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The Effect of Implementing IT-Based Chemistry Teaching Materials on the Chemistry Students' STEM Skills

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Abstract

This study aims to find out the effect of applying IT-based chemistry teaching materials on the chemistry students' STEM reasoning skills. The research sample involved 36 chemistry students with a quasi-experimental pretest-posttest control group design. The STEM reasoning skills were measured using an essay test and analyzed using an independent sample t-test. The findings show that; (1) the application of IT-based chemistry teaching materials has a significant effect on the chemistry students' STEM reasoning skills; and (2) there is a significant difference in the students' STEM reasoning skills between the experimental and control class. The most significant improvement was found in the reasoning evaluation (RE) and reasoning inference (RI) indicators in the experimental class. Thus, applying IT-based chemistry teaching materials can be an alternative solution to improve chemistry students' STEM reasoning skills.

Keywords: IT-Based Chemistry Teaching Materials, STEM Reasoning Skills, Chemistry students

1. Introduction

Developing 21st-century skills requires teachers and students to adapt to technology-based learning sources. These are the main learning demands in the industrial revolution 5.0 era (Wahyudiati & Qurniati, 2023; Ainun et al., 2022). One aspect of the 21st-century skills that chemistry teachers must have is STEM (science, technology, engineering, and mathematics) reasoning skills. Learning resources based on IT (information and technology) in developing STEM reasoning skills are essential to improve students' STEM skills effectively (Verawati et al., 2022; Ramma et al., 2015). However, technology in chemistry learning tends to be used only as a source of information, not as a source of learning or as learning media. It contributes to poor outcomes of chemistry learning objectives, especially STEM reasoning skills and students' critical thinking skills (Hendy & Wahyudiati, 2023; Wahyudiati & Qurniati, 2022).

Enhancing STEM reasoning skills in the current technological development period needs learning innovations that no longer rely on conventional learning but must lead to e-learning systems (Krumsvik, 2012; Verawati et al., 2022). It is expected that classroom learning design no longer uses conventional teaching materials. Therefore, lecturers must prepare IT-based teaching materials through e-learning to keep up with the pace (Kong & Matore, 2022). One is through developing teaching materials integrated with the Google Classroom (GC) or the LMS platform. These would be more practical since students could study anywhere and anytime.

Integrating the google classroom (GC) or the LMS platform could increase students' active involvement in constructing their STEM knowledge and reasoning skills. Students' STEM reasoning skills are an indicator of achieving learning objectives which among the indicators are analytical, inference, evaluation, and decision-making abilities (Ali et al., 2021). However, previous research showed that e-learning-based designs are ineffective in improving students' STEM reasoning skills (Prayogi et al., 2019; Verawati et al., 2022). Moreover, teaching chemistry concepts with a high level of abstraction needs learning materials that could train critical thinking skills. Hence, applying IT-based chemistry teaching materials could help to visualize abstract concepts more factual and contextually (Hendy & Wahyudiati, 2023). In addition, previous research proved that using virtual simulations and IT-based teaching materials in science learning could improve students' problem-solving skills and result in better academic achievement (Ramma et al., 2015; Prayogi et al., 2019).

Implementing an e-learning system through the application of IT-based teaching materials seeks to visualize more concrete materials which can be built in various forms, such as augmented reality-based teaching materials, bandicame applications, gamification, and virtual laboratories (Christiana & Anwar, 2021; Verawati et al., 2022). Based on the explanation above, this research focuses on IT-based chemistry teaching materials by integrating the Canva application through the LMS platform. The advantage of using Canva as a learning resource is that it helps students more easily understand abstract concepts to become more factual and concrete by displaying pictures or explanations in video form so that learning becomes more interesting and meaningful (Erlinawati & Sellan, 2021; Christiana & Anwar, 2021). Moreover, using the LMS platform in e-learning-based learning could enhance students' activeness, independence and critical thinking skills (Prayogi et al., 2019; Verawati et al., 2022).

The novelty of this research is to develop chemistry teaching materials using the Canva application integrated with the LMS platform to improve students' STEM reasoning skills. Not many studies focused on students' STEM skills. Instead, they are concentrating more on cognitive or understanding concepts. Furthermore, studies on the use of technology-based media and teaching materials in learning are primarily directed at measuring cognitive learning outcomes and have not been widely integrated with technological or technological-pedagogical content and technological knowledge (Estevemon et al., 2022; Wahyudiati et al., 2020; Ali et al. al., 2021). Thus, the contribution of this research is expected to positively contribute to IT-based learning, which could foster STEM reasoning skills since it is encouraged to support the learning chemistry goals at the tertiary level.

2. Literature Review

2.1 Characteristics of Chemistry Learning

Chemistry is a science that is obtained and developed based on experiments to answer the questions of what, why and how natural phenomena occur, especially the composition, structure and properties, transformation, dynamics and energetics of material. Chemistry teaches everything about the material and its changes involving skills and reasoning. In studying chemistry, it includes three domains (Chemist's Triangle), including; (1) macro (real); (2) abstract sub-micro; and (3) representasi (Johnstone, 2006).

Another special feature of chemistry is chemical concepts, which are always abstract. Chemical concepts are sequential and rapidly developed and not only about test-solving. The concepts are wide, and the characteristics of each topic are different. Consequently, most students at many levels of education experience difficulties in learning chemistry (Johnstone, 2000; McCarthy and Widanski, 2009). In addition, difficulties in learning chemistry are caused by demands that require students to be able to understand and apply all domains resulting in students experiencing excessive cognitive load (Treagust et al., 2003; Chittleborough and Treagust, 2007).

Likewise, the symbolic nature of chemistry has significant problems for beginners (Marais and Jordaan, 2000; Chittleborough and Treagust, 2007), as does a unique language that may seem unfamiliar (Ver Beek and Louters, 1991). To develop the chemistry concept, a great deal of information must be processed simultaneously. The Johnstone model suggests that the intrinsic cognitive load in chemistry is high not only because of inherent difficulties extending beyond many other learning domains but because the subject demands that participants change ontological categories. As a result, novice chemistry learners are particularly vulnerable to cognitive overload theory (CLT). Cognitive load theory, information processing models, and the chemical conceptual domain are primarily concerned with the cognitive factors involved in learning, including prior chemistry knowledge and academic achievement.

In addition to the cognitive understanding factors that affect chemistry learning, it is also influenced by the wide range of material with a short time allotment. As a result, the lecture method is considered to be the best method applied in the learning process (Anwar, 2018: 20). This creates students' poor motivation and interest in exploring the material (Varghese et al., 2012). Therefore, according to Owoyemi & Olowefa (2013), student achievement in the chemistry curriculum is determined by the quality and competence of available lecturers, material content, availability and adequate laboratory conditions, and a reasonable ratio of lecturers and students.

2.2 IT-Based Chemistry Teaching Materials

Information technology (IT)-based chemistry teaching materials contain a collection of chemistry materials combined with IT to help students describe something abstract, using pictures, photos, charts, and schemes to understand the material comprehensively (Dinatha, 2018). Complex material must be explained simply according to the student's level of thinking to make them understand more easily. Nowadays, students utilize Information and Communication Technology in almost all of their daily activities. Since they are familiar with its application, it is expected that not many obstacles will be encountered to create more significant learning activities.

Learning by using media to convey messages/information, such as IT-based teaching materials, ease students' understanding of the subject matter (Chinn & Silver, 2002). Media is a component of the learning system, that is, the delivery strategy (delivery system). The main focus of the delivery strategy is the selection and use of media (Verawati et al., 2022). The determination of the delivery strategy is based on the results of an analysis of learning resources (including media) or learning constraints (Degeng, 2013). Hence, media assessment will provide a variety of choices in implementing a learning material delivery strategy.

E-learning is a learning activity using information and communication technology in electronic form with computer-based media. E-learning combines text, animation and images; it is audio-visual media using information and communication technology (Hendy & Wahyudiati, 2023; Acesta & Nurmaylany, 2018). The application of e-learning as a medium makes learning more stimulating (Tapia et al., 2018). The implementation of e-learning can utilize a smartphone to be more practical. E-learning has the potential to become a medium of learning that attracts, inspires, motivates, explores and controls students. E-learning was chosen because it has the advantage of presenting more detailed 3D images. In addition, previous research has proven that e-learning is interactive, effective and easy to use.

2.3 STEM Skills

STEM stands for science, technology, engineering and mathematics. The STEM concept integrates four elements, namely technology, mathematics, science, and engineering, to solve life's problems (Utami et al., 2020). Students with STEM skills could develop their problem-solving, communication, and collaboration skills (Krajcik and Delen, 2017). STEM skills have several indicators including: (1) Formulating questions and problems, such as students asking relevant questions and problems, (2) Developing and using models, for example designing their own assignments or projects, (3) Planning and conducting investigations, such as planning an investigation and then carrying out the investigation, (4) Analyzing and interpreting data, by analyzing a problem and then presenting the results obtained by various methods, (5) Using mathematics and information technology; students using their ability to count, such as calculating the costs needed to complete a task or a project, (6) Building explanations and designing solutions by conducting investigations of topics related to real-world problems then designing solutions to overcome these problems, (7) Being engaged in arguments based on evidence; students are actively involved in discussion activities and expressed their opinions in discussions, (8) Evaluating and communicating information; evaluating the performed stages out and then conveyed the results (Aninda et al., 2019). STEM education positively impacts science learning by increasing student activity and motivation (Chittum et al., 2017). STEM education also influences students' attitudes and increases their confidence in learning (Wu, 2018).

3. Materials and Methods

3.1 Research Design

This research was conducted using a nonequivalent quasi-experimental design pretest-posttest control group design. The experimental group was treated using IT-based chemistry teaching materials. In contrast, the control group was taught without using IT-based chemistry teaching materials. This type of research is a quasi-experimental study with a one group pretest posttest design as shown in Table 1.

Table 1: The nonequivalent pretest and posttest control group design.

Group	Pretest	Treatment	Posttest
Experiment	Y_1	R	Y_2
Control	Y_1	X	Y_2

Note:
Y1 = STEM reasoning skills (pretest)
Y2 = STEM reasoning skills (posttest)
R = Learning with the application of IT-based chemistry teaching materials
X = Learning without the application of IT-based chemistry teaching materials

In the research conducted by developing IT-based chemistry teaching materials using the Canva application and applied to the LMS (learning management system) platform with sub-subjects covering: the sub-topics of covalent bonds, ionic bonds, and metallic bonds. It was taught for 7 meetings in the experimental and control classes.

3.2 Research Sample

The research sample involved 36 chemistry students at a university in Mataram. A total of 18 chemistry students (7 males, 11 females) were assigned as the control group, and 18 chemistry students (6 males, 12 females) were assigned as the experimental group using a saturated sampling technique. The entire sample voluntarily participated in the study and was not given incentives.

3.3 Research Instruments

The STEM reasoning skills instrument was an essay test which consisted of 4 indicators, namely reasoning analysis (RA), reasoning inference (RI), reasoning evaluation (RE), and reasoning decision

(RD). Each indicator consisted of two items, so the total number was 8 questions. The highest score for each item as the maximum reasoning skills was +4, and the lowest was 0 (no answer given). Based on the scoring criteria, these were converted into interval equations (Verawati et al., 2022) with interval categories of reasoning skills summarized in Table 2. Reasoning skills were measured based on indicator parameters (RSi).

Table 2: STEM Reasoning Capability Criteria Based on RSi Parameters

STEM Reasoning Capability Criteria	RSi Score Interval
High	RSi > 3.21
Good	2.40 < RSi ≤ 3.21
Fair	1.60 < RSi ≤ 2.40
Less	0.80 < RSi ≤ 1.60
Low	RSi ≤ 0.80

STEM students' reasoning ability data consists of 4 indicators, namely the ability to analyze, conclude, evaluate, and make decisions using description questions which total 8 description questions. The highest score for each item is given a value of +4 and the lowest score is 0 with an example of a question as shown in Table 3.

Table 3: STEM abilities instrument grid & sample questions

No	Indicator	Questions
1	**Reasoning-Analysis (RA)**	In everyday life we often use the following compounds: a. Vinegar Acid b. Sugar c. Nitric Acid d. Hydrochloric Acid Analyze the exact chemical bonds formed in these compounds!
2	**Reasoning-Inference (RI)**	A person makes a sugar solution by dissolving sugar in a water solvent. However, the solution obtained contains floating particles. Try suggesting how to get rid of these impurities!
3	**Reasoning-Evaluation (RE)**	The first beaker contains 200 ml of 0.2 M CH_3COOH solution. The second beaker contains 100 ml of 0.1 M NaOH solution. If Ka CH_3COOH = 10^{-5}. Predict accurately the PH of the solution in beakers 1 and 2, as well as the PH formed when the solutions in beakers 1 and 2 are mixed!
4	**Reasoning-Decision (RD)**	Draw conclusions regarding the most likely chemical bonds between the following elements! a. Phosphorus with chloride b. Hydrogen with chloride c. Natrium with chloride

3.4 Research Data Analysis

The measurement of STEM reasoning ability refers to the RSI indicator and the increase in STEM ability scores uses the n-gain formula (Hake, 1999). Then an independent sample test was carried out to find out that there was a significant effect of the application of IT-based chemicals on the STEM abilities of prospective chemistry teachers with a significance level of 5% ($p < 0.05$). At first, it was preceded by normality and homogeneity tests as prerequisite tests before proceeding to hypothesis testing (independent sample t-test) using the SPSS 24.0 program.

3.5 Research Procedure

Research was carried out in 7 sessions (June-July 2022) and each session comprised 160 minutes. The experiment group was taught with IT-based chemistry teaching materials by means of LMS platform, while the control was taught without IT-based chemistry teaching materials. Teaching for the each of the two groups was held once a week for 160 minutes. This research was conducted in stages as presented in the following Table 4.

Table 4: Research procedure

No	Stages	Activity
1	**Stages of Research Preparation**	Research design Study of literature Observing the school environment Development of IT-based chemistry teaching materials Making STEM reasoning abilities questions
2	**Stages of Research Implementation**	Validate the instrument on STEM reasoning abilities Carry out pretest Application of IT-based chemistry teaching materials in the experimental classes Carry out posttest
3	**Final Stages of Research**	Perform data processing and analysis Make a discussion of research results Making research conclusions

4. Results

The results of the STEM ability analysis of prospective chemistry teachers based on the N-Gain value and the RSI indicator are shown in Table 5.

Table 5: Results of measuring students' STEM reasoning skills

Group	**N**	**Score**	**Reasoning skill indicator**				**RSi average**	**Category**
			RA	**RI**	**RE**	**RD**		
Experimental	18	Pretest	1.13	1.23	1.18	1.15	1.14	Less
		Posttest	3.16	3.32	3.35	3.28	3.21	good
		N-gain	0.71	0.75	0.77	0.75	0.72	High
Control	18	Pretest	1.14	1.2	1.17	1.16	1.13	Less
		Posttest	1.39	1.58	1.49	1.43	1.48	Less
		N-gain	0.09	0.14	0.11	0.1	0.12	Low

Table 5 displays an increase from the pretest score to the posttest score of the chemistry students' STEM skills based on the RSi criteria, both in the experimental and control classes. In the experimental class, there was an increase from the less category to good, while in the control class, there was no increase in those criteria, which remained in the less category. The highest increase was found in the RE and RI indicators for the experimental group. In the control class, the highest increase was in the RI and RE indicators, although they were still in the less category. The average increase in the N-gain RSi score for the experimental class was 0.72 with high criteria and 0.12 for the control class, which was categorized as low. Visualization of the results regarding the RSi parameters in the experimental and control classes is shown in Figures 1 and 2.

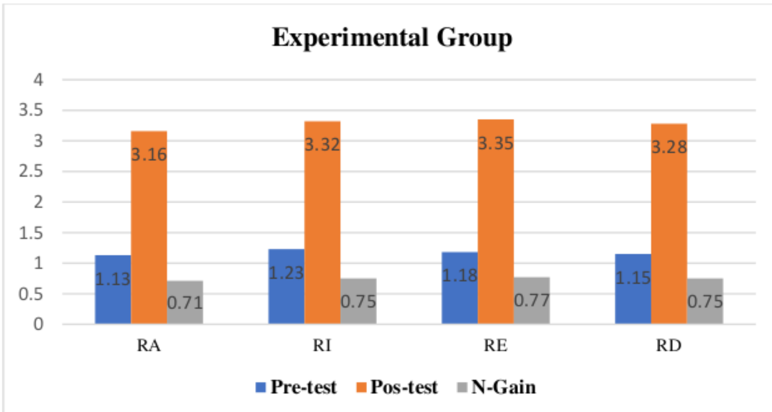

Figure 1: STEM reasoning skills in the Experimental class

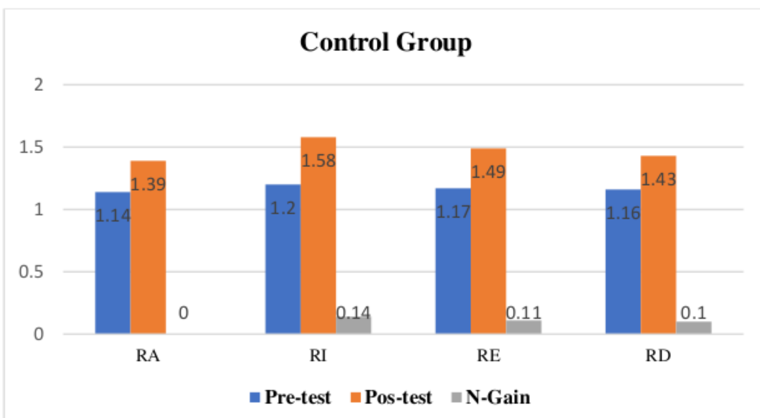

Figure 2: STEM reasoning skills in the Control class

Referring to Figure 2, it is clear that there are differences in the chemistry students' STEM reasoning skills between the two classes. Based on the results of the pretest and posttest showed that the STEM reasoning skills in the experimental class increased from the less to good category. Still, there was no increase in the control group, meaning it remained in the less category. Furthermore, the difference increase in the reasoning skills score between the two groups was tested statistically. It was based on the assumptions of normality and homogeneity as prerequisite tests. Based on the statistical test, the significance value for the homogeneity test was 0.12 (data is homogeneous), and the significance value for the normality test was 0.23 (data is normal), as shown in Table 6. The test results of the independent t-test obtained a sig. <p (0.05), meaning that there is a significant difference in the

STEM reasoning ability of chemistry students through the application of IT-based chemistry teaching materials.

Table 6: Independent t-test results, p <0.05

Value	Students Communicative Skills	t-test		
		t	df	Sig 2 tailed
Standard N-Gain	Equal variances assumed	3.311	34	0.000
	Equal variances not assumed	3.311	33.994	0.000

5. Discussion

Referring to the research results, students' STEM reasoning skills using IT-based chemistry teaching materials integrated with the LMS platform affect chemistry students' STEM reasoning skills. It agrees with previous research findings that virtual simulations improve students' reasoning skills (Verawati et al., 2022). Through visual representation, significant differences occur in student learning outcomes and reasoning abilities (Hakim et al., 2022). Likewise, Hendy & Wahyudiati's (2023) research showed that applying chemistry teaching materials based on the bandicame application significantly impacts students' collaboration and communication on chemical bonding material.

The influence of IT-based chemistry teaching materials application encourages students to be more actively involved in constructing knowledge and increasing academic achievement and STEM reasoning skills. In addition, integrating chemical bonding concepts with students' daily experiences relevant to the chemical bonding material creates more significant learning. This result supports that integrating chemical concepts with students' daily experiences makes learning more engaging and easy to understand, and it improves chemistry learning outcomes (Wahyudiati et al., 2019; Rahmawati & Fikroh, 2022; Ador & Norolyn, 2017). It also agrees with Qurniati (2022) that developing a virtual laboratory can increase students' motivation and chemistry learning outcomes.

This study's findings revealed that chemistry students' STEM reasoning skills were the highest on the reasoning evaluation (RE) and reasoning inference (RI) indicators. It is due to the excess of IT-based chemistry teaching materials to train students' ability to evaluate the correctness of chemical concepts with e-learning-based literature sources. In the end, students must be able to conclude carefully about the important concepts independently through the LMS platform to develop their critical thinking skills. The use of IT teaching materials as visual media is a potential tool to improve students' digital literacy skills and to improve students' higher-order thinking skills (HOTS) (Christiana & Anwar, 2021; Yoon and Lee, 2021; Prayogi et al., 2019).

Another current research finding was a significant difference in the students' STEM reasoning skills between the experimental and control groups. In the experimental group, there was an increase in the students' STEM reasoning ability before being treated from less to good in the category. In the control class, it did not increase; it remained in the less category. There was an increase in the students' STEM reasoning skills in the experimental group because IT-based chemistry teaching materials (canva application) integrated with the LMS platform allowed them to build visual representations during the learning process. It also develops the ability to construct abstract knowledge to become more factual. Therefore, it improves the chemistry students' STEM reasoning skills. Likewise, previous research also proved that the application of IT-based teaching materials and media could train reasoning abilities, analytical skills and problem-solving (Verawati, 2022; Hendy & Wahyudiati, 2022). In add7on, using the Canva application as a visual medium is a potential tool to provide opportunities for students to be actively involved in the learning process and improve students digital literacy and scientific literacy (Anggraeni & Pentury, 2021). Another advantage of implementing IT-based chemistry teaching materials assisted by the LMS platform is to help overcome physical and mental limitations in understanding abstract concepts to realize innovative learning to achieve optimal chemistry learning goals. Thus, applying IT-based chemistry teaching materials could be an alternative to developing chemistry students' STEM reasoning abilities and 21st-century skills.

6. Conclusion

Based on the results of the research, the conclusions are; (1) there is a significant effect of the application of IT-based chemistry teaching materials on the chemistry students' STEM reasoning skills; and (2) there is a significant difference in the chemistry students' STEM reasoning skills the experimental and control classes with the highest improvement found in the reasoning evaluation (RE) and reasoning inference (RI) indicators in the experimental class. It is encouraged to implement IT-based chemistry teaching materials as an alternative solution to improve STEM reasoning skills at the tertiary level.

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