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Effectiveness of PjBL-STEM on Based Chemistry E-Modules on Chemical Reaction Material on the Learning Outcomes of Phase E Students

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Abstract: This research focused on analyzing effectiveness of the PjBL-STEM based on Chemistry E-module on the topic of chemical reactions on the learning outcomes of SMAN 4 Padang E stage students. The type of research used fell into the category of *quasi-experimental research* and used design of a *non-equivalent control group design*. Population consisted of students from Class X E stage, and the sampling was done using the *purposive sampling* method. Class XE4 was selected as the experimental group, and Class XE3 was selected as the control group. The research instrument included tests to measure learning outcomes, and its validity, reliability, difficulty index, and uniqueness were validated. The data were statistically analyzed using test of n-gain, normallity, homogeneity, and hypothesis. Due to the normal distribution and homogeneity of the data, hypothesis testing was performed using t-test. Based on the data obtained, n-gain value of the experimental group was 0.73, which was classified as high, while the n-gain value of the control group was 0.66, which was classified as medium. The results of the hypothesis test showed that the Sig value (2-tailed) was less than 0.05, resulting in the rejection of H_0 and the acceptance of H_1. This indicates that the students of learning outcomes who were instruct chemical reaction materials using PjBL-STEM based chemical electronics module were significantly higher than those of students who didn't use the electronics module in the E phase of SMAN 4 Padang. In conclusion, the use of the PjBL-STEM based chemical electronics module on chemical reaction materials can effectively improve students' learning outcomes.

Keywords: Chemical reactions, E-module, Learning Outcomes, PjBL-STEM.

Penelitian ini difokuskan pada analisis efektivitas E-modul Kimia berbasis PjBL-STEM pada pokok bahasan reaksi kimia terhadap hasil belajar siswa SMAN 4 Padang tahap E. Jenis penelitian yang digunakan termasuk dalam kategori penelitian quasi eksperimen dan menggunakan desain non-equivalent control group design. Populasi penelitian adalah siswa kelas X tahap E dan pengambilan sampel dilakukan dengan metode purposive sampling. Kelas XE4 terpilih sebagai kelompok eksperimen dan kelas XE3 terpilih sebagai kelompok kontrol. Instrumen penelitian berupa tes untuk mengukur hasil belajar dan telah divalidasi, reliabilitas, indeks kesukaran, dan keunikannya. Data dianalisis secara statistik menggunakan uji n-gain, normalitas, homogenitas, dan hipotesis. Karena data berdistribusi normal dan homogen, maka pengujian hipotesis dilakukan dengan menggunakan uji-t. Berdasarkan data yang diperoleh, nilai n-gain kelompok eksperimen sebesar 0,73 yang tergolong tinggi, sedangkan nilai n-gain

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kelompok kontrol sebesar 0,66 yang tergolong sedang. Hasil uji hipotesis menunjukkan nilai Sig (2-tailed) lebih kecil dari 0,05 sehingga H0 ditolak dan H1 diterima. Hal ini menunjukkan bahwa hasil belajar siswa yang diajar materi reaksi kimia menggunakan modul elektronika kimia berbasis PjBL-STEM secara signifikan lebih tinggi daripada hasil belajar siswa yang tidak menggunakan modul elektronika pada fase E di SMAN 4 Padang. Dengan demikian, penggunaan modul elektronika kimia berbasis PjBL-STEM pada materi reaksi kimia secara efektif dapat meningkatkan hasil belajar siswa.

Kata Kunci: Reaksi kimia, E-modul, Hasil Pembelajaran, PjBL-STEM.

Introduction

Chemistry is an important subject studied at the secondary level (SMA/SMK/MA). One of the topics covered in the E-Stage or X Grade SMA is chemical reactions in order to meet the current requirements of the independent curriculum. Students investigate the properties, types, changes/reactions, and energy associated with chemical reactions, as well as how these relate to the macroscopic, submicroscopic, and symbolic levels of chemical representation (Yustiqvar et al., 2019). They also observe the changes that take place in matter. By integrating the key concepts when studying chemical reactions and representing then using chemical equations, the aim is to provide students with a better understanding of the material. However, students' activities in the learning process are often passive and lack creativity in learning and problem solving, causing them to become more focused listeners. The reasons for this are lack of interest, monotonous approach, and difficulty in understanding the material. This provides an opportunity for teachers to teach more actively through the lecture method, thereby achieving teacher-centered learning (Ardiansyah & Azhar, 2022). Ideally, the role of the teacher should be a facilitator of actual learning, providing guidance and allowing students the freedom to independently discover the concepts to be learned (Smitha, 2012). Therefore, students do not receive adequate guidance in these areas (Sari et al., 2018).

According to a survey of students and teachers at a public school in Padang City, many students believe that chemistry is a subject that is often considered complex and difficult to learn. One of the topics in the E-term chemistry course this semester is chemical reactions. The students' learning style is still mainly lecture-based, and about 62.6% of students find it difficult to learn the material due to the abstract nature of many chemical formulas. The study of (Suryani et al., 2018) showed that the modules focused more on students' activities during the learning process, which enabled students to participate more actively in the learning process and organize their knowledge more effectively. Previous studies have shown that using modules such as buffer solutions in chemistry education can effectively improve students' learning outcomes (Yerimadesi et al., 2017). Other studies have also found that students' learning outcomes can be improved by using chemical equilibrium modules (Said & Yerimadesi, 2021), and that modules can effectively improve critical thinking skills in redox and electrochemistry topics with very high categories (Bayharti et al., 2019). In today's era, technology is increasingly being used in all aspects of daily life, including education (Utami, et al., 2024). One of the applications of technology in education is the use of electronic modules or e-modules as learning resources in the educational process.

E-module development aims to create digital modules whose main advantages are the integration of various elements such as images, videos, audio, text and animation or a combination of these elements (text and images) and the provision of comprehensive digital content with tests or simulations to support the learning process. E-modules are designed to promote independence and active participation of students (Herawati & Muhtadi, 2018). They can be accessed through smartphones, laptops and computers, anytime and anywhere. The use of e-modules has been shown to be effective in improving students' chemistry learning outcomes, for example in the analysis of electrolyte and non-electrolyte solutions, very good results were achieved based on students' experience (Kristalia & Yerimadesi, 2021). Other studies have also shown that hydrocarbon e-modules can effectively improve students' academic performance (Fitriyanti & Yerimadesi, 2023). Similar results were observed in previous studies of acid-base materials (Alvi & Yerimadesi, 2022) and acid-base titration Rahmi & Yerimadesi 2022). In order to support students' activities in the learning process, a teaching model that enhances understanding is needed, such as: *Project based learning* model (PjBL) using the STEM approach (*Mathematics*, *Computer Science*, *Natural Science* and *Technology*). Previous studies have developed a chemical electronic module based on PjBL-STEM for chemical reactions, but its effectiveness has not been tested (Silvanny & Yerimadesi, 2023).

Project Based Learning (PjBL) emphasizes using a project centered model as the core of the Merdeka Curriculum (Syafe'i & Effendi, 2020). In PjBL, the learning process involves long- term activities where all students are engaged in designing, producing, and presenting their work to solve real world problems. This model helps students develop their abilities by exploring their skills, improving the quality of their outcomes, and building confidence and independence as they explore and deepen their understanding of the projects they design (Farihatun & Rusdarti, 2019). PjBL can also be combined with a STEM (*Science*, *Technology*, *Engineering*, and *Mathematics*) approach to guide students research, discussion, collaboration, creativity, and critical thinking skills. Integrating PjBL with the STEM approach offers various benefits, as demonstrated in research (Ma'wa et al., 2022). These benefits include encouraging students to conduct in depth investigations to solve problems, thereby enhancing their critical thinking skills. Additionally, the STEM approach stimulates creativity by involving students in the planning and revision of their final outcomes.

Effectiveness may be characterized by the student's level of learning accomplishment, where can be affected by multiple variables, including the instructional materials provided by e-modules. Research shows that e-modules are digital resources that incorporate images, text, animations, or a combination of these elements, featuring digital content along with tests or simulations for use in the learning process (Herawati & Muhtadi, 2018). This issue often arises because students engage in passive learning activities, such as simply listening, resulting in a lack of interest and difficulty in grasping the material.

Based on the review of previous studies, the chemical reaction material has been developed into a chemistry e-module using the PjBL-STEM approach. This e-module has been validated and proven practical, but its effectiveness has yet to be tested. Without testing its impact on student learning outcomes, the e-module cannot be widely distributed. Consequently, further research is necessary to evaluate the effectiveness of the PjBL-STEM based chemistry e-module on chemical reaction material concerning the learning outcomes of Phase E students at SMAN 4 Padang.

Method

This research used a *non-equivalent control group* d*esign*, which is a type of quasi-experimental research. The study was conducted at SMAN 4 Padang during the even semester of the 2023–2024 academic year. Students in Phase E of Class X were included in the population, and the sample was chosen via purposive sampling. This meant that class XE4 was the experimental group and class XE3 was the control group. While the control group used the school's pre-existing teaching resources, the experimental group received instruction on chemical processes utilizing the PjBL-STEM-based chemistry e-module.

There were twenty questions total in the written test, which consisted of five multiple-choice single-choice questions, four difficult multiple-choice questions, three matching questions, four true/false questions, and four essay questions. This written exam was suitable for use as a research tool since it satisfies the criteria for validity, reliability, discrimination index, and difficulty index (Latisma, 2011). Before beginning the learning process, both example classes took a pretest, and then they took a posttest. Following data collection, the learning results were examined using n-gain analysis, homogeneity tests, normality tests, and independent t-test for hypothesis testing.

Result and Discussion

The effectiveness of the PjBL-STEM based e-module centered on chemical reaction material was analyzed, leading to findings derived from data analysis on two sample classes, XE3 and XE4. In this study, XE3 served as the control class, while XE4 was designated as the experimental class. The research revealed the students' learning outcomes.

The assessment of student learning outcomes in the two sample classes was conducted using pretest and posttest scores, which represent cognitive domain learning outcomes. In this study, pretests and posttests were administered to the sample classes, with XE4 serving as the experimental class and XE3 as the control class. The pretest was conducted before the start of the chemical reaction lessons, while the posttest was administered afterward. To evaluate the learning outcomes, an n-gain test was used to specify the effectiveness of the PjBL-STEM based chemistry e-module on the chemical reaction material. The n-gain test results for both the experimental and control classes, based on the pretest and posttest scores, are presented in Table 1.

Table 1. Test Results of N-Gain for Sample Classes

Class	**N**	**Average**			**Category**
		Pretest	***Posttest***	**N-gain**	
Experiment	36	36,33	82,64	0,73	High
Control	36	39,42	79,11	0,66	Medium

The average of n-gain values for two sample classes XE4 being the experimental class and XE3 being the control class were determined using the technique shown in Table 1. Based on the pretest and posttest findings for the students in both classrooms, the experimental class had an average posttest score of 82.64, which was higher than the control class's average posttest score of 79.11. Following the determination of the average scores on the pretest and posttest, additional analysis showed that the experimental class had an average n-gain of 0.73, which was categorized as high, while the control class had an average n-gain of 0.66, which was classed as medium.

The n-gain in the experimental class was more than in the control class, according to the data, proving that using the PjBL-STEM based chemistry e-module on chemical processes enhances students' learning outcomes considerably. Statistical tests were performed to validate the efficacy of the e-module, and conclusions were derived from the outcomes of hypothesis testing. The data were examined using homogeneity and normality tests before being subjected to hypothesis testing. Table 2 displays the findings of the normalcy test.

Table 2. Test Results of Normality for Sample Classes

Class	α	(sig)	Status
Experimental	0,05	0,200	Normally
Control		0,200	distributed data

Table 2's analysis reveals that the experimental and control sample classes' normality test results show a significance (sig) value of 0.200, which is larger than the 0.05 threshold. This implies that both classes' worth of data have a normal distribution. Once the normal distribution of the data has been established, a homogeneity test must be conducted. To make sure there are no notable variations or heterogeneity between the samples in the experimental and control classes, this test is carried out. Table 3 displays the findings of the homogeneity test.

Table 3. Test Results of Homogeneity for Sample Classes

Class	α	(sig)	Status
Experiment	0,05	0,107	Homogeneous
Control			variance

Table 3 showing the test of homogeneity findings. For both the experimental and control classes, the significance (sig) value is 0.107. This suggests that there is homogeneity in the variances between the two sample classes. The next step is to use the independent t-test for hypothesis testing now that it has been shown that the data are normally distributed and that the variances are homogenous.

Table 4. Test Results of Hypothesis for Sample Classes

Class	Sig. (2-tailed)	Status
Experiment	0,00	H_0 rejected and H_1
Control		accepted

The hypothesis test findings for the sample classes, comprising the experimental and control groups, show a significance (2-tailed) value of 0.00 based on the analysis in Table 4. Since this result is less than 0.05, the alternative hypothesis (H_1) is accepted and the null hypothesis (H_0) is rejected. Accepting H_1 means that, compared to the control class, which did not use the e-module, students in the experimental class which utilized the PjBL-STEM-based chemistry e-module saw a considerably better increase in their learning outcomes. Thus, it can be said that the PjBL-STEM based chemical processes e-module at SMAN 4 Padang is useful for improving the learning objectives of Phase E pupils.

The e-module has proven to be effective in the learning process, as it significantly enhances the learning outcomes of students who use it. Previous studies support this finding, indicating that e-modules on topics such as electrolytes and non-electrolytes also improve student learning outcomes (Kristalia & Yerimadesi, 2021). E-modules are known to boost student learning independence, often categorized as high, and can positively influence learning outcomes, even if initially low(Linda* et al., 2021). They also contribute to increased student motivation and learning completion (Zaharah & Susilowati, 2020). The application of the PjBL-STEM based chemistry e-module led to higher learning outcomes in the XE4 experimental class compared to the XE3 control class, demonstrating its effectiveness in enhancing student learning outcomes. Thus, the PjBL-STEM based chemistry e-module is a valuable and supportive teaching resource in the educational process.

Applying the PjBL-STEM model can enhance the learning experience by making it enjoyable and engaging for students. It provides memorable experiences that boost students' motivation and interest in learning (Afifah et al., 2019). PjBL positively impacts students' critical and creative thinking abilities, improves their study habits, and fosters original problemsolving approaches.

In the PjBL model, the teacher's role involves guiding students through various stages of project activities. According to (Riyanti, 2020), these stages include: 1) formulating essential questions; 2) designing the project plan; 3) creating a schedule; 4) monitoring student progress; 5) evaluating the results; and 6) assessing the outcomes. This approach aligns with the teacher's role as a facilitator, who provides guidance while allowing students the freedom to explore and understand concepts independently (Smitha, 2012). To qualify as true PjBL, project-based learning activities must meet specific criteria, including the use of guiding questions, centrality to the curriculum, constructivist inquiry, student autonomy, and real-world relevance (Erlinawati et al., 2019). Additionally, students may see improvements in their skills, critical thinking, creativity, analytical abilities, and higher order thinking skills (Purwaningsih et al., 2020).

Project Based Learning (PjBL) enhanced by STEM approaches can significantly boost educational effectiveness by fostering meaningful learning experiences and preparing students for future careers. It achieves this by allowing students to tackle real-world problems through hands on activities in the classroom (Tseng et al., 2013) . This method also helps in developing students' character by enabling them to grasp scientific concepts (*science*) and apply their skills (*technology*). They can then design solutions (*engineering*) and analyze data mathematically (*math*), which can simplify tasks compared to previous methods (Triana et al., 2020). This approach supports the learning theory that emphasizes the importance of students constructing and developing their own understanding from the material they have studied (Saputro, M.N.A, & Pakpahan, 2021).

It has been demonstrated that using e-modules in the classroom improves learning outcomes and increases student comprehension. Comparing the XE4 experimental class, which utilized the PjBL-STEM based chemistry e-module, to the XE3 control class, which did not use the e-module, shows that the learning results in the former were better. Consequently, the PjBL-STEM based chemistry e-module can be a valuable resource for future chemistry instruction. Previous research supports this, indicating that STEM-PjBL based e-modules effectively improve student learning outcomes, as reflected by high n-gain scores (Agung et al., 2022). Other studies have also found that PjBL e-modules are effective, with significant improvements between pretest and posttest results (Laili et al., 2019). Moreover, e-modules can encourage innovative, critical, and creative learning, with the teacher serving as a motivator and facilitator throughout the process (Padwa & Erdi, 2021).

By effectively implementing PjBL-STEM based chemistry e-modules, it is anticipated that student learning outcomes will show more substantial improvement in the future. Thus, the findings of this study offer a viable alternative for future educational practices by integrating the PjBL model with the STEM approach. This strategy aims to facilitate a faster and more comprehensive understanding of the material, while utilizing e-modules as a tool to boost student engagement and enhance the overall effectiveness of learning.

Conclusion

Based on the analysis of previous research and the data collected, it can be concluded that the PjBL-STEM based chemistry e-modules significantly enhance learning outcomes for Phase E students at SMAN 4 Padang. The results show that students in the XE4 class, which used the PjBL-STEM-based e-modules, achieved notably higher learning outcomes compared to students in the XE3 class, the control group, who did not use the e-modules.

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