Table 1, the mean V value for five validators is 0.89. The result achieved is ≥ 0.8, signifying validity according to Aiken's V scale. The designed learning system has satisfied the standards needed for implementation in education settings (Ananda *et al*., 2023) [4].

Table 3: Analysis of Validity Results

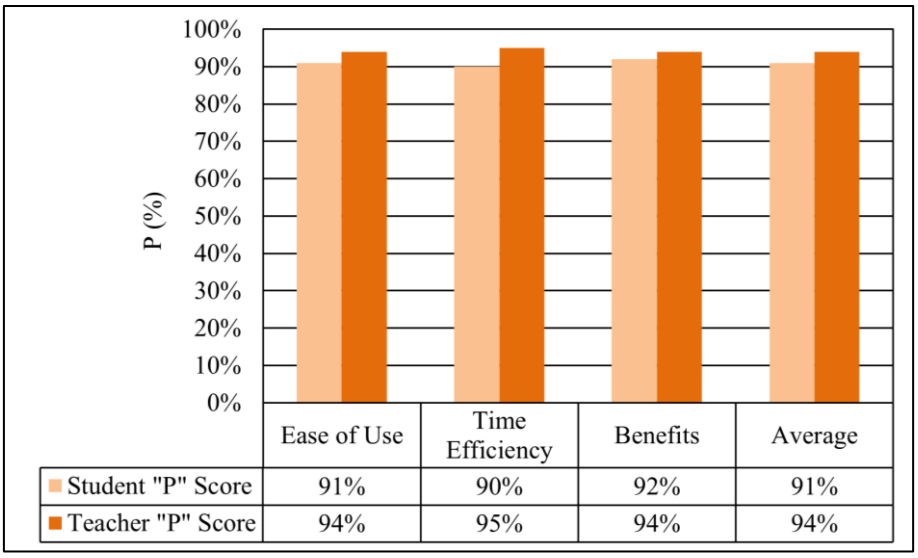
No.	Aspects Assessed	V	Criteria
1.	**Validity content**		
	Content Components	0,89	Valid
	Presentation Components	0,88	Valid
	Lingustic Components	0,89	Valid
	Graphic Components	0,85	Valid
	Average Content Validity	**0,88**	**Valid**
2.	**Validity construct**		
	Appearance Components	0,89	Valid
	Ease Components	0,88	Valid
	Average Construct Validity	**0,89**	**Valid**
Average Validity		**0,89**	**Valid**

In line with the expert review, one-to-one interviews will be conducted with three students from class XI phase F SMAN

8 Padang, each possessing distinct abilities (high, medium, and low). This phase seeks to ascertain student reactions to the forthcoming learning system that will be established. The outcomes of this phase reveal that the orientation video delivered through the Discord application features clear visuals and audio, with text that is easily comprehensible. Furthermore, the model during the exploration stage is both distinct and vibrant, rendering it engaging and facilitating students in addressing the essential questions presented. Students encountered no challenges utilizing the Discord application due to the clarity of the instructions for each syntax. Subsequently, modifications were implemented to Prototype II, with the objective of enhancing its quality. Later, a valid Prototype III was generated after the alteration of Prototype II.

Prototype IV

Following the establishment of Prototype III, the produced product may progress to the practicality stage via small group trials. A small group assessment was conducted with nine students in phase F of SMAN 8 Padang, representing varying skill levels: high, medium, and low, as per the chemistry teacher's recommendation. The researcher categorized the pupils into multiple study groups and thereafter replicated the utilization of the Discord application alongside the learning systems developed according to flipped guided inquiry learning. Students conducted this learning system process for one cycle on the acid-base sub-material. After that, researchers gave questionnaires to students, and students were asked to provide suggestions and criticisms. Additionally, data was gathered from two chemistry teachers at SMAN 8 Padang. The elements employed to measure practicality include ease of use, time efficiency, and benefits. Based on feedback from educators and learners, corrections will be implemented to enhance the quality of Prototype IV deliverables. Figure 9 illustrates the outcomes of Prototype IV's formation.



	Ease of Use	Time Efficiency	Benefits	Average
Student "P" Score	91%	90%	92%	91%
Teacher "P" Score	94%	95%	94%	94%

Fig 9: Analysis of Practicality Results

As per Figure 9, the developed product has a practicality percentage of 93%, in accordance with the outcomes of the practicality assessment, which categorizes it as highly useful. Details of practicality by teachers were 94%, and by students were 91%. The results were further refined to create a valid and practical Prototype IV.

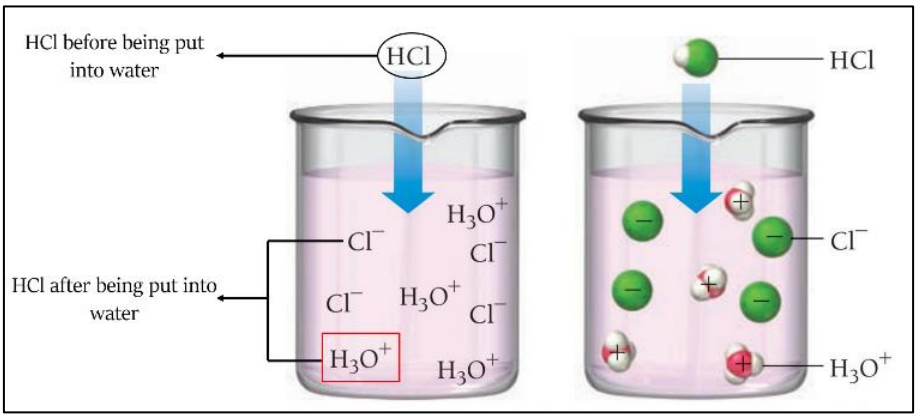


Fig 10a: Acid Arrhenius Model

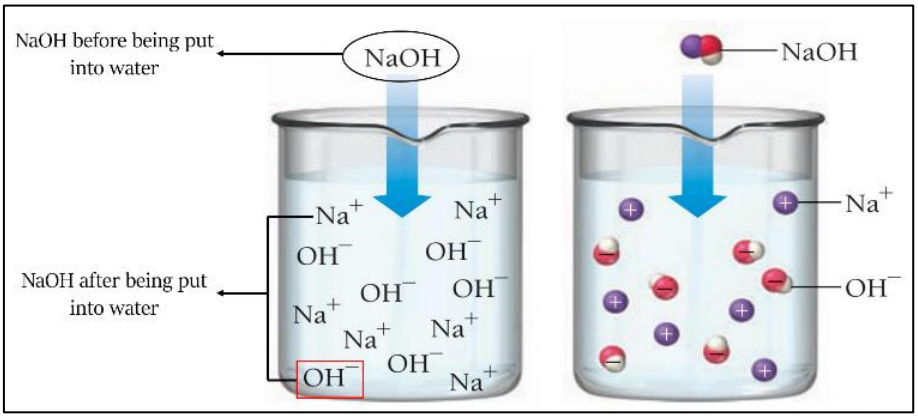


Fig 10b: Base Arrhenius Model
Fig 10: Model Representation at the Exploration and Concept Formation Stage (Nivaldo Tro, 2016)

A model of a key question for students is illustrated in Figure 10, where students are expected to comprehend the acid-base theory according to Arrhenius. Through the examination of the model, students may visually comprehend the difference between Arrhenius acids and Arrhenius bases. By Arrhenius' definition, HCl qualifies as an acid due to its generation of H^+ ions in solution. In contrast, NaOH is classified as a base for its production of OH^- ions in solution (Petrucci *et al*., 2011) [27]. HCl is a covalent compound that lacks ionic constituents. Nevertheless, when HCl is dissolved in water, it can form positive ions and negative ions. The ions are $H^+_{(aq)}$ and $Cl^-_{(aq)}$ (Nivaldo Tro, 2016). A detailed analysis was conducted on the model representation of three students during the exploration and concept formation stages to evaluate their comprehension of the model. The subsequent table delineates an outline of student comprehension.

Table 4: Description of Students' Answers to the Model in Figure 9

Respondent	Answer
1	Arrhenius' theory defines an acid as a substance that dissociates in solution to produce hydrogen ions (H^+), and a base as a substance that dissociates to produce hydroxide ions (OH^-).
2	In aqueous solutions, acids release H^+ ions through dissociation, whereas bases release OH^- ions.
3	Acids are substances that form H^+ ions, while bases are substances that form OH^- ions.

At this phase, students are needed to accurately respond to the key question and identify the intended concept by examining the model presented in the key question with the help of multiple representations. Analysis of students' responses indicates that student 1 demonstrates a superior degree of cognition compared to peers, as the answers are articulate and aligned with the textbook content. Student 2 a demonstrated moderate understanding of acid-base concepts according to Arrhenius' theory, given that their answer closely corresponded to the textbook material. Conversely, student 3 demonstrated limited knowledge, as his response failed to accurately articulate the observed phenomena, particularly at the sub-microscopic scale. All three students had shown an understanding that acids and bases, according to Arrhenius' theory, produce H^+ and OH^- ions. However, the third student did not understand that this reaction only occurs when substances are dissolved in water.

According to Figure 11, students are anticipated to respond accurately to the key question. The model suggested must encompass macroscopic, sub-microscopic, and symbolic representations to ensure that the comprehension achieved aligns with the desired concept (Delfianza *et al*., 2023) [7]. In addition, key questions should be arranged in stages, starting from the easiest to the most complex level, so that students can build understanding and discover concepts independently (Herpika & Mawardi, 2021) [12]. When students are only given macroscopic representations, they tend to have difficulty observing phenomena in more depth, thus experiencing obstacles in finding solutions to the problems given. Sub-microscopic representations play an important role in showing how compounds interact when dissolved in water, thus helping students understand the concept of acids and bases. On the other hand, symbolic representations in the form of chemical symbols or formulas are also very important to strengthen understanding, so that the concepts that students understand become intact and can be concluded appropriately (Waer & Mawardi, 2021) [12]. Therefore, the application of three levels of multiple representation in chemistry learning, namely macroscopic, sub-microscopic, and symbolic, is very effective in help depict concepts in a more focused manner, prevent misconceptions, and the learning process is more focused (Ismail & Mawardi, 2021) [12].

4. Conclusion

The flipped guided inquiry learning (FGIL) based learning system was developed and analysed for validity and practicality. The analysis found that this learning system possesses a validity score of 0.89, categorizing it as valid, with content validity at 0.88 and construct validity at 0.89. In addition, the practicality of this learning system reaches 93% and is categorized as very practical. In detail, the level of practicality according to teachers was 94%, while according to students, it was 91%. These findings indicate that the developed product can progress to the effectiveness testing phase, enabling broader application in the learning process.

5. Thank-You Note

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