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# Effectiveness of E-Modules Based Learning on Project Based Learning in Chemistry Learning: A Meta-analysis

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**Abstract:** This study aims to determine the effectiveness of Project-Based Learning-based E-modules in Chemistry Learning. This type of research is quantitative research with a meta-analysis method. The inclusion criteria in this study are the research was obtained through the google scholar database; Mendeley, ScienceDirect and ERIC, the research must be indexed by SINTA, Web of Science or Scopus, the research topic must be relevant, the research must be published in 2021-2024, the research must have a value of (r), (t) or (f), the research must have N ≥ 25. The data analysis technique in this study is with the help of the JSAP application version 0.16.3. The results of this study concluded that (a) the 19 studies analyzed were heterogeneous and normal, there was a significant influence of project-based learning-based e-modules with strong categories ($p < 0.05$; rRE= 1.06); and in this study, there is no publication bias. These findings show that there is a positive influence of project-based learning-based E-Module learning in chemistry learning.

**Keywords:** Chemistry Learning; E-module; Effect Size; Project Based Learning

## Introduction

Chemistry plays an important role in various fields of science and technology (Demelash et al., 2024); (Ali et al., 2024; Syafruddin et al., 2024). In biology, chemistry helps to understand the structure and function of biological molecules, such as proteins and DNA, which are essential for understanding biological processes and developing medical therapies. In science, chemistry helps understand the physical and chemical properties of materials, such as electrical and thermal conductivity properties, which are essential for developing technologies such as batteries and refrigeration systems (Ozkan, 2023); Dewi et al., 2021; Santosa et al., 2022; Syafruddin et al., 2024; Utomo et al., 2023). In addition, chemistry helps develop a variety of products, such as pharmaceuticals, building materials, and synthetic chemicals. Furthermore, chemistry also helps to develop stronger and more durable building materials, as well as synthetic chemicals used in various industrial applications (Setemen et al., 2023; Demelash et al., 2023). Overall, chemistry plays a crucial role in understanding and developing technologies that provide great benefits in chemistry learning (Irdalisa et al., 2024a; Oktarina et al., 2021; Zulyusri et al., 2023).

Effective chemistry learning is essential to improve students' understanding and skills because chemistry is the underlying science of many natural and technological phenomena (Sulisetijono et al., 2023). A good understanding of chemical concepts allows students to apply such knowledge in everyday life, such as understanding chemical reactions in cooking, keeping the house clean, or even understanding environmental issues such as pollution and climate change (Sulisetijono et al., 2023); . With effective learning methods, students can develop their analytical and critical abilities, thereby being able to solve problems scientifically and make better decisions based on evidence (Rahman et al., 2023). Furthermore, effective chemistry learning also helps improve students' skills in critical and analytical thinking. In chemistry, students must be able to analyze

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data, make hypotheses, and solve problems(Kiliç, 2022; Sulaiman et al., 2023). Therefore, teachers must assign tasks that require students to think critically and analytically, such as analyzing experimental data or making reports on chemical processes(Utomo et al., 2023; Oktarina et al., 2021). Thus, students can improve their ability to think critically and analytically, as well as improve their ability to analyze and solve chemistry problems (Klinhom & Wuttphan, 2022). Thus, students can become reliable chemists and are ready to face challenges in the field of chemistry.

The main problem in learning chemistry students often lies in the lack of understanding of basic concepts and low student involvement in the learning process (Lukitasari et al., 2021); (Luo et al., 2024). Many students find it difficult to abstract chemical concepts, such as atomic structure, chemical bonds, and chemical reactions, which are often taught theoretically without a clear practical application (Siew & Chai, 2024). The lack of adequate laboratory facilities and opportunities to conduct experiments also limits students' ability to understand concepts in depth and develop practical skills (Ozkan, 2023); (Muzana et al., 2021). In addition, less interactive and invaried teaching methods can make students bored quickly and less motivated to learn, so they cannot reach their full potential in understanding and applying chemistry(Asih et al., 2022). In addition, there is a lack of teaching materials used by teachers in the chemistry learning process. One of the solutions is the need for an E-module that can help students' chemistry learning activities (Nurtamam et al., 2023).

E-Module is an innovation in the world of education that presents learning materials digitally, making it easier to access and interact for students and teachers(Maksum & Purwanto, 2022; Ichsan et al., 2023). With E-Modules, subject matter can be presented in a more interactive manner through the use of multimedia such as videos, animations, and simulations that clarify concepts that are difficult to understand (Luo et al., 2024). The flexibility of the E-Module allows students to learn at their own pace and repeat the material as needed, improving comprehension and retention of information (Sulaiman et al., 2023). In addition, E-Modules can be accessed anytime and anywhere, making them a very effective tool in supporting distance learning or blended learning (Kuit & Osman, 2021). With the integration of automatic evaluation and feedback features, E-Module also helps teachers monitor student progress and provide more targeted guidance.

The chemistry E-Module has become an effective means of improving the quality of chemistry learning at various levels of education(Maksum & Purwanto, 2022; Pitorini et al., 2024). By using interactive technology, e-modules can help students understand chemistry concepts more effectively through simulations, animations, and learning videos. In the e-module, students can actively participate in learning activities, such as data analysis, hypothesis making, and problem-solving, thereby improving their critical and analytical thinking skills (Saraswati et al., 2019). Thus, e-modules help improve the quality of chemistry education and improve students' ability to analyze and solve chemical problems (Anggrella & Sudrajat, 2024; Hariyadi et al., 2023; Hikmawati et al., 2020; Wulandari & Yl, 2023; Ali et al., 2024).

Furthermore, the chemistry learning E-module can be linked to the project-based learning model. Project Based Learning (PBL) is an innovative learning approach that emphasizes student involvement in real and meaningful projects as a means to develop their understanding and skills(Shiyamsyah et al., 2024; (Sudarmin et al., 2023); Kiong et al., 2022). In PBL, students not only learn about theory, but also apply that knowledge to solve problems or create products that are relevant to real life. This method encourages collaboration, critical thinking, and creativity, as students work in teams to design, implement, and evaluate their projects (Yang et al., 2024). In addition, PBL strengthens communication and time management skills, as students must present the results of their projects and organize workflows effectively. By facing real-world challenges, PBL prepares students to become competent and innovative problem solvers of the future (Irdalisa et al., 2024b ; Santosa et al., 2023).

Previous research by project-based e-modules based learning has been effectively applied in chemistry learning (Ardiansyah et al., 2023; Irdalisa et al., 2024). Research by (Agustin et al., 2023) said that the implementation of project-based learning E-modules can improve student learning outcomes. Research by Wijayanto et al., (2023) Project-based learning e-modules are effective in improving students' higher-level thinking skills. The gap in this research is that there are many studies related to project-based learning-based E-modules, and there has been no research related to the effect size of project-based learning-based E-modules in chemistry learning. Therefore, this study aims to determine the effectiveness of Project-Based Learning-based E-modules in Chemistry Learning through the use of meta-analysis.

## Method

*Research Design*

This research is a type of meta-analysis research. Meta-analysis is a research approach that analyzes primary studies quantitatively to obtain in-depth and accurate conclusions (Kahraman, 2023; Öztop, 2023; Putra et al., 2023; Zulkifli et al., 2022; Santosa et al., 2022).

Furthermore, through meta-analysis, the strengths and weaknesses of an analyzed study can be known. This meta-analysis aims to determine the effectiveness of project-based learning-based e-modules in chemistry learning.

*Eligibility Criteria*

The eligibility criteria in this meta-analysis are (a) the research was obtained through the google scholar database; Mendeley, ScienceDirect and ERIC, (b) the research must be indexed by SINTA, Web of Science or Scopus, (c) the research topic must be relevant, (d) the research must be published in 2021-2024, (e) the research must have a value of (r), (t) or (f), (f) the research must have N ≥ 25. The data selection process through the PRISMA method consists of identification, screening; eligibility and included. In the selection of data, 19 relevant studies were obtained which can be seen in Table 1.

**Tabel 1**. 19 Research included in Meta-analysis

| Kode Jurnal | N | r | t | F | Sample |
|---|---|---|---|---|---|
| PL1 | 34 | 0.61 | | | SMA |
| PL2 | 68 | | 11.081 | | SMA |
| PL3 | 120 | | 5.062 | | SMA |
| PL4 | 100 | 0.91 | | | College |
| PL5 | 80 | 0.54 | | | College |
| PL6 | 36 | | 8.00 | | SMA |
| PL7 | 20 | 0.87 | | | SMA |
| PL8 | 48 | | | 114.07 | SMA |
| PL9 | 36 | 0.78 | | | SMA |
| PL10 | 178 | 0.61 | | | College |
| PL11 | 50 | | 2.84 | | College |
| PL12 | 80 | | 3.67 | | SMA |
| PL13 | 39 | 0.50 | | | College |
| PL14 | 110 | | | 9.96 | SMA |
| PL15 | 90 | 0.96 | | | SMA |
| PL16 | 66 | 0.82 | | | SMA |
| PL17 | 64 | 0.43 | | | College |
| PL18 | 48 | | 3.71 | | SMA |
| PL19 | 36 | | 2.874 | | SMA |

*Researh Prosedure*

The research procedure in this meta-analysis is a) searching for articles according to the research topic; b) select articles that meet the inclusion criteria; c) perform data coding; d) change the value of F to t and r, or the value of t to r; f) conducting data normality tests; g) conducting data heterogeneity tests; h) calculate the average value of effect size and standard error; i) calculation of the summary effect size value; j) checking publication bias through funnel plots; Rosenthal Test Fail Safe N and Egger's Test (Hidayah et al., 2023). Data analysis in the study was carried out with the help of the JSAP application. Furthermore, the effect size criteria in this study are guided by Cohen's effect size criteria which can be seen in Table 2.

**Tabel 2.**Cohen's Effect Size Criteria

| Value | Criteria EffecT Size |
|---|---|
| 0.00≤ES≤ 0.20 | Low |
| 0.20≤ES≤ 0.80 | Medium |
| ES ≥ | High |

## Result and Discussion

*Results*

Based the 19 studies analyzed that have had r, t and F values obtained from each study. Before the heterogeneity test is carried out on all publications that do not have an r value, the t or F value is converted to an r value. The results of the heterogeneity test can be seen in Tables 3 and 4.

**Tabel 3.** Heterogeneity Test Result

| | Q | df | P |
|---|---|---|---|
| Omnibus test of Model Coefficients | 67.143 | 1 | < 0.001 |
| Test of Residual Heterogeneity | 119.056 | 18 | < 0.001 |
| Note. p -values are approximate | | | |
| Note. The model was estimated using the Restricted ML method | | | |

**Tabel 4.** Residual Heterogeneity Estimates

| | | 95% Confidence Interval | |
|---|---|---|---|
| | Estimates | Lower | Upper |
| $\tau^2$ | 0.316 | 4.081 | 7.820 |
| T | 0.472 | 5.724 | 9.117 |
| $I^2$ (%) | 93.182 | 94.017 | 96.018 |
| $H^2$ | 7.006 | 11.237 | 23.013 |

Based on Tables 3 and 4, the results of the heterogeneity test analysis obtained a value of Q = 119,056 with a p < 0.001; $\tau^2$ or $\tau$ > 0 and I2 are close to 100 %. These findings show that the 19 studies analyzed were heterogeneously distributed. Next, calculate the value of summary effect size or mean effect size with a random effect model which can be seen in Table 5.

**Tabel 5.** Summary Effect Size

| | Estimates | Standard Errpor | Z | P |
|---|---|---|---|---|
| Intercept | 1.015 | 0.273 | 9.038 | < 0.001 |

*Note.Walt Test*

Table 5. The results of the analysis with a random effect model showed that the application of project-based learning-based e-modules had a significant effect

on chemistry learning (z = 9.038; p < 0.001). The effect of project-based learning-based e-modules in chemistry learning in the high effect size category (rRE= 1,015). Next, check publication bias through plot funnels and Egger's Test. The funnel plot functions to find out the effect size drawn by the points at a certain interval (Romadiah et al., 2022). Checking publication bias for 19 studies through funnel plots can be seen in Figure 1.

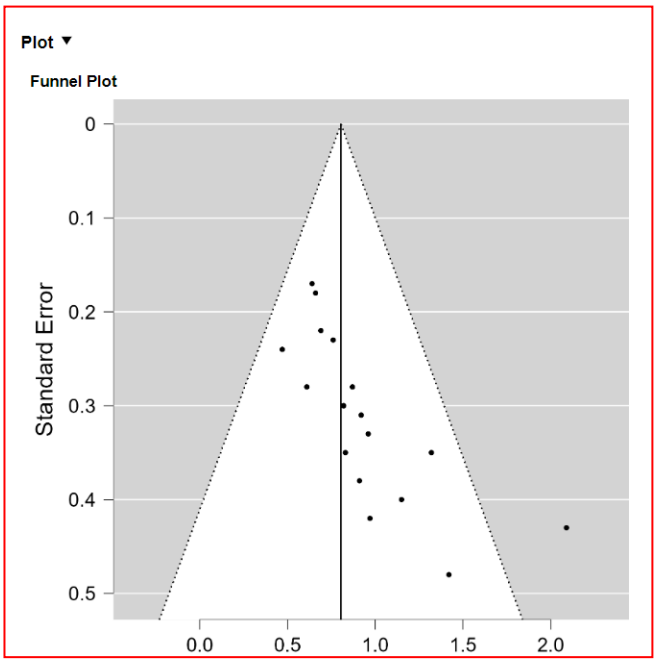


**Figure 1**. Funnel Plot Standard Error

Based on figure 1. The analysis of the 19 effect size cannot yet be known whether the plot funnel curve is symmetrical or asymmetrical. Therefore, it is necessary to carry out Egger's test which can be seen in Table 6.

**Table 6.** Egger's Test

| | Z | P |
|---|---|---|
| Sei | 3.215 | 0.001 |

Table 6, Egger's test analysis obtained a value of z = 3.215; p < 0.001, then the plot funnel analysis is symmetrical. These findings explain that the 19 publications of the researchers analyzed did not have publication bias and the results of the study could be declared valid.

*Discussion*

Based on the results of the analysis of 19 research publications included in the meta-analysis data, it was concluded that the application of project-based learning-based e-modules had a significant effect on students' chemistry learning (p-value < 0.001; rRE = 1.015). The application of project-based e-modules based learning can foster students' interest and thinking skills (Gusman et al., 2022; Yulkifli et al., 2022; Adhelacahya et al., 2023). Project-Based Learning (PBL)-based e-modules have shown effectiveness in improving students' ability to understand chemical concepts (Kahraman, 2023). By using E-modules, students can actively participate in projects relevant to daily life, so that they can understand the concepts of chemistry more deeply and more effectively. For example, students can create a project on the synthesis of drugs that uses basic chemical concepts such as chemical reactions and the properties of chemicals (Saraswati et al., 2019).

PBL e-modules can also improve students' ability to think critically and analytically. In the given projects, students must analyze data, create hypotheses, and test theories. As such, students can develop the critical and analytical thinking skills necessary in a variety of fields, including chemistry(Asih et al., 2022). For example, students can create a project on drinking water analysis that uses critical and analytical thinking skills to determine the quality of drinking water (Rusmansyah et al., 2023). In addition, PBL E-modules can also improve students' ability to cooperate and communicate (Yang et al., 2024). In the given projects, students must cooperate with other friends to achieve the goal. Thus, students can develop the necessary cooperation and communication skills in a variety of fields, including chemistry (Wulandari, 2023). For example, students can create a project on drug synthesis that uses the ability to work together and communicate to solve problems that arise.

Furthermore, PBL e-modules can also improve students' ability to use technology. In the given projects, students must use various technologies such as computers, the internet, and software to achieve the goals. Thus, students can develop the ability to use the necessary technology in a variety of fields, including chemistry (Wijayanto et al., 2023). Project-Based Learning (PBL)-based e-modules have shown effectiveness in improving students' abilities in understanding chemical concepts, critical and analytical thinking, cooperating and communicating, using technology, and developing soft skills (Habibi et al., 2022; Rusli et al., 2024). Thus, the PBL E-module can be an effective alternative in chemistry learning, especially in today's digital era. Therefore, teachers and educators must pay attention to the use of PBL E-modules in chemistry learning to improve the quality of education.

## Conclusion

From the results of the study, it can be concluded that the 19 studies analyzed were heterogeneous and normally distributed, there was a significant influence of project-based learning-based e-modules with strong categories (p < 0.05; rRE= 1.015); In this study, there is no publication bias. These findings show that there is a

positive influence of project-based learning-based E-Module learning in chemistry learning. Students who use e-modules in PBL not only show higher improvement in academic scores compared to traditional learning methods, but also report higher levels of engagement and positive attitudes towards chemistry learning. The integration of e-modules provides an interactive and adaptive learning environment, while PBL encourages critical thinking, problem-solving, and collaboration skills that are essential for their future in STEM fields. Therefore, incorporating these technologies in teaching practice can be an important step in preparing students for the challenges of the 21st century.

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**Conflicts of Interest**
The authors declare no conflict of interest.

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