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The Effect of Chemsketch on STEAM-Based Learning in Improving Critical Thinking Skills on Chemical Bonding Materials

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ABSTRACT

Chemistry learning, especially in Indonesia, has not been able to direct students to master critical thinking skills. Using appropriate media and learning models can improve students' critical thinking skills. One of the efforts to improve critical thinking skills is using Chemsketch media with STEAM-based learning models (Science, Technology, Engineering, Art, Mathematics). This study aims to analyze the effect of using ChemSketch in STEAM-based learning (Science, Technology, Engineering, Art, Mathematics) on improving students' critical thinking skills on chemical bonding material. This study used a Non-equivalent control group design. The population in this study were all grade X students of SMA Negeri 1 Karangwareng in the 2023/2024 school year, with the samples used including one class X-7 as the experimental class and one class X-6 as the control class. The data obtained were then analyzed using the N-Gain and simple linear regression tests. The results showed that: 1) STEAM-based learning significantly increases critical thinking skills with an N-Gain value of 0.66. 2) STEAM-based learning significantly affects critical thinking skills with a value of 0.002. It can be concluded from the results of this study that students in the experimental group experienced a significant increase in critical thinking skills compared to the control group. This indicates that integrating ChemSketch in STEAM-based learning can be an effective strategy to improve students' ability to analyze, evaluate, and solve problems related to chemical bonding.

PENDAHULUAN

Chemistry is the science that explains chemical structures that have a relationship between properties and substances in chemistry. One of the chemistry materials at the high school level is chemical bonding material (Tsuroyya *et al.*, 2022). Chemical bonding is one of the fundamental concepts in chemistry. However, it is very complex because it consists of several types and involves other concepts such as molecules, atoms, protons, neutrons, electrons, ions, cations, anions, opposite charge attraction, and similar charge repulsion (Sitepu & Herlinawati, 2022). According to (Malik, 2019), Chemical Bonding is a material containing abstract chemical concepts. Based on observations at school, it appears that chemistry learning still uses the lecture method. This is a teacher-centered learning method where students only listen to receive material the teacher delivers. So, students need help understanding abstract and complex chemical materials (Rahayu et al., 2022).

Choosing a suitable learning method can improve students' understanding and critical thinking skills. A teacher must be able to determine the right learning model to improve the learning outcomes of chemical bonding material. Therefore, this study applies a STEAM-based learning model. The STEAM learning model can develop the competencies it has to compete in the era of globalization, able to solve problems in everyday life through technology (Amelia & Marini, 2022). According to (Darmadi et al., 2022), STEAM is

learning that combines science, technology, engineering, art, and math. STEAM (Science, Technology, Engineering, Art, and Mathematics) is a learning approach that provides opportunities for students to expand science and science in improving 21st-century skills (Mu'minah, 2020). STEAM is usually used to develop students' ability to think critically and creatively and solve complex problems, as often encountered in real life.

Using this STEAM method, engaging media is needed to increase students' interest in learning chemistry. Therefore, selecting learning media is also essential in improving student understanding; the media used in this study is the Chemsketch application. Chemsketch is a widely used software in the field of chemistry research and education. It helps users create simple and comprehensive models of chemical structures, making it an ideal tool for visualizing complex chemical concepts (Oktariana & Refelita, 2024). The ChemSketch application is a perfect choice for this study, especially in digitally depicting the shape of molecules; this application is a chemical software that is easy to use, flexible, and affordable.

The concept of chemical bonding is very abstract; based on observations at school on chemical bonding, many students need help visualizing or describing the shape of the bond between molecules. The chem sketch application can equip students to convert 2D molecular representations into 3D. The change in representation is to hone students' skills in connecting structures so that they can imagine structures in 3D (Nuranisa et al., 2020). The use of chem sketch applications in chemistry learning can help students understand and make students more interested in the learning process of chemical bonding material.

In 21st-century education, known as the era of the Industrial Revolution 4.0, with the development of digital technology, teachers have the task of developing students' skills (Setiawan et al., 2022). 21st-century skills are the main focus of improving human resources following the development of the 21st century (Prastika et al., 2024). These skills include critical thinking, creative thinking, communication, collaboration, and proficiency in using technology. According to (Halimah et al., 2023), students need skills to compete in the development of the 21st century; one of these skills is critical thinking skills. Specifically, there needs to be more understanding of how teachers can effectively design and implement learning models that simultaneously enhance critical thinking skills and address the challenges of the Industrial Revolution 4.0 era. This gap highlights the need for further studies on innovative teaching approaches that align with the demands of 21st-century learning.

Critical thinking skills are critical in solving problems in everyday life (Mcgill & Bax, 2005). According to (Susilawati et al., 2020), someone with critical thinking skills will be able to think logically, answer problems well, and make rational decisions about what to do or what to believe. It can be concluded that critical thinking skills can solve a problem well. Indicators of critical thinking skills according to Ennis (1985) consist of 5, namely: (1) elementary clarification, or providing explanations which include focusing on questions, analyzing opinions or arguments, question and answer processes to find information to solve a problem; (2) essential support or building students' basic abilities which include source credibility and observation considerations; (3) inference or drawing conclusions which include compiling deduction and induction, considering deduction, induction and completion results; (4) advanced clarification or providing arguments and explanations including identifying and considering definitions and assumptions; (5) strategies and tactics or managing tactics and strategies which include determining actions (Supriyati et al., 2018)

Despite the increasing emphasis on critical thinking skills as essential competencies for 21st-century education, Indonesian students still need more mastery (Kurniawati & Ekayanti, 2020). One of the underlying causes is that classroom learning tends to be monotonous and needs more innovative approaches to engage students effectively (Nida Winarti et al., 2022). While several studies have explored strategies to enhance critical thinking, there is limited research that combines the STEAM (Science, Technology, Engineering, Arts, and

Mathematics) learning model with interactive digital tools like Chemsketch to address this issue, particularly in the context of chemical bonding material. This study introduces a novel approach by integrating the STEAM learning model with Chemsketch media to create an engaging and interactive learning environment. By focusing on chemical bonding material, this research aims to fill the literature gap by evaluating this combination's effectiveness in improving students' critical thinking skills. Chemsketch media provides a unique technological intervention that aligns with 21st-century learning goals, offering new insights into how digital tools can enhance conceptual understanding and critical thinking in chemistry education.

METHODS

Research Design

This research uses a quasi-experimental method with a Non-equivalent control group design. According to Creswell, (2017) Non-equivalent control group design is the most popular approach in quasi experiments, experimental groups and control groups are selected not by randomization.

Tabel 1. Research Design

Kelompok	Pretest	Perlakuan	Posttest
Eksperimen	O_1	X	O_2
Kontrol	O_3	-	O_4

Source: Sugiono, (2017)

Description:
O_1= Pre-test in the experimental class
O_2= Post-test in the experimental class
O_3= Pre-test in control class
O_4 = Post-test in the control class
X = Treatment with STEAM-based learning model and chemsketch media

Research Target

The population in this study was class X students of SMA Negeri 1 Karangwareng as many as 350 students, with samples taken from class X-7 as the experimental class with 30 students and control class data, namely students from class X-6 with 30 students.

Research Data

The method used in this research is a quantitative method that refers to numbers and analysis using statistics (Sugiyono, 2017)

Research Instruments

The instrument used in this study is a test question. This test question amounted to 10 items, this test was conducted at the beginning of learning (pretest) and at the end of learning activities (post test) through wordwall links on chemical bonding material based on critical thinking indicators according to Ennis (1985).

Data Analysis

The data analysis technique used in this research is quantitative data analysis. The data obtained from the answers to the test questions will be processed using a score based on a Likert scale to measure students' understanding in answering questions.Test questions before use: Validation tests were carried out by three validators, namely one validator from lecturers and two other validators from chemistry teachers at school. According to Sugiyono (2017),

"A valid instrument means that the instrument can be used to measure what should be measured." Further analysis is needed to determine how much influence the use of the Chemsketch application has on STEAM-based learning by using a simple linear regression test. According to Sugiyono (2017), simple linear regression is based on the functional or causal relationship of one independent variable (independent) and one dependent variable (dependent).

RESULTS AND DISCUSSION

This study applies a STEAM-based learning model (Science, Technology, Engineering, Art, Mathematics) to the experimental class learning process. STEAM in this study is as follows; 1)Science: Chemical bonding materials in the learning process are ion bonds, covalent bonds, metal bonds, molecular geometry shapes, and chemical bonds in everyday life. 2) Technology: The technology used in learning is word wall media as a tool in delivering Pretest-Posttest, and chemsketch application as a means for making molecular shapes digitally/3D. 3) Engineering: Techniques or strategies in this study are techniques in digitally operating the shape of molecular geometry using the chem sketch application and making accurate molecular shapes using simple tools. 4) Art: Art skills in learners include accurate and 3D molecular geometry shapes. 5)Mathematics: Calculate the number of valence electrons, Lewis structure, etc. Using this STEAM learning model, the Chemsketch application is a medium for making digital molecular shapes.

The data on critical thinking skills used in this study are indicators of critical thinking, according to Ennis (1985). It can be seen from the results of the average value of the experimental class as follows;

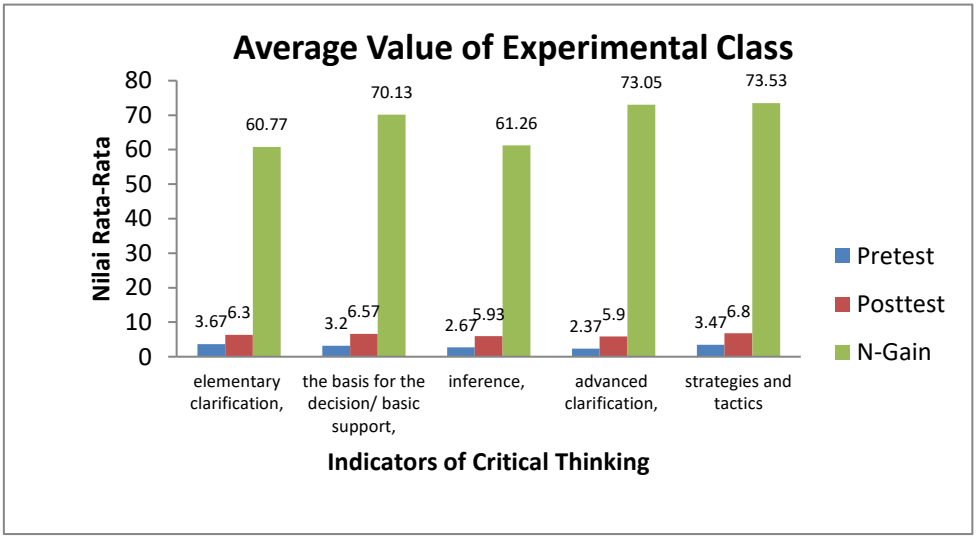


Figure 1. Graph of Average Value of Critical Thinking Skills Indicators in Experimental Classes

Based on the data above, the results show that the average value of critical thinking skills indicators in the experimental class has increased from the posttest value to the pretest. The average posttest value is much higher than the pretest value, the highest average indicator value is in the Strategies and tactics indicator of 6.8 with an N-Gain value of 73.53%.

This study uses a simple linear regression test to determine the effect of Chemsketch on STEAM-based learning in improving critical thinking skills. The results of the experimental class simple regression test using the SPSS application are as follows:

Tabel 2. Simple Regression Test Results Experimental Class

Coefficients[a]					
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std.Error	Beta	T	Sig.
(Constant)	64.218	4.420		14.529	.000
STEAM	.378	.113	.535	3.350	.002

Based on the Regression Test Results in the experimental class, it is known that the Constant (a) value is 64.218 while the regression coefficient (b) is 0.378. So that the regression equation can be written;

$$Y = a + bx$$
$$Y = 64.218 + 0.378x$$

Based on Table 3, the thing value is 3.350 while the table value at freedom (dk) = 30-2 = 27 and a significance level of 5% is 2.04841. Then, the count value is 3.350> Table 2.04841. In addition, it can be seen from the significance of 0.002 <0.05, which means there is a significant effect on the STEAM-based learning model to improve students' critical thinking skills on chemical bonding material.

In addition to the regression test, the N-Gain test was also carried out to determine the use of chem sketch with a STEAM-based model to improve critical thinking skills; it can be seen from the test results as follows;

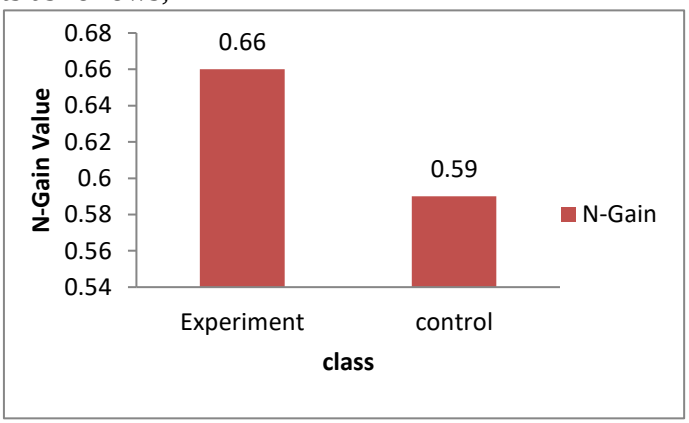


Figure 2. N-Gain Test Results

Based on the table above, it can be concluded that the average increase in creativity in the experimental class and control class reached the medium category with moderate effectiveness. The N-Gain value in the experimental class was 0.66, while the N-Gain value in the control class was 0.59. The improvement in the experimental class was much more significant than the control class's. This aligns with the research of Nurjanah and Purwantoyo (2023). The STEAM-based Project-based learning model effectively improves students' critical thinking and process skills regarding environmental change material. This is reinforced by Nurjanah and Purwantoyo (2023). The STEAM-based Project-based learning model effectively improves students' critical thinking and process skills regarding environmental change material. More detailed data can be seen in the graph below.

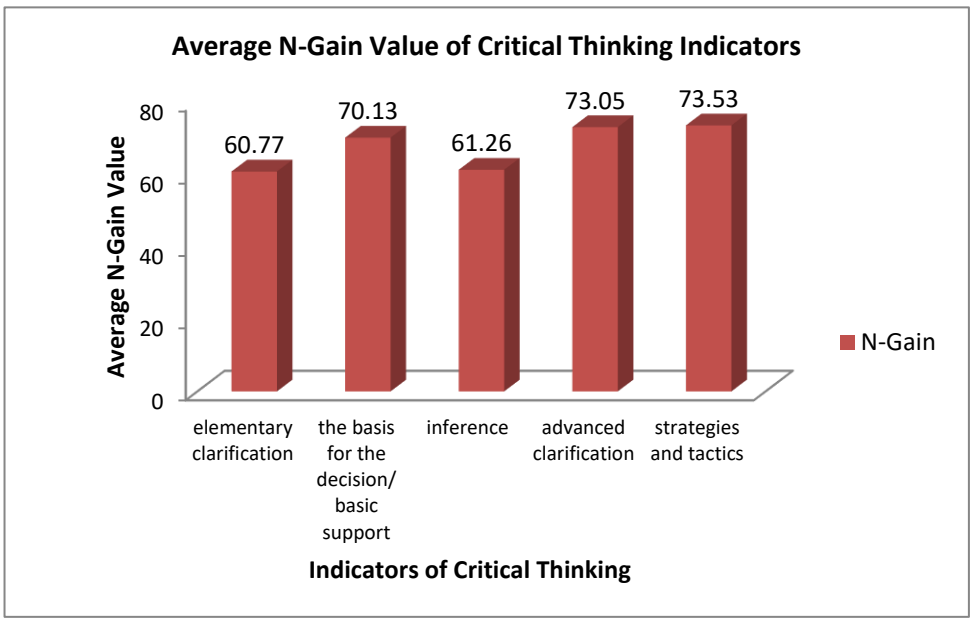
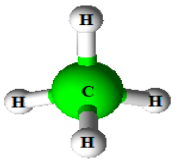
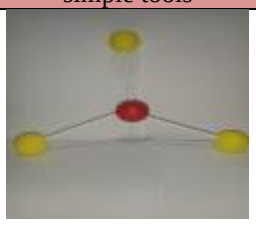
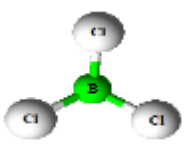
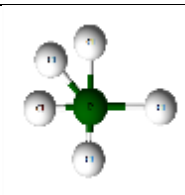
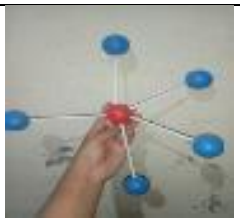
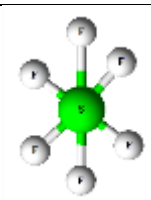


Figure 3. Graph of Average N-Gain of Critical Thinking Indicators

The highest increase was in the indicator of strategies and tactics of initial ability in the control class; the percentage of pretest values was 31.67%, and the experimental class pretest value was 43.33%. With students' low critical thinking skills in strategies and tactics, they have yet to decide on actions to solve a problem regarding organizing strategies and tactics to determine chemical bonds found in everyday life and create the correct chemical structure. However, based on the posttest results on the aspects of strategies and tactics in the control class, the N-Gain value was 71.94, and the experimental class was 73.53; the difference in the N-Gain value of the two classes was 1.59. It can be seen from the posttest results that the increase in critical thinking skills in the control class and experimental class in this aspect, the experimental class experienced a more significant increase. This can be seen in the implementation of learning in experimental classes that use STEAM-based learning models (Science, Technology, Engineering, Art, and Mathematics) in its syntax, namely Evaluate (evaluate) researcher direct students to analyze, evaluate, and conclude their learning outcomes. The following are the results of molecular geometry using the chem sketch application and molecular shapes made using simple tools such as ping pong balls and straws.

Table 3. Results of Students' Molecular Shape Making

Group	ChemSketch	Molecular shapes made using simple tools
Group 1: CH_4		
Group 2: BCl_3		

Group 3: PCl_5		
Group 4: SF_6		

Based on the results of making molecular shapes above between molecular shapes using the Chemsketch application and making molecular shapes using simple tools, students can compare molecular geometry models that students make using simple tools with the results obtained from simulations using the ChemSketch application; students can draw general conclusions about the concept of molecular geometry based on the results of experiments and simulations. It can be concluded from comparing actual (using simple tools) and digital (using ChemSketch) molecular modeling that accurate models help students understand concepts concretely and develop creativity. In contrast, digital models provide higher accuracy and flexibility. So, it can be concluded that the influence on using the STEAM model has a good (positive) influence. As in his research Afifah *et al.* (2019), the use of STEAM-based PjBL learning models can improve students' concept understanding (medium) and improve students' critical thinking skills (high).

CONCLUSIONS AND SUGGESTIONS

From the research and discussion above, it can be concluded that using chem sketch media with a STEAM-based learning model significantly increases critical thinking skills on chemical bonding material, as seen from the N-Gain value of 0.66. This study also had a positive influence, with regression test results of 0.002. So, it can be concluded that using chemistry with STEAM-based learning models to improve critical thinking skills has a positive influence. As for suggestions for further research, it is hoped that it can develop the use of other technologies as a tool in the learning process.

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