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THE EFFECTIVENESS OF USING GUIDED INQUIRY BASED MODULES WITH CONCEPT CARTOON TO MINIMIZE MISCONCEPTIONS IN BUFFER

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ABSTRACT

Buffer solutions are a chemistry topic that contains many abstract concepts, calculations, and requires a strong grasp of prerequisite material. The use of inappropriate teaching materials can lead to student misconceptions. This study aims to determine the effectiveness of guided inquiry-based module equipped with concept cartoons in minimizing misconceptions regarding buffer material. This study used an experimental method with a 'Randomized Control Group Pretest-Posttest Design.' The research population consisted of 18 classes of eleventh-grade students from three high schools categorized as high (A), medium (B), and low (C) performance in the Karanganyar Regency. The sample consisted of two classes as the control and experimental groups. Data collection used a testing instrument that had been previously validated by experts. The effectiveness of module was analyzed using a t-test. The results showed that the use of a guided inquiry-based module equipped with concept cartoons was effective in minimizing misconceptions about buffer material. The percentages of misconceptions reduction were 71% for students at SMA A, 56% for students at SMA B, and 52% for students at SMA C. This module is a potential tool for remediation in learning. Concept cartoons in this module can help detect and remediate misconceptions through inquiry.

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1. INTRODUCTION

Learning in school will be successful if supported by many factors. Factors that influence this success include motivation, learning methods, and the learning environment. Motivation is the basis for students to achieve maximum learning outcomes. Students will study diligently if they have high motivation to learn. Teachers must make every effort to motivate students to learn. In addition, teaching methods also have a direct impact on the effectiveness of the learning process. Interactive methods have been proven to increase student engagement and deepen their understanding of the material. Teachers need to design methods that allow students to learn through exploration, idea sharing, and collaboration in order to achieve learning objectives. A conducive learning environment also plays a role in achieving learning objectives. Both the physical and social learning environments have a significant influence on student comfort and concentration. The physical environment includes a clean classroom, adequate lighting, and complete learning facilities. Meanwhile, a supportive social environment, where students feel accepted and appreciated, can increase their confidence and involvement in learning (Hasanah et al., 2025; Suratimah et al., 2022). These three factors greatly support the success of chemistry learning. However, based on the interview results, the majority of students have low motivation in learning chemistry because they find it difficult. In addition, teachers still use learning models that do not involve students in the learning process, so students are passive and only listen to the teacher. If they do not understand, students are also afraid to ask questions.

Chemistry is a branch of science that has abstract characteristics, simplifies real-life situations, and is sequential and hierarchical. These characteristics make chemistry one of the most difficult subjects for students to learn. This is in line with the results of questionnaire given to students at three high schools in Karanganyar Regency with high, medium, and low categories, in which 88% of students stated that chemistry was difficult, especially the material on buffers. Buffer material is considered difficult because it consists of abstract concepts, calculations, and requires a strong mastery of prerequisite material such as chemical equilibrium, acid-base theory, and stoichiometry. If students experience difficulties and misconceptions in the prerequisite material, it can have an impact on learning buffer material. In understanding chemistry, three levels of representation are needed, namely the macroscopic level, which can be observed directly by the senses. In buffer solutions, the macroscopic level can be observed in the role of buffer solutions in everyday life. The submicroscopic level refers to phenomena at the molecular, atomic, and ionic levels. At the submicroscopic level, the components of buffer solutions in saliva are explained. Meanwhile, the symbolic level refers to the application of chemical formulas, symbols, and chemical reaction equations in buffer solutions, explaining how buffer solutions work to maintain pH. Most teachers explain at the macroscopic level directly to the symbolic level in chemistry lessons. This will cause students to have difficulty connecting the macroscopic and symbolic levels with the submicroscopic level. Students' inability to connect these three levels of representation will lead to misconceptions because they do not have the opportunity to find out and develop their own ideas at the submicroscopic level (Barke et al., 2009). This is supported by the results of interviews with chemistry teachers in Karanganyar district, who stated that many students had misconceptions about buffer material. Misconceptions occur in almost all buffer concepts. In addition, the average completion rate of students' daily tests on this material is still below 50%. Students' difficulties with buffer solution material are also explained in a study conducted by (Orgill & Sutherland, 2008). Furthermore, several studies explain that many misconceptions are found in this material (Kusumaningrum & Kristyasari, 2022); (Mutlu & Şeşen, 2016); (Cyril, 2015); (Orgill & Sutherland, 2008). Specifically, empirical evidence shows that these misconceptions often involve the neutralization process within the buffer system. For instance, many students mistakenly believe that when a small amount of strong base is added, it reacts with the conjugate base rather than the weak acid (Orgill & Sutherland, 2008). Furthermore, there is a common misconception that the pH of a buffer solution is always neutral (pH 7) or that the pH does not change at all after the addition of a strong acid or base, failing to understand the concept of buffer capacity. These errors stem from a lack of understanding of the dynamic equilibrium at the submicroscopic level."

Many factors influence misconceptions, including: the characteristics of the learning material, personal thinking, learning methods, and teaching materials (Rohmah et al., 2023). The majority of teaching materials used by students in Karanganyar Regency are textbooks.

Based on the results of content analysis, the textbooks used still contain several incomplete or incorrect concepts that can lead to misconceptions. The textbooks used contain general material and questions that students find difficult to understand. In addition to the teaching materials, based on student needs analysis and interviews with teachers, learning about buffer solutions is still teacher-centered on average. Students only listen to the teacher's explanations and read books according to the teacher's instructions without being given the opportunity to construct knowledge. This can be one of the causes of misconceptions in buffer solution material.

Based on the fact that many misconceptions are found in buffer solution material, it is necessary to develop teaching materials that increase student activity, provide opportunities for students to construct knowledge, contain instructions for independent use, and can improve student understanding. In addition, based on the results of interviews with several high school students in Karanganyar Regency, 97% of students stated that they needed teaching materials that were easy to understand, contained instructions for use, related the material being studied to everyday life, and included practice questions and discussions. Teaching materials that meet these criteria are modules. Modules are very useful in learning, namely increasing student motivation, increasing student activity, making learning more meaningful, and improving learning outcomes (Sholeh et al., 2023). In addition, modules also increase student understanding because students can review the material independently and be involved in discovery (Idayanti & Suleman, 2024). Modules can also be used to minimize misconceptions (Safarulli, 2025); (Imaningtyas et al., 2016). Based on the results of this study, the development of modules is considered effective in complementing the teaching and learning process, making it easier for students to understand concepts related to buffer solutions and minimizing misconceptions.

The module should be integrated into a student-centered learning model to increase student activity and provide opportunities for students to construct knowledge. The knowledge constructed by students can improve understanding and remain in their minds longer. Learning can take place more effectively if it begins with observing a phenomenon, formulating a problem, and then students seek and find solutions to the problem so that learning prioritizes the learning process and outcomes, which are part of the development of thinking skills (Abdi, 2014). One learning model that is oriented towards the learning process and outcomes is inquiry (Joyce et al., 2011). However, in this case, the guided inquiry learning model was chosen because the majority of teachers in Karanganyar district rarely or never use inquiry learning, so students need to be guided in formulating problems, developing hypotheses, collecting data, analyzing data, and drawing conclusions. The guided inquiry learning model can improve opinion-forming skills, scientific thinking skills (Acar, 2014), increase learning achievement, reduce anxiety among students who consider chemistry to be a difficult subject (Sarumaha & Harefa, 2022), and reduce misconceptions (Suharto, 2020); Mujiyati, 2020). Modules can be used as a support in guided inquiry learning. The combination of modules and this learning model can maximize learning, increase student activity in knowledge building, and minimize misconceptions

However, modules integrated with the guided inquiry learning model are more optimal in minimizing misconceptions if they are equipped with a misconception diagnosis tool. The diagnostic tools required are not only to detect misconceptions but also to minimize them. The appropriate detection tool is concept cartoons. Concept cartoons are pictorial aids containing ideas related to the material being studied, and they provide a place for students to symbolically describe meaningful situations.

Concept cartoons can increase student activity, stimulate discussion, and bring out ideas from students when solving problems, thereby improving students' understanding of the concepts being studied and eliminating misconceptions (Ergin, 2025; Hizon et al., 2024; Oskay, 2016; Sepeng, 2013; Gafoor & Shilna, 2013). In this study, concept cartoons serve as a crucial bridge to visualize the submicroscopic level, which is often invisible and difficult for students to imagine. By presenting "debates" between characters regarding molecular behavior in a buffer system, these cartoons force students to connect macroscopic observations with submicroscopic explanations and symbolic formulas. Despite the abundance of research on guided inquiry, there is still a gap in the integration of diagnostic tools that can simultaneously trigger cognitive conflict and provide immediate conceptual correction within a module. Most existing modules focus on procedural steps without specifically addressing pre-existing misconceptions through visual debate. This study contributes by filling this gap through the integration of concept cartoons, which serve as a bridge between the students' initial ideas and scientific concepts, providing a more targeted approach to minimizing specific misconceptions in buffer solutions. Guided inquiry-based modules equipped with concept cartoons are expected to minimize misconceptions about buffer solutions. The learning sequence begins with the presentation of problems through concept cartoons so that misconceptions in the material can be detected. Students then develop several problem-solving strategies and explore their knowledge through experiments and other sources to find solutions to the problems. This minimizes misconceptions and improves students' understanding.

Based on the problems identified above, this study aims to address the following research questions:

a. How effective is the development of a guided inquiry-based module equipped with concept cartoons in minimizing students' misconceptions about buffer solutions?
b. Is there a significant difference in the reduction of misconceptions between students using this integrated module compared to those using conventional learning materials?"

2. METHOD

This study used an experimental method with a randomized control group pretest-posttest design, as shown in Table 1.

Table 1. Randomized control group pretest-posttest design

Class	Initial Treatment	Learning	Final Treatment
Experiment	Pre-test	X1	Post-test
Control	Pre-test	X2	Post-test

This study was conducted in three high schools in Karanganyar Regency, categorized as high (A), medium (B), and low (C), with a population of all Grade XI science classes in the three schools, totaling 18 classes. Total of The sample for this study was 180 students consists of two classes selected from six classes in each school with a t-matching test based on the final chemistry scores for the odd semester. One class as the experimental class and was taught using a guided inquiry-based module with concept cartoons, while the other class as the control class and used teaching materials that teachers normally used in their lessons.

Data collection in this study used a test instrument in the form of a two-tier multiple-choice test, which had been previously validated by experts and tested in other classes, then analyzed using Iteman Dos software to determine its validity, reliability, discriminating power, and level of difficulty. The test instrument was used to assess misconceptions.

Before being given the treatment, students in both classes were given a pretest to determine their initial abilities in each class. After being given the treatment, both the experimental and control classes were given a posttest with the same questions. The average data difference between the pretest and posttest scores was then tested for normality, homogeneity and analyzed using a t-test to determine the effectiveness of the guided inquiry-based module with concept cartoons to minimize misconceptions. The effect size determined by Cohen's d.

3. RESULT AND DISCUSSION

3.1. Result

a. Students' Initial and Final Diagnostic Test Results

These diagnostic test results are categorized into four categories, namely Conceptual Understanding, Partial Understanding, misconception, and Not Known. A clearer comparison of student's initial diagnostic test (X1) and final diagnostic test (X2) results at SMA A was presented in Table 2.

Table 2. Comparison of Students' Initial and Final Diagnostic Test Results at SMA A

	Treatment	Average Score (%)	
		Control (C)	Experiment (E)
Conceptual Understanding	X1	41,6	40,1
	X2	73,3	77,1
Partial Understanding	X1	0	0
	X2	0	0
Misconception	X1	37,5	38.0
	X2	21,8	18,3
Not Known	X1	20,9	22,0
	X2	4,9	4,6

Meanwhile, for a clearer picture of the data in Table 4, see Figure 3.

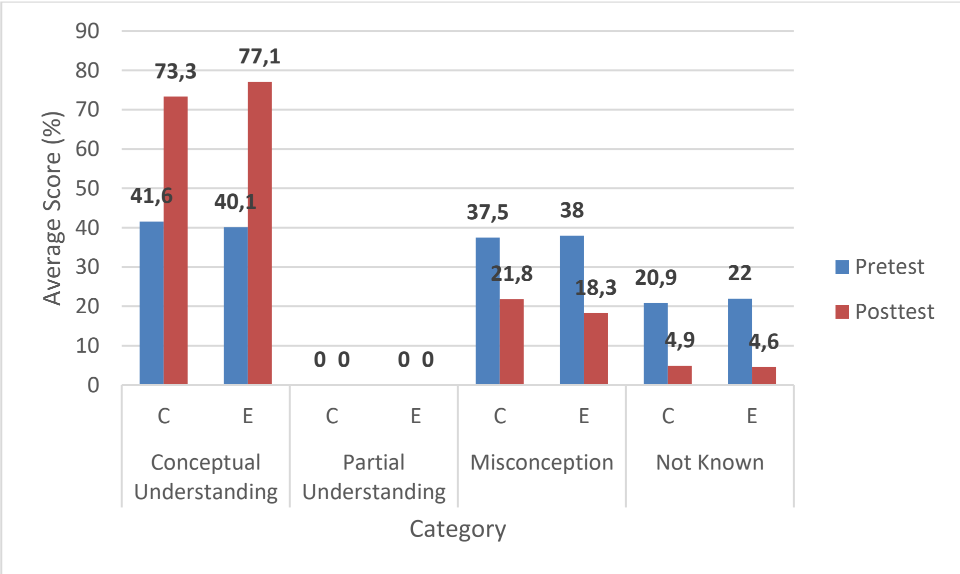

Figure 1. Histogram Comparison of Students' Initial and Final Diagnostic Test Results at SMA A

Based on Figure 1, it can be seen that there was an increase of student conceptual understanding in both the control and experimental classes. In terms of average percentage, the experimental class showed a greater increase than the control class. Meanwhile, in terms of misconceptions, there was a greater reduction in the experimental class than the control class. Furthermore, when viewed from the category of not known, students in the experimental class had a greater percentage decrease compared to the control class. A clearer comparison of the results of the initial diagnostic test (X1) and the final diagnostic test (X2) for student at SMA B was presented in Table 3.

Table 3. Comparison of Students' Initial and Final Diagnostic Test Results at SMA B

	Treatment	Average Score (%)	
		Control (C)	Experiment (E)
Conceptual Understanding	X1	39,7	35,1
	X2	73,6	75,6
Partial Understanding	X1	0	0
	X2	0	0
Misconception	X1	37,9	41,0
	X2	20,8	18,2
Not Known	X1	22,5	35,1

	X2	18,9	23,8

Based on Table 3, students hold an increase of conceptual understanding after the learning process. Judging from the percentage scores, students in the experimental class showed a greater increase than the control class. In addition, students also hold a decrease in misconceptions after the learning process, with the experimental class showed a greater percentage decrease than the control class. Students in the experimental class hold a greater reduction in not known of the material compared to the control class. A clearer picture of the data in Table 3 can be seen in Figure 2.

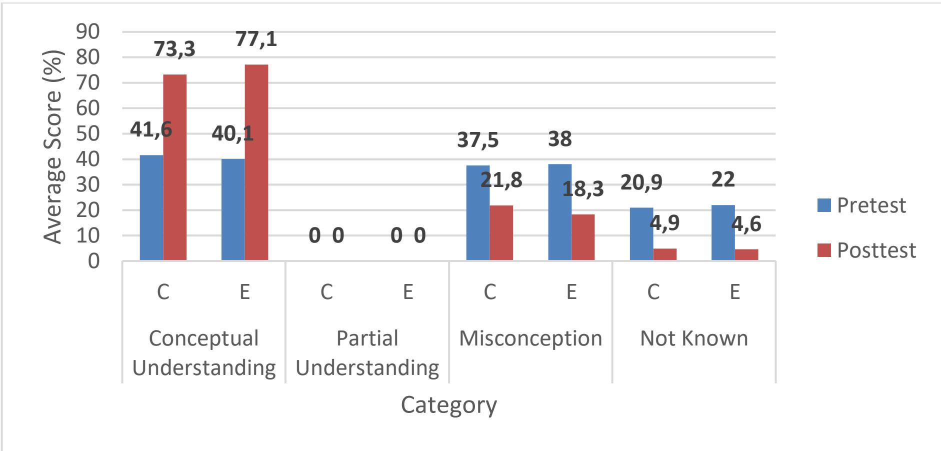

Figure 2. Histogram Comparison of Students' Initial and Final Diagnostic Test Results at SMA B

Meanwhile, the comparison of the initial and final diagnostic test results for student at SMA C can be seen in Table 4.

Table 4. Comparison of Students' Initial and Final Diagnostic Test Results in SMA C

	Treatment	**Average Score (%)**	
		Control (C)	**Experiment (E)**
Conceptual Understanding	X1	41,6	40,1
	X2	73,3	77,1
Partial Understanding	X1	0	0
	X2	0	0
Misconception	X1	37,5	38,0
	X2	21,8	18,3
Not Known	X1	20,9	22,0
	X2	4,9	4,6

Meanwhile, the comparison of the initial and final diagnostic test results for student at SMA C can be seen in Table 4.

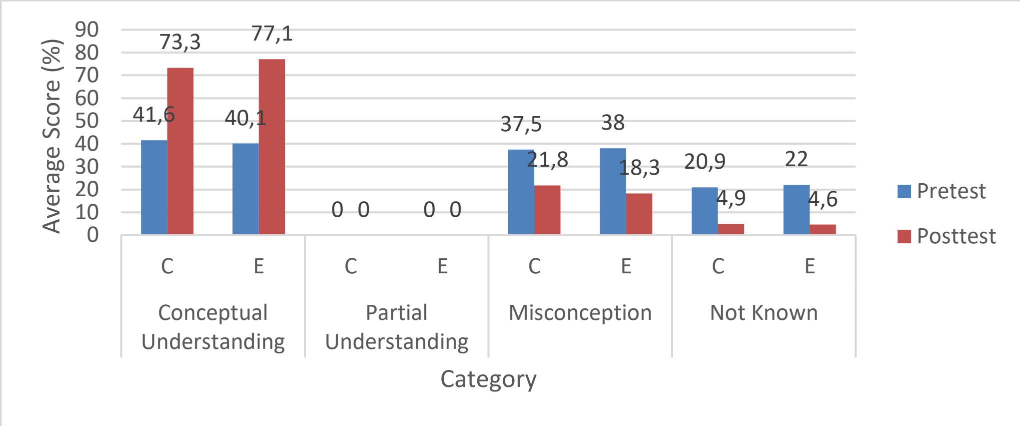

Figure 3. Histogram comparison students' initial and final diagnostic test results at SMA C

Based on Table 4 and Figure 3, there has been an increase of student conceptual understanding, where the average percentage of the experimental class was higher than the control class. As for the category of misconceptions, students hold a decrease in misconceptions, where the experimental class has a higher percentage of decrease than the control class. The category of not know of buffer solution material, showed that the average of the experimental class has a greater decrease percentage than the control class.

The diagnostic test results also showed a decrease in misconceptions for each buffer solution concept, consisting of concept 1, which is the definition of a buffer solution; concept 2, which is the components of a buffer solution; concept 3, which is the working principle of a buffer solution; concept 4, which is the role of a buffer solution; and concept 5, which is the pH calculation of a buffer solution. The decrease of student's misconceptions at SMA A can be seen more clearly in Figure 4.

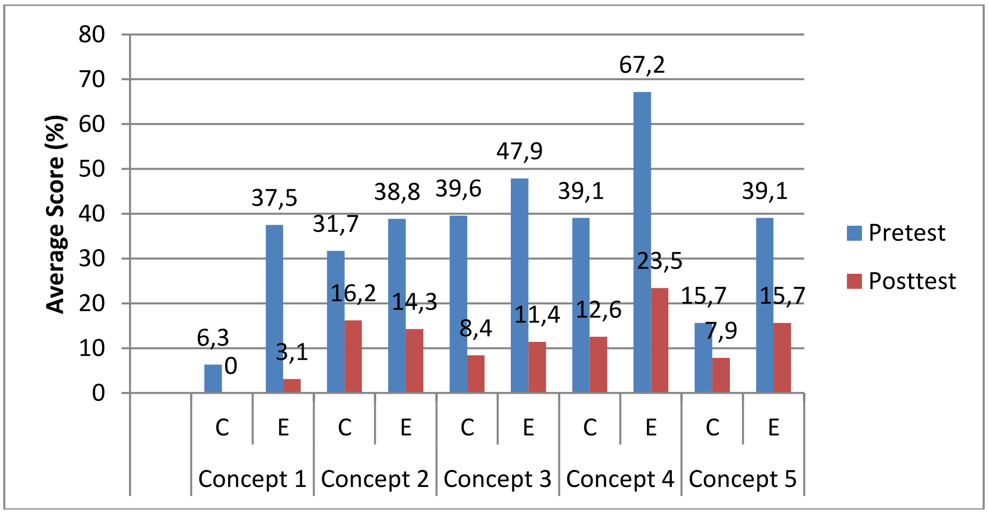

Figure 4. Histogram of the Decrease of Students Misconceptions at SMA A

Based on Figure 4, there was a decrease of misconceptions occur all buffer solution concepts. The greatest decrease in misconceptions for the control and experimental classes was in concept 3, namely the working principle of buffer solutions. Concept 4, namely the role of buffer solutions, also a significant decrease in the experimental class. The decrease of students misconceptions among at SMA B can be seen in Figure 5.

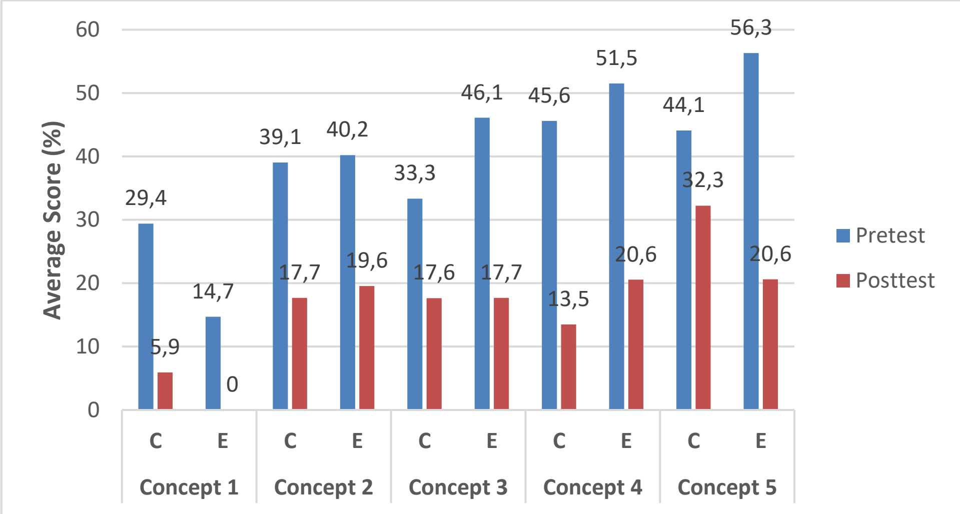

Figure 5. Histogram of the Decrease of Students Misconceptions at SMA B

Based on Figure 5, there was a decrease in misconceptions occur all buffer solution concepts. The greatest decrease of misconceptions for the control and experimental classes was in concept 4, namely the role of buffer solutions. However, concept 3, namely the working principle of buffer solutions, also a significant decrease in the experimental class. The decrease of misconceptions among students at SMA C can be seen in Figure 6.

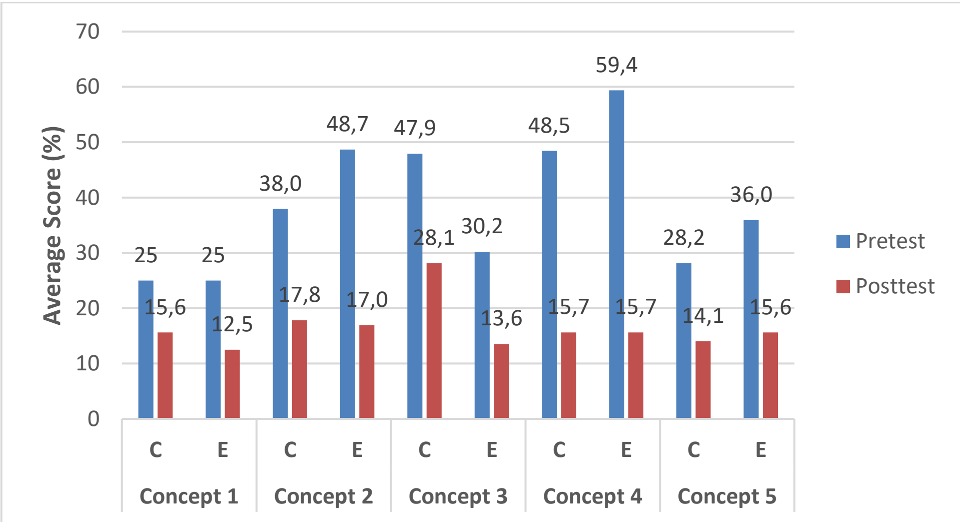

Figure 6. Histogram of the Decrease of Students Misconceptions at SMA C

Based on Figure 6, there has been a decrease of students misconceptions occur in all buffer solution concepts. The greatest decrease of misconceptions for the control and experimental classes was in concept 4, namely the role of buffer solutions.

b. Prerequisite Test Results

Before testing the effectiveness of the module, a prerequisite analysis test was conducted in the form of a normality test and a homogeneity test. The normality test on data SMA A showed a significance of 0.112 for the experimental class and 0.487 for the control class. Because the significance was >0.05, the data was normally distributed. Data SMA B showed a significance of 0.525 for the experimental class and 0.688 for the control class. Because the significance was >0.05, the data was normally distributed. Data SMA C shows a significance of 0.669 for the experimental class and 0.431 for the control class. Since the significance was >0.05, the data was normally distributed.

After conducting the normality test, a homogeneity test was then conducted on both classes in each school. The homogeneity test at SMA A shows a significance of 0.218. Since the significance was >0.05, the population variances was homogeneous. The homogeneity test at SMA B shows a significance of 0.142 because the significance was >0.05, so the population variance was homogeneous. The homogeneity test at SMA C shows a significance of 0.083 because the significance was >0.05, so the population variance was homogeneous.

c. t-test

The t-test results for both classes at SMA A, B, and C showed significance of 0.000; 0.001; 0.001 because the significance was < 0.05, so H_o is rejected, meaning that the average of the experimental class is better than the average of the control class. The effectiveness test results show that the developed module was effective for using in learning.

d. Effect Size

The effect size for both classes at SMA A, B, and C based on the Cohen's d value showed 0,92; 0,79; 0,78. This showed that guided inquiry-based modules equipped with cartoon concepts was effective in minimizing misconceptions, with a High category for SMA A and a Medium category for SMA B and C.

3.2. Discussion

Based on Tables 2, 3, and 4, it can be concluded that the use of guided inquiry-based chemistry modules with concept cartoons significantly improves student learning outcomes and minimizes misconceptions regarding buffer materials. These findings are consistent with research by (Dewi & Mulyani, 2024; Margunayasa et al., 2021; Tsaparlis & Anastasiou, 2015), which found that structured learning modules enhance conceptual understanding. Furthermore, the average decrease in misconceptions for SMA A was 64% in the control class and 71% in the experimental class, for SMA B it was 45% in the control class and 56% in the experimental class, and for SMA C it was 42% in the control class and 52% in the experimental class. That is demonstrates the module's effectiveness compared to control groups.

The integration of concept cartoons within a guided inquiry framework serves as a powerful catalyst for conceptual change. This module works by creating a structured environment for cognitive conflict resolution. The concept cartoons act as the "trigger" by presenting non-scientific views that challenge students' existing mental models. When students encounter a character in a cartoon expressing a common misconception—such as the belief that a buffer's pH is always neutral, they experience cognitive dissonance. The guided inquiry process then provides the necessary scaffolding to resolve this conflict. Instead of receiving passive explanations, students investigate the "debates" within the cartoons through data collection and collaborative discourse. This allows students to correct their misconceptions and actively build scientifically accurate concepts in an interactive environment. As noted in the observations, this process also increased student motivation and engagement, aligning with the results of (Hizon et al., 2024; Yong & Kee, 2017; Naylor & Keogh, 2013; Oskay, 2016; Sepeng, 2013; Webb et al., 2008).

Theoretically, this study reinforces Johnstone's (2000) Triplet Representation. Buffer material is notoriously difficult because students often fail to connect the pH values (symbolic level) with the actual behavior of ions in the solution (sub-microscopic level). Traditional teaching often leaps from macroscopic observations to symbolic calculations, leaving a "gap" in sub-microscopic understanding. This module "forces" a connection between these levels: the concept cartoons visualize the particle behavior (sub-microscopic), while the inquiry process handles the symbolic calculations and macroscopic observations. This multi-level approach is essential for deep conceptual understanding and prevents the formation of "fragmented knowledge" where students can calculate answers but cannot explain the underlying chemical principles.

The findings also suggest that student input influences the rate of conceptual change. The more significant decrease in SMA A (71%) suggests that students with a stronger initial conceptual base are more responsive to cognitive conflict. In contrast, progress in SMA B and C was likely moderated by the need to first establish basic chemical literacy before restructuring deeper misconceptions. While most students understood the concept by the end of the lesson, a small number still retained misconceptions in the diagnostic test. This was primarily observed when students were faced with questions different from those in the cartoons or when they failed to review the module independently. This highlights that while the module is a highly effective remedial and learning tool, its success remains dependent on consistent student engagement and literacy.

4. CONCLUSION

Based on the results of the study, it can be concluded that the use of guided inquiry-based chemistry modules with concept cartoons is effective in minimizing misconceptions based on the results of the t-test analysis, with an average reduction in misconceptions of 71% for students at SMA A, 56% for students at SMA B, and 52% for students at SMA C. The finding that combining guided inquiry and concept cartoon effectively bridges the gap between abstract chemical theories and student's cognitive perceptions. Consequently, this module serves as a vital pedagogical tool within the Merdeka Curriculum, offering a proactive solution for teachers to detect and eliminate misconception early in the learning process. However, the variation in effectiveness in three schools indicates that student readiness and environmental factors may influence the module's success. Future research should, therefore, investigate these external variables and explore the application of this module to other complex chemistry topics to further validate its consistency in fostering conceptual clarity.

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